

**The Development of a Construction and Demolition
Waste Recycling Facility in Galway
– A Case Study**

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This dissertation 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

August 2002

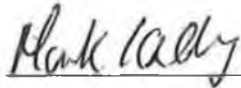
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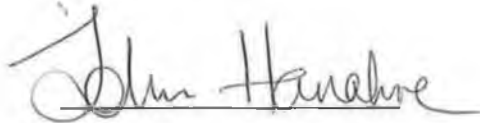
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The Development of a Construction and Demolition Waste Recycling Facility – A Case Study

Candidate: Mark Kelly

Abstract

Construction and demolition waste is conservatively estimated to account for approximately 17.5 per cent of the total amount of non-agricultural waste produced in Ireland each year. The European Commission identified it as a priority waste stream in 1991 for two reasons: firstly, it usually consists of bulky materials taking up considerable landfill space; and secondly, it has a high potential for recovery and reuse. With landfill space becoming increasingly scarce and expensive, the Irish government set out a number of targets in 1998 to divert waste from landfills [Department of the Environment and Local Government (DoELG) 1998]. One of the major targets was the recycling/reuse of 50 per cent of construction and demolition waste by 2003; with a progressive increase to 85 per cent by 2013. The main barrier in achieving these ambitious targets is the current lack of infrastructure available to process the construction and demolition waste materials (DoELG, 2002).

This study aims to examine the development of a construction and demolition waste recycling facility in the Galway region. This case study will be integrated into an extensive examination of all facets of construction and demolition waste management. This will form the basis for an economic and operational evaluation to provide a set of best practice indicators for subsequent developments as recommended by the recent policy statement *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002).

Acknowledgements

I wish to express my gratitude to the staff of the Department of Building and Civil Engineering, especially my supervisor Mr. John Hanahoe for his continued guidance and support throughout the course of my research.

I thank Mr. Sean Curran and Mr. Christo Balfe of Barna Waste Ltd. for their co-operation and continued interest in the research topic. I thank Mr. Eamon McPartlin of Patrick J. Tobin Consulting Engineers and Co. for his co-operation in providing information essential to the study.

Finally, I thank my parents and Fiona for their understanding, encouragement and patience during the course of my research.

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Acronyms

BATNEEC	Best Available Technology Not Entailing Excessive Cost
BPEO	Best Practicable Environmental Option
CEN	European Standards Body
CIF	Construction Industry Federation
C&D W	Construction and demolition waste
CUR	Civiettechnisch Centrum Vitroering Research en Regelgeving
NCDWC	National Construction and Demolition Waste Council
DoELG	Department of the Environment and Local Government
DGXI	European Commission Directorate General
EC	European Commission
EEA	European Environmental Agency
EPA	Environmental Protection Agency
EWC	European Waste Catalogue
EU-15	Fifteen Member States of the European Community
EuroStat	European Statistical Office
FIEC	European Construction Industry Federation
GDP	Gross Domestic Product
IPC	Integrated Pollution Control
IPPC	Integrated Pollution and Prevention Control
LCA	Life Cycle Analysis
MSWS	Municipal Solid Waste Stream
mt	million tonnes

Acronyms

OECD	Organisation for Economic Co-operation and Development
PHS	Public Health Service
ppd	per person per day
RPCCA	Recycled Portland Cement Concrete Aggregate

Organisation of the Dissertation

Chapter 1 : Introduction and Methodology

This chapter introduces the scope of the study outlining the main aims and objectives. The methodology is described to illustrate the reasoning behind the research strategy adopted.

Chapter 2 : Definitions, Legislation and Policy Actions

This chapter examines the legal responsibilities involved in the management of construction and demolition waste by investigating the definitions, legislation and policy actions involved.

Chapter 3 : Characteristics of Construction and Demolition Waste

This chapter outlines the characteristics of the construction and demolition waste stream by examining the nature, source, composition and the quantities arising.

Chapter 4 : The Potential of Construction and Demolition Waste for Recycling and Reuse

This chapter investigates previous research carried out to identify the recycling and recovery potential of construction and demolition waste materials.

Chapter 5 : Construction and Demolition Waste Recycling Facilities

This chapter investigates the design considerations and the various processing technologies available for the development of a construction and demolition waste recycling facility.

Chapter 6 : Best Practice Case Studies

This chapter reports on three case studies identified to illustrate best practice.

Chapter 7 : Best Practice Indicators

This chapter identifies the common conditions that exist in the best practice case studies.

The identification of nine conditions, each consisting of indicators provides the basis for a best practice checklist for the development and operation of a construction and demolition waste recycling facility.

Chapter 8: The Development of the Barna Waste Ltd. Waste Transfer and Recycling Facility

This chapter provides a descriptive overview of the development of the Barna Waste Ltd.

Waste Transfer and Recycling Facility.

Chapter 9: Assessing the Operational Effectiveness of the Barna Waste Construction and Demolition Waste Recycling Facility

This chapter assesses the operational effectiveness of the Barna Waste Ltd. Facility by comparing its development with the three case studies identified in Chapter 6 using the best practice indicator checklist.

Chapter 10 : Examination of the Economic Viability of the Barna Waste Construction and Demolition Waste Recycling Operations

This chapter examines the economic viability of different levels of processing technology to ascertain which one is the most appropriate to the current operations at the Barna Waste Ltd. Facility.

Chapter 11 : Conclusions and Recommendations

This chapter outlines the main conclusions of the study and outlines some recommendations for continued research in this area.

Chapter 1 : Introduction and Methodology

1.1 Introduction

The main aim of this chapter is to introduce the methodology used in the research to describe the logical sequence connecting the data to the study's initial aims and objectives and ultimately, to its conclusions.

1.2 Scope of Study

The study is concerned with the examination of the development of a construction and demolition waste recycling facility in the Galway region. An extensive investigation of the relevant factors associated with the management of construction and demolition waste was carried out to:

1. Examine the relevant definitions, legislation, regulations and policy actions.
2. Determine the characteristics of the construction and demolition waste stream.
3. Investigate previous research into the potential of construction and demolition waste materials for recycling and reuse.
4. Determine the infrastructure required to process construction and demolition waste materials.
5. Evaluate areas of best practice.
6. Examine the development of the Barna Waste Facility on the outskirts of Galway city.

These factors evolved in a focused manner to provide the basis for the main aims and objectives of the study.

1.3 Main Aims and Objectives

The main aim of this project is to examine the development of a construction and demolition waste recycling facility in the Galway region with a view to establishing:

- 1 A set of best practice indicators for the development and operation of a construction and demolition waste recycling facility.
- 2 The economic viability of a construction and demolition waste recycling operation.

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

- Identify the various definitions, legislation and policy actions specifically related to construction and demolition waste management.
- Examine the characteristics of the construction and demolition waste stream.
- Assess the potential of construction and demolition waste materials for recycling and reuse.
- Examine the design criteria and equipment choices available for the development of construction and demolition waste recycling facilities.
- Identify areas of best practice and evaluate them to establish a set of best practice indicators.
- Examine the development of the Barna Waste Facility and evaluate its operational effectiveness.
- Examine the economic viability of the alternative processing operations available to the Barna Waste Facility.

1.4 Methodology

A number of different research methods were considered during the course of the study. However, it was decided the most appropriate method was the case study approach supported by quantitative and qualitative analysis. Case study research is especially suited to 'how' or 'why' questions being asked about a contemporary set of events over which the investigator has little or no control (Yin, 1994). This formed the basis for the initial questions of the study, i.e. why is the development of a construction and demolition waste recycling facility taking place and how do you do it?

The initial chapters (chapters 2 to 3) are of a qualitative nature, involving an extensive literature review to establish: the legal responsibilities for the management of the construction and demolition waste stream; and to define the characteristics of the construction and demolition waste stream.

This initial review helped to develop sharper and more insightful questions about the topic. It was discovered that the production of construction and demolition waste posed an enormous problem throughout the world, especially in Europe. The next logical step was to identify any potential solutions to the problem.

Chapter 4 examines the historical development of previous research into the potential of construction and demolition waste materials for recycling and/or reuse. It was concluded that there was a potential solution to the problem provided the necessary infrastructure was in place.

Chapter 5 addresses the need for the appropriate infrastructure to provide facilities to realise the full potential of recycled and recovered secondary materials. This is where the study moved from descriptive theory to exploratory theory. It was identified that there was a lack of guidance available for the development of construction and demolition waste recycling facilities. This led to the decision to establish a set of best practice indicators to make an original contribution in this area.

The most appropriate strategy considered was to identify best practice facilities throughout Europe and examine their development to identify any common conditions that may exist. Chapter 6 describes the development and operation of each facility, based on site visits and informal interviews. The three case studies identified were the Copenhagen Recycling Centre in Denmark, the Sysav Waste Management Facility in Sweden and the DemCon 20/20 Project in Cork. It was discovered that a number of common conditions existed providing examples of best practice. From this, a checklist was devised in Chapter 7 incorporating the various conditions supplemented by relevant indicators and was termed the 'Best Practice Indicator Checklist'.

The study continued in Chapter 8 to describe the current development of the 'core' case study, the Barna Waste Ltd. Recycling Facility. The operational effectiveness of the facility was examined in Chapter 9 by comparing the development of the Barna Waste Ltd. Facility with the three areas of best practice using the 'Best Practice Indicator Checklist'. It was discovered that the Barna Waste Ltd. Facility needed to consider alternative processing systems to improve its current operations. Chapter 10 investigated the economic viability of

three alternative processing systems concluding that the current level of technology being used was appropriate but needed to be flexible to adapt to changes in the composition and quantity of construction and demolition waste material being received at the facility.

1.5 Conclusions

The use of comparative case studies proved successful as it provided the means to establish a checklist of best practice indicators for the development and operation of construction and demolition waste recycling facilities across the country, providing an original contribution to exploratory research in an area lacking definitive guidelines.

This evolved to examine the effectiveness and economic viability of operations at a newly constructed construction and demolition waste recycling facility, thus contributing to the assessment of its operational performance.

The study was limited to the four case studies due to financial and time constraints. An increase in the number of case studies would have provided a more comprehensive analysis for the establishment of best practice criteria. On review the use of structured interviews for each of the identified case studies may have provided more comparative analysis to determine the best practice indicators. The idea of comparing 'good practice' with 'poor practice' was considered but the general consensus arising out of the research was that the very fact that a construction and demolition waste facility was operating at all was an indication of good practice.

The next chapter begins the investigation by examining the legal responsibilities involved with the management of the construction and demolition waste stream by investigating the relevant definitions, legislation, regulations and policy actions.

Chapter 2 : Definitions, Legislation and Policy Actions

2.1 Introduction

The first step in defining current practice in construction and demolition waste management is to determine the legalities involved. The following will examine the development of waste management definitions, regulations, legislation and policy statements that are specifically related to the construction and demolition waste stream.

2.2 International Influences

The realisation that we live in a world of finite resources has increased the focus on the future and sustainable development. The concept of sustainability became part of the world environmental vernacular in 1987, when Gro Brundtland, the Prime Minister of Norway authored the *Brundtland Report* (also entitled *Our Common Future*) in which she defined sustainability as:

"...A development that meets the need of the present without compromising the ability of future generations to meet their own needs."

In a society based on sustainable development, the wasteful use of resources resulting in excessive pollution is minimised so the management of the various streams of waste is of the utmost importance. Waste minimisation, recycling and reuse then become the cornerstones of the future (Castledine, 1990), The publication of the *Brundtland Report* (Brundtland, 1987) led to the slow acceptance of sustainable development throughout all

sectors of society and commerce, including the construction industry. Today, six general principles of sustainable construction are generally accepted (Kibert, 1994). They are:

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

The Earth Summit in Rio de Janeiro in June 1992 brought the 'green agenda' on to a global scale. Sustainable development was agreed as a laudable goal and the Brundtland definition was accepted. This universal concept was translated through national strategies on sustainable development and into local Agenda 21 programmes. Agenda 21 is a global action plan, which places the responsibility for establishing sustainable development on national governments. Agenda 21 emphasises the need to work in a broad series of partnerships with international organisations, regional and local governments and all interested groups.

The International Community bases its environmental policy on the following four principles (www.wastewatch.org.uk, 2001):

1. The Precautionary Principle – we should anticipate potential problems.
2. The Polluter Pays Principle – whoever causes pollution must pay to clean it up.
3. The Prevention Principle – waste production must be minimised where possible.
4. The Proximity Principle – waste should be disposed of as close as possible to where it is produced.

These form the four underlying principles for the European Community as well. It is through treaties that the environmental sector is regulated on an international scale.

Compliance with much of this legislation is voluntary and applies only to hazardous waste. Each country has the power to make their own waste management policies and this leads to a great deal of variation in waste management practices throughout the world. It is extremely difficult to monitor these practices and establish a consistent system for the global community due mainly to factors including: different definitions; use of different methods of data collection; and variations in technology.

The European Community has tried to tackle this problem by introducing a comprehensive regulatory framework, which aims to provide a common terminology throughout Europe.

2.3 The Waste Management Framework in Europe

Waste legislation has developed dramatically since the Treaty of Rome in 1957, which established the European Economic Community (EEC). No mention of the environment was made in this original treaty. In 1972 the Member States asked the European Commission to draw up an environmental policy for the European Community (EC). The response was the formulation of the first *Action Programme on the Environment*. Four further action programmes have followed, one every five years.

In 1986, the Single European Act (EC, 1986) amended the Treaty of Rome to include the aim of environmental protection. In 1989, the European Commission (EC) produced the *European Community Strategy for Waste Management* (EC, 1989). This document forms the cornerstone of European waste policy. The strategy contained the following points:

- The establishment of a hierarchy of waste management. This prioritises the prevention of waste followed by its reuse and recycling and lastly the optimisation of its final disposal through, for example energy recovery (Figure 2.1).
- Confirms the proximity principle. This requires that waste is dealt with as near as possible to its source.
- The goal of waste disposal self-sufficiency at every level is emphasised.

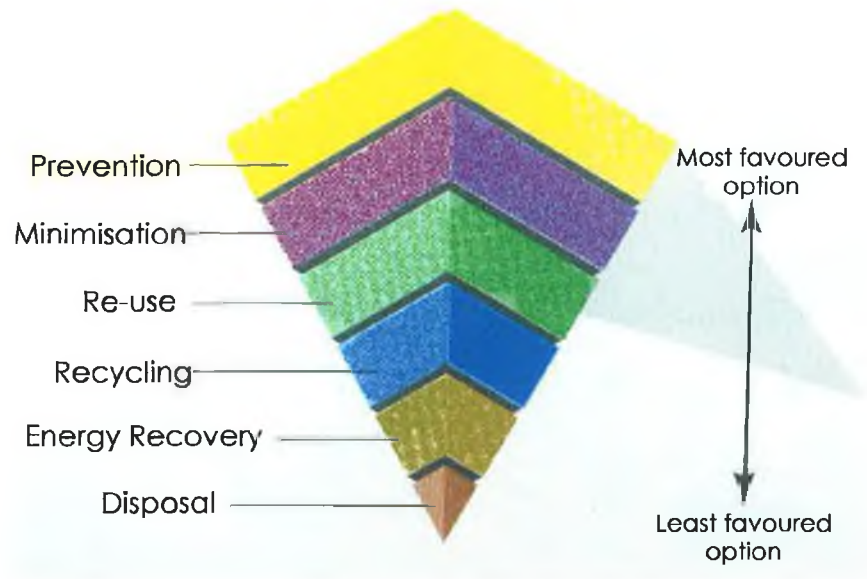


Figure 2.1 Waste Management Hierarchy Model (EC, 1989)

Council Directive 75/442/EEC on waste (Council of European Communities, 1975), as amended by Council Directive 91/156/EEC (Council of European Communities, 1991), set out objectives to complement the *European Community Strategy for Waste Management* as follows:

- Increased prevention and reduction of waste through the development of clean technologies as well as of products that can be re-used or recycled.
- Recycling and recovery of waste as a secondary raw material.
- Recovery and disposal without endangering human health and the environment.
- Drawing up of waste management plans by competent authorities.

- Aim at self-sufficiency in waste disposal by the Member States.
- Establishment of an integrated and adequate network of disposal installations, taking into account best available technology and enabling the Community as a whole to become self-sufficient.
- Use of waste as a source of energy.

This Directive (91/156/EEC) is sometimes termed the 'Framework' Directive for European waste legislation and it provided common terminology for waste management in the European Union. Annex 1 of the Directive listed different categories of waste with the following relevant to construction and demolition waste:

- Products for which the holder has no further use.
- Contaminated materials, substances or products resulting from remedial action with respect to land.
- Unusable parts or substances, which no longer perform satisfactorily.

Included in this common terminology was a standard definition for waste, given in Article 1(a) of the 'Framework' Directive:

“ Waste shall mean any substance or object in the categories set out in Annex 1, which the holder discards or intends or is required to discard”.

The Directive also elaborated to define construction and demolition waste:

“Any substance or object which the holder disposes or is required to dispose, which arises from construction, renovation and demolition activities”.

At the time there were a number of definitions and interpretations for construction and demolition waste, most notably from Culham (1975) and Skoyles (1976a). These interpretations were general in nature and did not provide an accurate form of classification. The European Commission acknowledged this in 1991, when Article 1(a) of Council Directive 91/156/EEC required the Commission to draw up a list of wastes. This led to the Council Decision 94/3/EC (Council of European Communities, 1993) of 20th December 1993, which established a list of wastes known as the European Waste Catalogue (EWC).

The aim of the EWC was to provide a common terminology throughout the European Community with the purpose of improving the collection and management of data on waste and by so doing, improve the efficiency of waste management activities. The structure of

the EWC was that each type was assigned a six-digit code made up of three digit sub-codes. The catalogue described the type of process, industry or sector, in which a waste type arose. For example, construction and demolition waste was assigned the code 17 00 00. It further sub-divided construction and demolition waste into hazardous and non-hazardous waste categories. It stated that hazardous waste included asbestos, waste oils, wood preservatives, heavy metal waste and demolition waste from specific sites. This was a development on Council Directive 91/689/EEC (Council of European Communities, 1991), which established a list of criteria (Annex III of Council Directive 91/689/EEC) to be used when the hazardousness of wastes was being determined. This list was subsequently published as Council Directive 94/904/EEC (Council of European Communities, 1994) known as the hazardous waste list. The EWC was published in Ireland as the *Waste Catalogue and Hazardous Waste List* (EPA, 1996). Only one waste type from the construction and demolition waste section 17 00 00 was identified as hazardous. This was waste type *17 06 01 – insulation material containing asbestos* (this was to change with the revised version of the EWC published in 2002).

At around the same time and in order to accelerate the achievement of these objectives in the Member States, the European Council Resolution of 7th May 1990 on Waste Policy considered it desirable to establish action programmes for particular types of wastes. These wastes were termed ‘priority wastes’ and included construction and demolition waste.

In 1992, the European Commission set up the *Priority Waste Streams Programme* and following consultation with the Member States, six priority waste streams were identified:

1. Used tyres.
2. End-of-life vehicles.
3. Chlorinated solvents.
4. Health care waste.
5. Construction and demolition waste (C&D W).
6. Waste from electric and electronic equipment.

The *Priority Waste Streams Programme* represented a new approach in the development of Community policy and stemmed from one of the primary objectives of the Treaty on European Union, which is the promotion of sustainable growth respecting the environment. As a result of this programme, the *Construction and Demolition Waste Project Group* was set up in 1992. This group included representatives from: the national, regional and local governments and agencies as well as the construction industry; the construction materials supply industry; and the waste management industry. The group produced a draft report (Symonds Travers Morgan/ARGUS, 1995) in 1995, which outlined a number of recommendations. These recommendations covered a wide range of objectives embracing: waste prevention; the promotion of clean technologies; market creation; cost effectiveness; and protection of the environment.

One of the most important recommendations concerned the EWC. The report recommended that:

“ Member States should be encouraged to adopt the following classifications (taken from the EWC) as the framework within which future construction and demolition waste management planning will be undertaken, and waste arising collected and reported:

- *Concrete, bricks, tiles, ceramics and gypsum based materials (EWC code 17 01 00)*
- *Wood (EWC code 17 02 01)*
- *Glass (EWC code 17 02 02)*
- *Plastic (EWC code 17 02 03)*
- *Asphalt, tar and tarring products (EWC code 17 03 00)*
- *Metals, including their alloys (EWC code 17 04 00)*
- *Soil and dredged soil (EWC code 17 05 00)*
- *Insulation materials (EWC code 17 06 00)*
- *Mixed C&D W (EWC code 17 07 00)*

Hazardous components of C&D W should also be identified”.

Since the recommendation was made, the European Commission decided that the EWC should be reviewed and an expert working group was drawn up from Member States, European Commission Directorate General (DGXI) and European Statistical Office (Eurostat).

In July 1996, a review of the *European Community Strategy for Waste Management* was carried out and the following points were added:

- The EU will investigate possible actions on incineration and the implications of using waste as a fuel at installations not originally designed for this.
- The Commission will introduce targets to substantially reduce the amount of waste generated and to generally achieve high waste recovery objectives.
- The principle of producer responsibility (where waste producers are actively involved in the waste management of their products) will be incorporated in all future measures.
- The commission will come forward with proposals to control landfill.
- 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 initiative on *Priority Waste Streams* had been abandoned due to slow progress, although some follow up work on the original five waste streams was to continue in the short term.

The Organisation for Economic Co-operation and Development (OECD) issued a '*Final guidance document for distinguishing waste from non-waste*' in 1998. This document was developed within the context of transfrontier movements of wastes destined for recovery operations and it provided some helpful pointers in determining when construction and demolition material is and is not a waste. The guidance document observed that the intended destination of a material is the decisive factor, not the fact that it has to be discarded. The document suggests that:

"... A waste ceases to be a waste when a recovery, or another comparable process eliminates or sufficiently diminishes the threat posed to the environment by the original material (waste) and yields a material of sufficient beneficial use..."

(OECD, 1998)

In 1999, a European Commission funded report was published entitled '*Construction and Demolition Waste Management Practices and their Economic Impacts*'. The project was undertaken by Symonds Group (UK) in association with ARGUS (Germany), COWI Consulting Engineers and Planners (Denmark) and PRC Bouwcentrum (the Netherlands). The main aim of the project was to investigate the quantities of construction and demolition wastes arising in Europe and to identify the measures that each Member State had taken to improve the re-use and recycling of this waste stream.

The report discovered that there were some difficulties in the interpretation and use of the EWC in some Member States. Some countries interpreted and recorded the EWC

categories in slightly different ways. For example, in Germany and the Netherlands, a quantity of concrete waste with a comparatively small proportion of brick and gypsum mixed in with it, would be recorded under EWC code 17 01 00 (concrete, bricks, tiles, ceramics, gypsum-based materials). This is in contrast with the UK, where the same material would probably be recorded as EWC code 17 07 00 (mixed C&D W). This affected the accurate quantification and composition percentages of C&D W arising in the European Community (EU-15¹). The report also addressed the interpretation of the definition of waste, recommending that:

“The Commission should review the definition of waste in Council Directive 75/442/EEC on waste, as amended by Council Directive 91/156/EEC, with the objective of developing a proposal whereby products and materials destined for re-use and recycling are not defined as waste”.

(Symonds *et al.*, 1999)

The report also narrowed the definition into a ‘core’ element. The report defined ‘core’ construction and demolition waste as:

“The mix of materials obtained when a building or piece of civil engineering infrastructure is demolished, though it includes under the heading, the same materials when they arise as a result of construction. ‘Core’ construction and demolition waste excludes road planings, excavated soil (whether clean or contaminated), external utility and service connections (drainage pipes, water, gas and electricity) and surface vegetation”.

(Symonds *et al.*, 1999)

¹ EU-15 represents the 15 Member States of the European Union.

On the 31st of May 1999, representatives of the construction industry, European Commission and the Member States drew up a list of priority actions for improving the competitiveness of the construction industry. One of these actions aimed:

“To develop a strategy for the use and promotion of

- *environmentally friendly construction materials*
- *energy efficiency in buildings and*
- *construction and demolition waste management*

in order to contribute to sustainability”.

It was decided to set up three Task Groups (TG) designated as follows:

- TG1: Environmentally friendly construction materials.
- TG2: Energy efficiency in buildings.
- TG3: Construction and demolition waste management.

Reports were drafted for each of these task groups and a ‘covering report’ was produced in May 2001. This report addressed the wider issue of sustainable construction in general and was entitled ‘*The Competitiveness of the Construction Industry – An Agenda for Sustainable Construction in Europe*’.

The *Task Group Report (TG3)* was produced on the 28th of September 2000. The report contained a number of recommendations, which are summarised as follows:

- All parties involved in the construction process should encourage the use of recyclable primary materials. Environmental assessments, codes of practice, specifications and product standards would all aid the promotion of the use of secondary materials.
- Member States are encouraged to draw up national waste management plans to enable reliable statistics on construction and demolition waste be collected and examined. The implementation of the Landfill Directive is identified as an important step in the sustainable use of natural resources.
- The European Community should aim to provide a common methodology for construction and demolition waste statistics. This would involve the use of the EWC classifications, data collection and accounting methods. Extensive research is required throughout Europe to demonstrate best practice in construction and demolition waste management.

On the 26th of May 2001, the European Construction Industry Federation (FIEC) adopted its '*Charter for the Environment*'. It constituted a statement of principles of professional organisations representing European construction enterprises. Its aim was to promote construction activity, which respects the environment. One of its objectives was to



encourage construction firms and their clients to use recyclable and/or reusable materials. To this end, FIEC, through the identification and adoption of European best practice will encourage construction firms and their clients to endeavour to bring about conditions which will make it possible to remove the economic, regulatory and cultural obstacles which hinder recycling of previously used materials.

On the 1st of January 2002, a new revised EWC came into affect. This catalogue comprises four documents. A replacement waste list and hazardous waste list was introduced in 2000, which was to come into force on 1st January 2002. Since that time, this new combined list has been amended three times to give a set of four documents:

1. Commission Decision 2000/532/EC of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/ EC establishing a list of wastes pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste.
2. Commission Decision 2001/118/EC amending Decision 2000/532/EC as regards the lists of wastes.
3. Commission Decision 2001/119/EC amending Decision 2000/532/EC as regards the list of wastes.

4. Council Decision 2001/573/EC amending Commission Decision 2000/532/EC as regards the list of wastes.

The Environmental Protection Agency in Ireland produced a document entitled the '*European Waste Catalogue and Hazardous Waste List, 2002*' (EPA, 2002), which represents a consolidated version of all four documents. This was to ease the task of understanding the legislation associated with the classification of waste and hazardous waste.

Construction and demolition waste is still contained in section 17 00 00. The new version contains a greater range of categories (Appendix A). The classification is outlined as construction and demolition waste (including excavated soil from contaminated sites), whereas in the previous catalogue the classification was outlined as construction and demolition waste (including road construction) [Appendix B]. There are eight main categories divided into thirty-eight sub-categories in the new catalogue compared to seven main categories divided into twenty-four sub-categories in the older version. This gives a more extensive range of construction and demolition waste materials. The other major change has been the increase in the classification of construction and demolition waste that is hazardous. In the original catalogue, the only construction and demolition waste listed as hazardous was *17 06 01 – insulation materials containing asbestos*. In the new catalogue, the number of materials deemed hazardous has increased to sixteen.

2.4 The Waste Management Framework in Ireland

2.4.1 Pre-1990s

Apart from the Litter Act, 1982, primary legislation on solid waste related primarily to the public health functions of local authorities. The use of landfill was the predominant waste management option due to its relatively low cost, favourable geological conditions and settlement pattern. Landfills were generally small in size and were often badly operated.

2.4.2 1990 onwards

A modern waste policy was needed and development during the period 1990-1996, helped establish a comprehensive legislative framework that facilitated the implementation of sustainable waste management practices (www.environ.ie/environ/envindex.html). The first significant development was the establishment of the Environmental Protection Agency (EPA) under the Environmental Protection Agency Act, 1992. This had the following effect:

- Enabled the establishment by the EPA of a national waste database.
- Required the specification and publication of criteria and procedures for the selection, management, operation and termination of use of landfill sites.
- Provided for a system of integrated pollution control (IPC). This addressed the generation, recovery and disposal of wastes by relevant activities (which included

hazardous and non-hazardous waste incineration) and emphasised progressive waste minimisation.

In 1994, a national recycling strategy, *'Recycling for Ireland'* was published by the Department of the Environment and Local Government (DoELG). The strategy focused on packaging waste, newsprint and organic waste. It set an overall target of diverting 20 per cent of municipal waste from landfill by recycling by 1999 (the recycling rate in 1993 was 7.4 per cent). It also set an overall minimum target recovery rate of 30 per cent for waste packaging, and for extending the network of collection points for recyclable materials throughout the country. No mention was made of construction and demolition waste as a recyclable material. The 'polluter pays' principle was introduced, where producers take responsibility for the waste produced by their products and the strategy also recommended more involvement of the local authorities.

The Waste Management Act, 1996 was enacted in May 1996, and has completely reformed Ireland's waste legislation. The principal objective of the Act is to provide a legal framework that will ensure that the holding, transportation, recovery and disposal of waste does not cause environmental pollution. The Waste Management Act, 1996 recognises and further develops the role assigned to the EPA under the Environmental Protection Agency Act, 1992 and is complementary in its approach and objectives.

To date, the primary focus in relation to the operation and implementation of the Waste Management Act has been to:

- Improve waste management practice and infrastructure by developing and improving the waste management planning system.
- Ensure a high standard of environmental protection by implementing an effective and comprehensive waste licensing and permitting system.
- Improve waste recovery performance by developing producer responsibility initiatives.
- Introduction of secondary legislation in response to EU and national requirements reflected in the Act.

This Regulatory system provided for in the Act is being introduced through a series of regulations together with key European enactments (listed in Box C.1, Appendix C).

The Act has brought about radical changes to waste planning in Ireland. Waste management planning was first introduced on a statutory basis in 1979 for non-hazardous waste and in 1982 for hazardous (toxic and dangerous) waste. These plans were prepared by local authorities and were mainly aimed at the disposal of waste and ensuring that adequate arrangements were made for safe disposal. The plans did not address waste reduction and waste recovery. Under the 1996 Act, local authorities are now responsible for the preparation and implementation of waste management plans for all waste produced in

their area. Regional plans are now being implemented by a number of local authorities to provide the framework for improved waste management and are aimed towards:

- Waste prevention.
- Waste minimisation.
- Waste recovery.
- Regional / local authority waste management planning.
- Safe disposal of non-recoverable waste without causing environmental pollution.
- Making the polluter pay.
- Public consultation.

The Waste Management Act, 1996 provides for the regulation and control of disposal and recovery activities. The Act requires that operators of all significant waste disposal and recovery activities obtain a waste licence from the EPA. The principal objective of this licensing system is to ensure that waste activities such as landfills, transfer stations and recycling depots are operated in a manner, which does not cause environmental pollution.

This work has been underpinned by clear policy direction in particular, the *National Sustainable Development Strategy* (DoELG, 1997) and the 1998 policy statement on waste management, *Changing Our Ways* (DoELG, 1998).

The overall policy in relation to waste management is firmly grounded in the waste hierarchy, with prevention and minimisation as the most favoured option and disposal the least favoured option, as illustrated in Figure 2.1 (EC, 1989).

The publication of the *National Waste Database Report, 1998* (EPA, 2000) provided a more accurate update of waste management statistics, as there was considerably more information available than in 1995 (the previous year for which national waste statistics were published). It also provided a definition for construction and demolition waste:

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

Dredge spoil is described in “Ireland’s Marine and Coastal Areas and Adjacent Seas, An Environmental Assessment” (Marine Institute, 1999) 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 sands. 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.”

(EPA, 2000)

This report highlighted the urgent need for action in regard to construction and demolition waste. A figure of 2.7 million tonnes was estimated for construction and demolition waste in 1998 with a recycling percentage of approximately 43 per cent.

These figures were recognised by the report to be somewhat unreliable, stating that:

“The amount of construction and demolition waste arising in 1998 is likely to be higher than the 2.7 million tonnes reported. However, waste flow data does not permit a comprehensive analysis of construction and demolition waste flows in Ireland.”

(EPA, 2000)

The *Changing Our Ways* policy statement was a response to the findings in the *State of the Environment in Ireland Report* (EPA, 1996) and a report from the European Environmental Agency, *Europe’s Environment: A Second Assessment* (EEA, 1998), which highlighted the fact that waste generation continued to grow annually and that there were relatively low levels of waste recovery and high degree of reliance on landfill. The policy statement was intended to provide a national policy framework for the adoption and implementation by local authorities of strategic waste management plans under which national objectives and targets will be attained. A number of key issues and considerations were outlined in the document and the following recommendations given:

1. Need for a dramatic reduction in reliance on landfill in favour of integrated waste management approaches, which utilise a wide range of waste treatment options.
2. Strategic planning on a regional basis.

3. Greater participation by the private sector in the provision of waste management services.
4. A more effective system of waste charging to promote waste minimisation and recovery.
5. Extending the scope of producer responsibility initiatives by the greater utilisation of legislative instruments and the encouragement of greater public participation and support.

The policy document also set out specific targets over a fifteen-year timetable to try and reverse the trend of waste growth (Box 2.1).

Box 2.1: Targets set out in *Changing Our Ways* (DoELG, 1998)

Waste Management - Changing Our Ways

Targets

- Diversion of 50% of overall household waste away from landfill.
- A minimum of 65% reduction in biodegradable waste going to landfill.
- The development of waste recovery facilities employing environmentally beneficial technologies.
- Recycling of 35% of municipal waste.
- Recycling of at least 50% of construction and demolition waste within a five year period, with a progressive increase to at least 85% over fifteen years.
- Reduction of the number of landfills.
- An 80% reduction in emissions from landfill.

The policy statement specifically mentions construction and demolition waste in Sections 3.7 and 3.8:

“Local Authorities have an opportunity, in the relative short term, to divert significant volumes of construction and demolition waste from landfill. Construction and demolition waste is a very significant component of the overall waste stream, particularly with current high levels of building construction, renovation and demolition. Very large quantities of this waste are being landfilled, despite its potential resource value. The technology for the segregation and recovery of stone and concrete from construction and demolition waste is well established, readily accessible and inexpensive, and there is a ready re-use market for aggregates, as fill for road, drainage and other construction projects”.

(DoELG, 1998)

The document also encouraged the use of a regional approach in combating the waste problem. The need for the implementation of the *Regional Waste Management Plans* was of paramount importance to the Government to address these waste management issues. These plans were met with opposition in some areas and the Department of the Environment and Local Government reacted by introducing the Waste Management (Amendment) Act 2001 (No. 36 of 2001), which was enacted on 17th of July 2001. The aim of this amendment was to provide a legal mechanism by which the current waste management planning process can be brought to an early conclusion. Prior to the commencement of the Act, three out of fifteen local authorities in three regional groups had refused to adopt the relevant proposed regional plan. Other local authorities purported to

adopt a relevant regional plan, but did so subject to conditions or qualifications. Section 4 of the Act, provided that the making of a waste management plan became an executive (management) function, while the power to vary or replace a plan remained a reserved function of the elected members of the local authorities. The Act also introduced a number of initiatives, the most relevant of which are:

- A levy on the landfill of waste, at an initial rate of not more than £15 (€19) per tonne.
- The establishment of an 'Environmental Fund', through which the proceeds of these levies will be disbursed to finance beneficial environmental initiatives in a range of areas including waste management, environmental education and awareness.

In order to speed up the implementation of these plans the Government committed money to fund the establishment of waste management infrastructure in Ireland, under the auspicious of the National Development Plan 2000-2006. The National Development Plan's main objective is to address the infrastructural deficit, which threatens to inhibit the achievement of Ireland's economic and employment potential. The recent levels of economic growth have exceeded the capabilities of the existing waste management infrastructure and extensive investment is required to meet the current and future demands. Local authorities are required under the Waste Management Act, 1996 to prepare waste management plans. Most local authorities have done so, either on a regional basis or individually. The investment in the waste management infrastructure will be based on the

recommendations of these plans. It is estimated that €825 - €950 million will be required to provide the necessary infrastructure.

On the 19th of March 2002, a call for proposals under the Waste Management Infrastructural Grant Scheme was launched. A total of €127 million is available to local authorities and the private sector to support the development of waste recycling/recovery facilities, including: bring centres; civic amenity sites; transfer stations facilitating waste recovery; material recovery facilities; biological treatment plant; and hazardous waste landfill capacity.

Also in March 2002, the publication of a new policy statement, *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002), reinforced and expanded on the targets and proposals set out in the 1998 policy statement, *Waste Management – Changing Our Ways* (DoELG, 1998). The policy statement identified two construction and demolition waste recycling facilities, which have been established in Cork (DemCon 20/20) and Dublin (Ballealy Landfill). It proposes that a network of approximately eighteen construction and demolition waste recycling facilities are required throughout the country, supported by the provision of mobile crushing plant to serve population centres in rural areas where stockpiles of construction and demolition waste are accumulated.

Four key areas are identified to encourage an improvement of Ireland's current recycling performance:

1. Better separation and sorting of waste at source, allied to segregated collection, to provide cleaner waste fractions and single material waste streams.
2. Provision of an adequate infrastructure for the collection and management of waste arisings.
3. Greater reprocessing capacity to convert waste into usable products or raw materials.
4. Generation of markets and improved demand for recycled or recyclable materials, especially in the manufacturing and construction sectors.

The Policy Statement also addresses the work of the *Taskforce on Construction and Demolition Waste* and encourages the construction industry to take financial responsibility for the implementation of the recommendations contained in the report (B4 Taskforce, 2001).

2.4.3 Response of the Irish Construction Industry

The Irish construction industry responded to the recommendations of the *Priority Waste Streams Programme Report, 1995* by applying for funding in 1997, from the Department of Trade, Enterprise and Employment (under the ADAPT Programme²) for the Construction Aims 2000 Project. The overall objective was to assist construction enterprises, particularly small to Medium-Sized Companies (SME's), to adapt successfully to the challenges of industrial change.

The project contained four strands as follows:

- Strand 1 – Registration of construction companies
- Strand 2 – Information technology in business administration
- Strand 3 – Enterprise Development and Marketing
- Strand 4 – Construction Waste Management

² The ADAPT Programme was a European social policy instrument that was aimed at increasing competitiveness by helping companies and employees adapt to and cope with the challenges and opportunities posed by global industrial change. The National Authority for ADAPT in Ireland was the Department of Enterprise, Trade and Employment.

The formal launch of the project outputs was in February 2000. Strand 4 – Construction Waste Management addressed the following:

- Types of construction and demolition waste
- Legislative and regulatory requirements
- Management of construction and demolition waste
- Measures used to promote re-use and recycling of construction and demolition waste
- Constraints on the recycling and re-use of construction and demolition waste
- Economics of the re-use and recycling of construction and demolition waste
- The role of the designer in minimising construction and demolition waste
- European experience of construction and demolition waste management

In response to the targets set out in the *Changing Our Ways* policy document (DoELG 1998), the Forum for the Construction Industry set up a Task Force, in October 1999, with the following terms of reference:

“To co-ordinate the development and implementation of a voluntary construction industry programme to meet the Government’s objectives for the recovery of construction and demolition waste as set out in the Policy Statement on Waste Management “Changing Our Ways” and to present this programme with an implementation timetable to the Minister for the Environment and Local Government by 1st July 2000”.

This Task Force was made up of representatives from: the Construction Industry Federation (CIF); the Irish Concrete Federation; the Building Materials Federation; Enterprise Ireland; FAS; local authority management; the Department of the Environment and Local Government; Government Contracts Committee; and the Environmental Protection Agency. The Task Force did not meet the deadline of the 1st of July 2000. The draft report was submitted to the Department of the Environment and Local Government for consideration in February 2001. Some of the more important recommendations were:

- The formation of a National Construction and Demolition Waste Council (NCDWC) for the construction industry. This Council would fully implement the recommendations set out in the Task Force Report.
- The implementation of a voluntary documented waste management system by industry to effectively manage and control the flow of materials arising from each construction project.
- The provision of facilities for the recycling of construction and demolition waste. Marketing guidance and incentive programmes are required to facilitate investment.
- The consideration of a reduced VAT level on recycled materials and tax relief for using recycled materials.
- The setting of realistic landfill charges to make landfill the most expensive option.

- The encouragement of segregation through the pricing structure at recycling facilities. High prices for un-segregated and lower prices for segregated waste.

This draft report is currently under consideration (July 2002) by the Department of the Environment and Local Government.

Recently a series of seminars (May – June 2002) have been organised by FAS and the Construction Industry Federation (CIF) to increase awareness of this issue in the construction industry. The associated publication of the handbook entitled '*Construction and Demolition Waste Management – A Handbook for Contractors and Site Managers*' (FAS/CIF, 2002) has been a welcome development in this education process

2.5 Regional Waste Management Policy

The *Waste Management Plan for the Connaught Region 1999-2004* [M.C. O'Sullivan Consulting Engineers (MCOS) and COWI, Consulting Engineers and Planners of Copenhagen, Denmark, 1998] was prepared in accordance with Section 22 of the Waste Management Act, 1996 and the Waste Management (Planning) Regulations, 1997. The plan has regard to all non-hazardous waste generated within the functional areas of each of the following local authorities: Galway, Mayo, Sligo, Roscommon and Leitrim.

A previous study, *Galway Waste Management Strategy Report*, was prepared for the Galway region in 1998 (MCOS, 1998). This was expanded to incorporate all the counties located in the Connaught area resulting in the *Waste Management Plan for the Connaught Region 1999-2004*. This was in response to the waste management policy document, *Changing Our Ways* (DoELG, 1998), which highlighted the following benefits from adopting a regional approach:

- Provides a viable framework in planning and volume terms for the development of integrated and innovative waste management solutions, facilitating segregation prior to collection and incorporating organic waste treatment, thermal treatment technologies and residual landfill.
- Provides a more favourable climate for the creation of beneficial partnership arrangements between local authorities and the private sector.

The plan is based on a waste management strategy, which was presented to the Connaught local authorities in April/May 1999. The strategy recommended an integrated approach to waste management involving improved public education, new recycling initiatives, biological and thermal treatment of wastes and finally landfill of residual waste. The *Regional Plan* outlined the following points in relation to construction and demolition waste:

- There is an absence of regulation of construction and demolition waste making it impossible to control the waste stream and divert it from landfill.
- There is a lack of specification at national level for use of recycled construction and demolition waste materials in road and general engineering works.
- There are currently no facilities to recycle this material in the region.

It also outlines a proposed future waste management policy:

- Provision of a construction and demolition waste recycling facility located close to Galway city. Other areas to be served by mobile plant recycling stockpiled construction and demolition waste at defined locations in the region.

This plan has been controversial, primarily because of the inclusion of thermal treatment and incineration options. In February 2001, the Minister for the Environment and Local

Government empowered the local authority executive to make a decision without the sanction of the elected representatives and the Connaught Waste Management Regional Plan was finally adopted.

2.6 Conclusions

The aim of this chapter was to establish the legal responsibilities involved in the management of construction and demolition waste. This has been achieved by examining the development of construction and demolition waste definitions, regulations, legislation and policy actions from an international, European, national and regional perspective. It can be concluded that:

- There has been a considerable influx of legislation and regulation into Ireland over the past decade. The implementation of the Waste Management Act, 1996 has provided the necessary legal framework to ensure that the holding, transportation, recovery and disposal of waste does not cause environmental pollution.
- The publication of the various policy statements and research reports have provided much needed direction for the successful management of construction and demolition waste. The *Changing Our Ways* (DoELG, 1998) document heralded a new approach in Ireland by setting targets for various waste streams. The recent publication *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002) is timely in that it reinforces and elaborates on the previous targets.
- The response of the Irish construction industry has been slow. The formation of the B4 Taskforce on construction and demolition waste and its subsequent draft publication was a positive step, and the construction industry is awaiting its ratification. The

construction industry will need to act on the recommendations contained in the B4 report to meet its legal and moral responsibilities.

The next chapter will examine the characteristics of the construction and demolition waste stream: identifying the nature, source, composition and the quantities being produced.

Chapter 3 : Characteristics of Construction and Demolition Waste

3.1 Introduction

This chapter will examine the characteristics of the construction and demolition waste stream concentrating on the nature, source, composition, and the quantities being produced.

3.2 Classification of Construction and Demolition Waste

The lack of reliable and accurate statistical data available on construction and demolition waste means that accurate classification can prove to be a difficult task (Gavilan and Bernold, 1994). To classify construction and demolition waste, we need to look at four aspects:

1. The nature of construction and demolition waste.
2. The source of construction and demolition waste.
3. The composition of construction and demolition waste.
4. The quantity of construction and demolition wastes being produced.

3.2.1 Nature and source of construction and demolition waste

The most comprehensive research carried out into the nature and source of construction and demolition waste was undertaken in the U.K. by E.R. Skolyes and J.R. Skoyles from 1963 to 1983. They analysed the principal causes of waste, based on studies of 280 building sites of varying size. They attempted to determine the source of construction and demolition waste by defining the exact nature of the waste stream (Skoyles, 1976 a, b, c). They defined the exact nature of waste as direct waste and indirect waste. Direct waste represented the complete loss of a material (waste that can be prevented and involves the actual loss or necessary removal and replacement of a material) while indirect waste represented a loss of materials value, usually to the contractor. Indirect waste was divided into three broad classes:

1. Substitution waste: when materials are used for purposes other than those for which they are intended in the specification.
2. Production waste: represents materials used in excess of those indicated in the bill of quantities, because of the dictates of the production process.
3. Negligence waste: some materials are used extra to the amount required by the contract due to the contractor's own negligence.

The Priority Waste Stream Project Group Report, 1995 (Symonds Travers Morgan/ARGUS, 1995) identified that construction and demolition waste originated from a

wide range of activities including building, renovation, development, civil engineering, transport infrastructure, rehabilitation and maintenance. These activities were further categorised to illustrate the variety in the composition of construction and demolition waste (Symonds Travers Morgan/ARGUS, 1995):

- Building and development works
 - Residential, commercial and industrial development.

- Civil Engineering infrastructure works
 - Power generation stations, substations and electricity distribution networks.
 - Gas production works and distribution networks.
 - Dams, reservoirs, water supply treatment works and distribution networks.
 - Sewers and sewage treatment works.

- Transport infrastructure works
 - Road construction and ancillary structures.
 - Rail construction and ancillary structures.
 - Airports and associated developments.
 - Waterways, canal construction and ancillary structures.

- Renovation, rehabilitation and routine maintenance
 - Works undertaken with the aim of prolonging the economic lifespan of the above works.

- Demolition
 - The process of the deliberate destruction or dismantling of the above works.

Following on from this, Symonds *et al.* (1999) outlined the origin and nature of construction and demolition waste in Europe as follows:

1. Waste arising from the total or partial demolition of buildings and/or civil infrastructure.
2. Waste arising from the construction of buildings and/or civil infrastructure.
3. Soil, rocks and vegetation arising from land levelling, civil works and/or general foundations.
4. Road planings and associated materials arising from road maintenance activities.

The U.S. Environmental Protection Agency employed a different system of classification when attempting to determine the characteristics of building-related construction and demolition debris in the United States in a 1998 report to the U.S. E.P.A (Franklin Associates, 1998). The waste stream was divided into six broad categories (Franklin Associates, 1998):

1. Residential construction.
2. Residential demolition.

3. Residential renovation.
4. Non-residential construction.
5. Non-residential demolition.
6. Non-residential renovation.

The categorisation was based on the relationship between available census data and empirical composition factors, i.e. calculating waste tonnages by multiplying percentage waste figures by the total square metres of new construction.

3.2.2 Site Types

The nature and composition of construction and demolition waste is affected by the type of construction and/or demolition activity. Table 3.1 (Symonds *et al.*, 1999) outlines different site types that generate construction and demolition waste providing definitions for each one.

Symonds *et al.* (1999) also identified five basic activities, some or all of which may occur on all the sites outlined in Table 3.1:

1. Remove selected materials from existing structure(s), possibly after in-situ treatment.
2. Demolish the balance of the structure(s), sort into waste streams as appropriate, and treat each waste stream on or off-site prior to recycling or final disposal.
3. Clear surrounding land surface and any unwanted existing services/utility connections, broken down into two sub-categories:
 - a. Remove any hard surface coverings and any unwanted existing services and utility connections for recycling/disposal, and/or
 - b. Clear and dispose of unwanted surface vegetation.
4. Prepare site for sale or construction, broken down into two sub-categories:
 - a. Prepare new levels and foundations for new structures, and/or

- b. Prepare to leave site clear and vacant
5. Erect new structure, then treat/dispose of construction waste materials.

Table 3.1: The different types of sites that generate construction and demolition waste (Symonds *et al.*, 1999)

Site Type	Definition
‘Demolish & Clear’ sites	Site with structures or infrastructure to be demolished, but on which no new construction is planned in the short term.
‘Demolish, clear & 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 infrastructures are to be erected.
‘Road build’ sites	Sites where a new road (or similar) is to be constructed on a green field or rubble free base
‘Road Refurbishment’ sites	Sites where an existing road (or similar) is to be resurfaced or substantially rebuilt.

The nature and origin of construction and demolition waste will only determine the general characteristics of the waste stream. To properly evaluate the recycling potential of construction and demolition waste, it is imperative to identify the composition to enable the producer to assess what actions are needed.

3.3 Composition of Construction and Demolition Waste

3.3.1 The United States

Spivey (1974a) documented one of the earliest efforts to categorise construction waste. He classified the most common components of work-site wastes as follows:

1. Demolition materials (i.e. concrete, brick, wallboard, plaster and used lumber).
2. Packaging materials (i.e. paper, cardboard, plastic, excelsior and metal retaining bands).
3. Wood (including trees and scrap lumber).
4. Waste concrete and asphalt.
5. Garbage and sanitary waste.
6. Scrap-metal products.
7. Rubber, plastic, and glass.
8. Pesticides and pesticide containers.

Wilson *et al.* (1976) followed this up by attempting to identify the components of construction and demolition waste. He compared the following:

- The quantities of various materials that have gone into the construction of buildings presently standing (i.e. potential candidates for demolition).
- The total number of buildings (when new) represented by these quantities of materials.
- The characteristics of buildings that have been or will be demolished.

Nine significant materials of construction and consequently nine components of demolition waste were accounted for, including: ferrous metals, copper, aluminium, lead, concrete, wood, brick, glass and plastics. Other efforts to identify the components of construction and demolition waste that have been carried out include Apotheker (1990), who attempted to quantify the components of construction and demolition waste resulting from residential construction and identified that the composition of construction and demolition waste is highly variable depending on the type of construction/demolition practice activity. The main components identified were: concrete, wood, brick, roofing tiles, plastics, metals, drywall, rubble, asphalt and miscellaneous (refuse, dirt, sweepings and aggregates).

3.3.2 Europe (EU-15)

Symonds *et al.* (1999) identified that the composition of construction and demolition waste can vary enormously from site to site. Generally, it is divided into three types of waste, originating from:

1. New construction.
2. Renovation.
3. Demolition.

Renovation waste and demolition wastes are very similar in composition. Construction waste is generally caused by damaged materials and over-ordering. Figure 3.1 illustrates the division of the construction and demolition waste into demolition waste, renovation waste and construction waste across the EU-15.

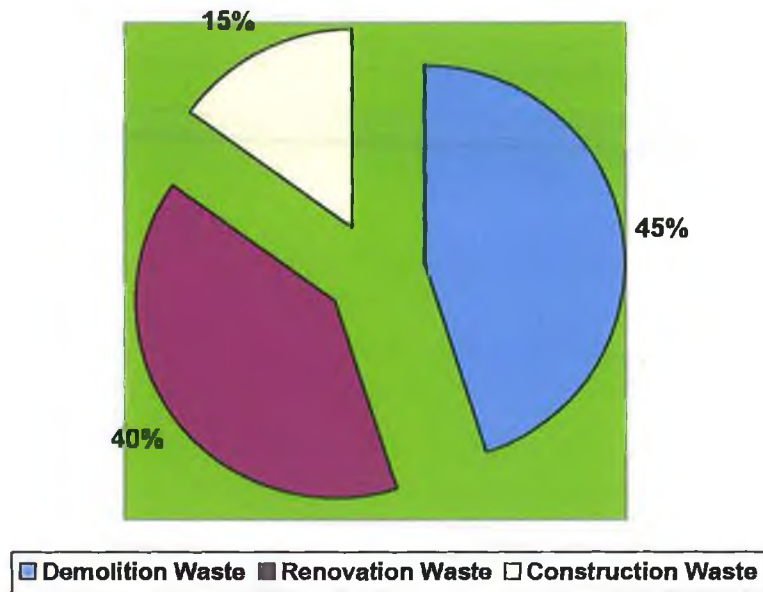


Figure 3.1 Division of the construction and demolition waste stream
(adapted from Symonds *et al.*, 1999).

The composition is influenced by the amount of selective demolition, which has taken place. In some cases, construction waste can be 'cleaner' than demolition waste.

The most important fraction of the construction and demolition waste stream is the inert fraction due to its quantity and potential for recycling. This is made up of bricks, stones, concrete and tiles, which comprises at least 70 per cent of all 'core' construction and demolition waste. In some Member States, this is even higher, accounting for 90 per cent of the construction and demolition waste stream (Symonds *et al.*, 1999).

The nature of today's construction and demolition waste is directly influenced by the building techniques and materials, which are used. It has to be taken into account that different construction methods will lead to varying components of the construction and demolition waste stream, e.g. wood is much more widely used in Scandinavia than elsewhere in the EU-15 and results in a higher percentage of wood waste. In the last 30 years, an increasing number of non-inert materials, such as plastics and metals have been used in construction. This has led to a change in the composition of construction and demolition waste with the non-inert fraction comprising a larger percentage of the waste stream. However, for the moment, the inert fraction is still the predominant fraction of the construction and demolition waste stream.

Due to the variety in the composition of construction and demolition waste across the EU-15, it is difficult to accurately list each component. 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 / ARGUS, 1995). These are:

- Soils and subsoils
- Excavated fill materials and made ground
- Concrete
- Asphalt and bituminous materials
- Bricks and tiles
- Timber (treated and untreated)
- Plaster, plasterboard and other internal finishes
- Plastics
- Metals
- Architectural features
- Mixed debris (delivery packaging, paper, cans, etc.)

3.3.3 Ireland

The first comprehensive attempt at quantifying waste production and disposal practices in Ireland was undertaken by Foras Forbartha (AFF) with the publication of the *National Database on Waste* in 1986 (as cited in EPA, 1996). This report concentrated on household and commercial waste collected by local authorities because this category was considered to be the only one where accurate and reliable data could be collated. The *National Database on Waste* was updated (partially) by the toxic and dangerous waste surveys carried out by the Department of the Environment in 1988 and 1992. Further surveys on waste arisings were conducted by and on behalf of the Department of the Environment (ERL 1993; MCOS, 1994; Department of the Environment, 1994). The generation and disposal of industrial waste was the topic of a survey carried out by Forbairt, formerly EOLAS in 1993 (ERU, 1993). The *State of the Environment Report* (EPA, 1996) summarised existing knowledge about waste arisings and disposal practices in Ireland.

It was not until the publication of the *National Waste Database Report, 1995* (EPA, 1996), that any significant statistics on waste were available. The report included information on: municipal (household and commercial) wastes; hazardous and non-hazardous industrial wastes; priority and other waste streams; as well as geographically referenced information on the locations of waste recovery; and recycling and disposal facilities throughout the country.

The estimated quantity of construction and demolition wastes arising in Ireland in 1995 was 1.32 million tonnes per annum. The composition of construction and demolition waste

was not addressed fully but the report did state that it estimated that approximately 36 per cent of the estimated total was comprised of soil and stones. It also stated that out of the 0.53 million tonnes that was estimated to be recovered in 1995, 97 per cent of this comprised soil and stones.

In a construction and demolition waste conference in Dublin Castle in September 1999, the Construction Industry Federation (CIF) gave a more comprehensive breakdown of the composition of the construction and demolition waste stream (Figure 3.2).

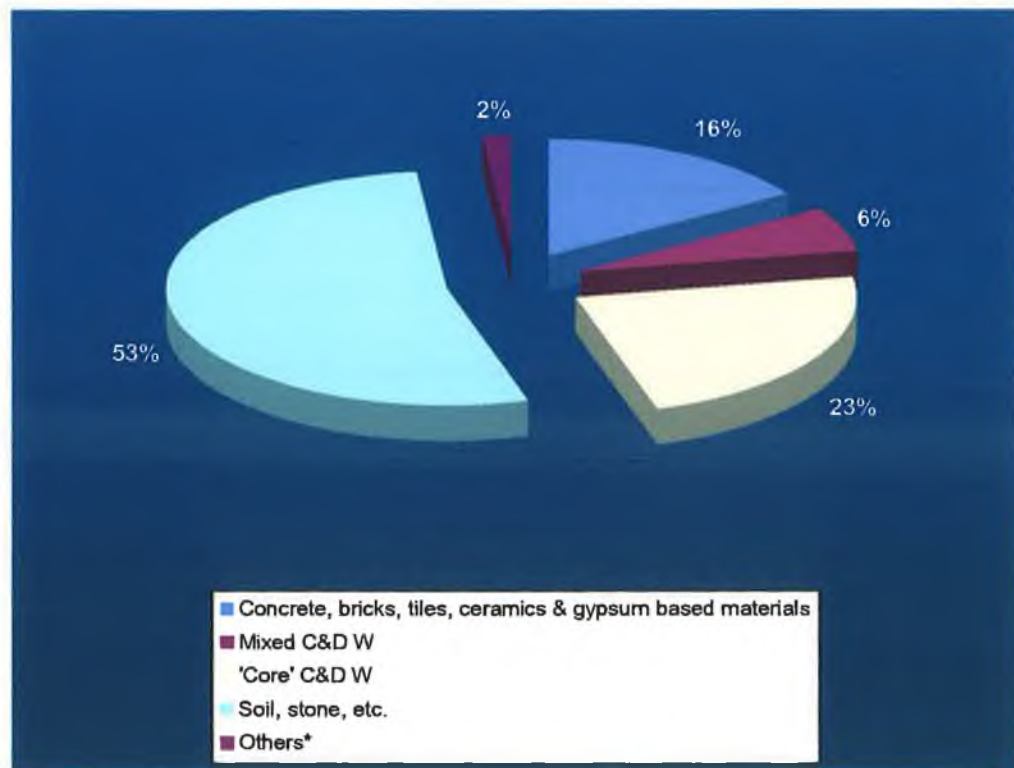


Figure 3:2 Estimated composition of construction and demolition wastes in Ireland in 1995
(Construction Industry Federation, 1999)

* Others represent wood, glass, plastics, metals and insulation.

This was followed by the publication of the *National Waste Database Report 1998* (EPA, 2000) which provided a more up-to-date summary of construction and demolition waste arisings in Ireland. Figure 3.3 illustrates the estimated composition of construction and demolition waste in Ireland for 1998.

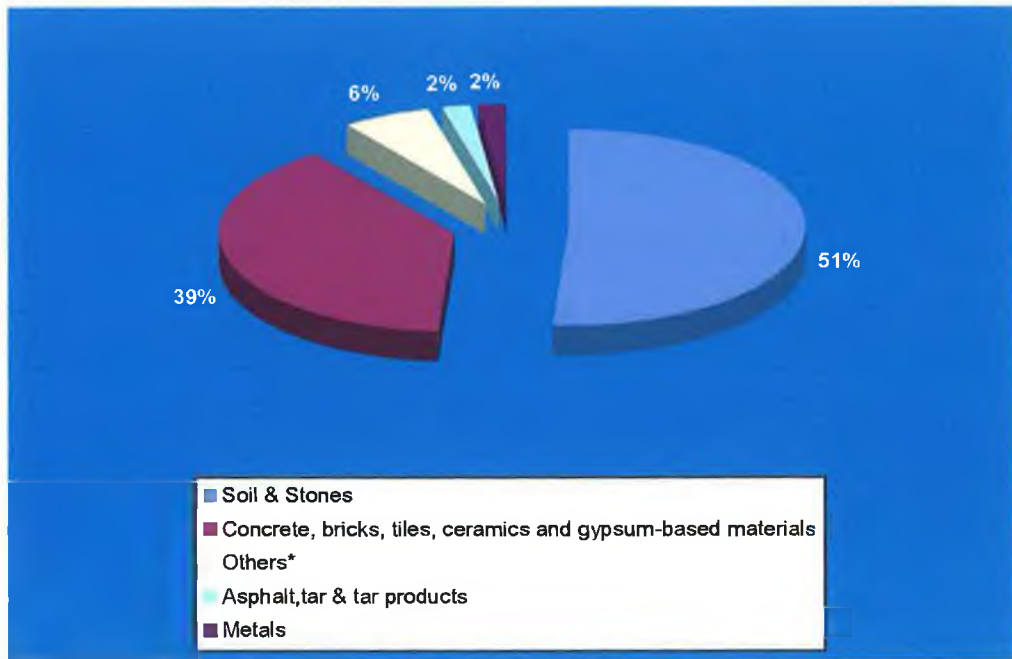


Figure 3.3 Estimated composition of construction & demolition waste in Ireland in 1998 (EPA, 2000)

* Others represents materials such as glass, wood, insulation etc.

It can be seen from both sets of data that the soil and stones fraction represents the largest fraction of the construction and demolition waste stream. There also seems to be a dramatic increase in the concrete, bricks, tiles, ceramics and gypsum based materials fraction from 16 per cent in 1995 to 39 per cent in 1998. This could be partly due to the different classifications used in the reports, e.g. in the 1998 report, the composition estimates were

based on a single survey from 1996 while in the 1995 report, the estimates were based on information received from returned questionnaires.

3.3.4 Connaught Region

There is no reliable data available on the composition of construction and demolition waste in the Galway Region. Figure 3.4 illustrates the composition and quantities of construction and demolition waste generated in the Dublin Region (CIF, 1999). This gives an indication of the possible composition of construction and demolition waste that may arise in the Connaught region.

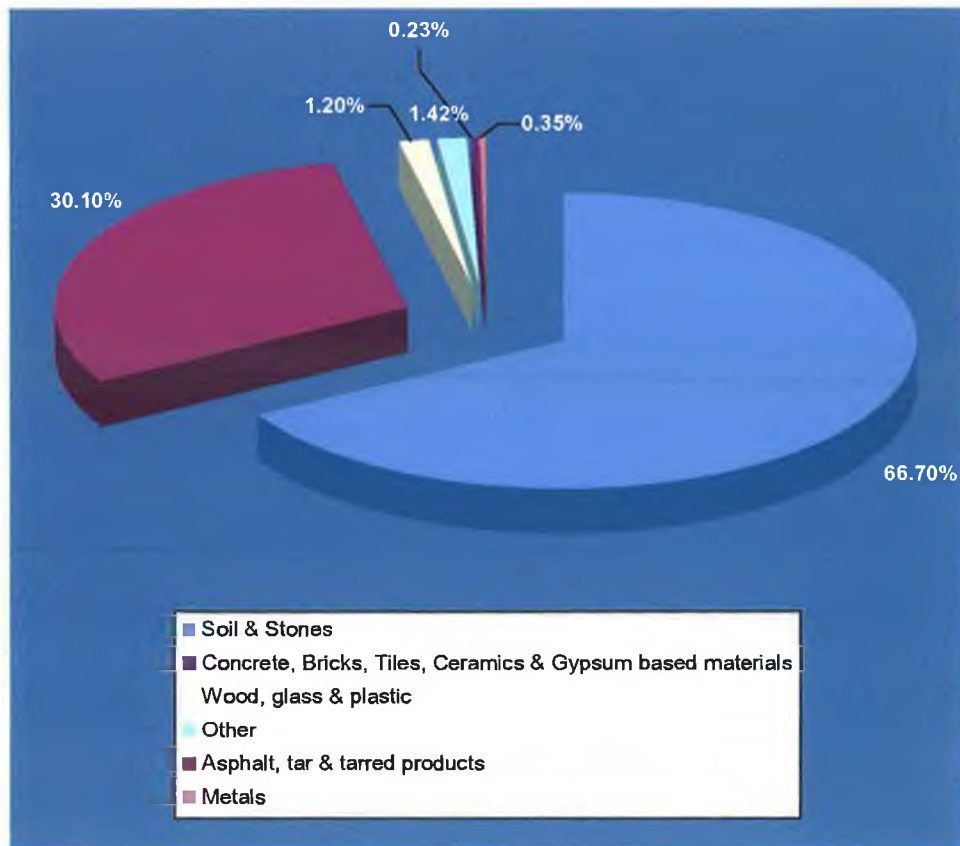


Figure 3.4 Estimated composition and quantities of construction and demolition waste generated in the Dublin region (CIF, 1999)

The inert fractions consisting of soil, stones, concrete, bricks, tiles, ceramics and gypsum-based materials account for 66.7 per cent and 30.1 per cent respectively resulting in an estimated total of 96.8 per cent. The *Galway Waste Management Strategy Report, 1998* (MCOS, 1998) estimated that two-thirds of the construction and demolition waste stream comprised soil in some form in County Galway.

3.4 Quantification of Construction and Demolition Waste

3.4.1 International waste flows and key trends

It is estimated, based on a 'best wild guess', that 2 to 3 billion tonnes of building waste is produced each year throughout the world (Lauritzen, 1994). As would be expected, the largest economies are contributing the largest volumes of construction and demolition waste. For example, construction and demolition waste accounts for a significant portion of America's municipal solid waste stream (MSWS). National estimates of construction and demolition waste generation rates have been limited in the past to the extrapolation of local data, such as population or construction employment figures. There have been four main studies in the past 35 years that have made national generation rate estimates.

The first was a *Public Health Service (PHS) Study*, which reported a national average of 0.66 pounds per person per day (ppd) (PHS, 1969). The same study reported an average urban generation rate of 0.77 ppd. This figure was reported in the 1986 U.S. EPA *Municipal Solid Waste Characterisation Report* as an estimate for the national average (U.S. EPA, 1986). This report estimated a figure of 31.5 million tonnes (mt) per annum of construction and demolition waste generation (based on the population of 240 million). In 1994, a draft report was prepared for the National Renewable Energy Laboratory (Franklin Associates, 1994) and it identified 22 cities, counties or states for which construction and demolition waste data was reported. A figure of 64.4 mt per annum was reported, a significant increase from the 1986 report. The most recent report prepared for the U.S. EPA by Franklin Associates, gives a new estimate for construction and demolition waste generation for building related activities (excluding wastes from roadways, bridges, land-

clearing and excavation) of 136 mt per annum in 1996 (Franklin Associates, 1998). This accounts for 24 per cent of the municipal waste stream and is in agreement with previous research, which produced an estimate of 23 per cent (Apotheker, 1990).

This figure of 24 per cent also correlates to research carried out in Australia, where various studies estimated construction and demolition waste to account for 22 per cent by weight of Melbourne's municipal solid waste stream in 1984/85 (EPA Victoria: Municipal Waste Services in Victoria, cited in Puplick and Nicholls 1992) and 27.4 per cent of landfill by weight in Perth (Department of Commerce and Trade (Western Australia) and W.A. Municipal Association, 1993). Craven (1994) extrapolated these figures to estimate that construction and demolition activity is likely to generate between approximately one fifth and one third of all waste entering Australia's landfills nationally.

Further research in other countries found similar results. One report estimated that the amount of construction waste generated in Brazil to be as much as 20 per cent of all materials delivered to site, by weight (Formoso, *et al.* 1993).

3.4.2 European waste flows and key trends

The European construction market, including civil, construction and building construction is valued at 754 billion Euro and the total employment is estimated at ten million [European Construction Industry Federation (FIEC) *Statistical Report*, December 1997] which makes the construction industry Europe's largest industrial employer, accounting for 7.5 per cent of total employment and 28.1 per cent of industrial employment in the EU-15.

In 1999, the European construction industry accounted for 9.7 per cent of Gross Domestic Product (GDP) and 47.6 per cent of fixed capital formation. Construction activities consume more raw materials by weight (approximately 50 per cent) than any other industrial sector. It is responsible for producing Europe's largest waste stream estimated at 40 and 50 per cent of the total waste stream (*EU Sustainable Construction Working Group, 2001*). Table 3.2 outlines how the European employment figures are broken down between Member States.

Table 3.2 Turnover and employment in the EU construction industry (FIEC, 1997)

	% Share of EU-15 by turnover		% Share of EU-15 by employment	
	(Ranking) Actual %	Cumulative	(Ranking) Actual %	Cumulative
Germany	(1) 37.0	37.0	(1) 24.8	24.8
U.K.	(2) 12.5	49.5	(4) 13.7	38.5
France	(3) 11.4	60.9	(3) 14.2	52.7
Italy	(4) 11.4	72.3	(2) 16.0	68.7
Spain	(5) 8.4	80.7	(5) 11.7	80.4
The Netherlands	(6) 4.7	85.4	(6) 4.1	84.5
Belgium	(8) 2.8	88.2	(10) 2.2	86.7
Austria	(11) 1.3	89.5	(12) 1.3	88.0
Portugal	(10) 1.8	91.3	(7) 3.4	91.4
Denmark	(9) 2.2	93.5	(11) 1.7	93.1
Greece	(13) 1.1	94.6	(8) 2.5	95.6
Sweden	(7) 3.1	97.8	(9) 2.2	97.8
Finland	(12) 1.2	99.0	(13) 1.2	99.0
Ireland	(14) 1.0	99.9	(14) 0.9	99.9
Luxembourg	(15) 0.1	100.0	(15) 0.1	100.0
Total	100.0	100.0	100.0	100.0

Note: The employment figures for Greece and Luxembourg are estimates from Symonds et al., 1999.

From Table 3.2, it is evident that five Member States, Germany, France, UK, Italy and Spain, contribute over 80 per cent of the European total in value terms and this is reflected in Table 3.3, which outlines figures for construction and demolition waste arising in Europe.

Table 3.3 Construction and demolition wastes arising and recycling in EU-15

(Symonds *et al.*, 1999)

Member State	“Core” C & DW Arising (m tonnes, rounded)	% Re-used or Recycled	% Incinerated or Landfilled
Germany	59	17	83
UK	30	45	55
France	24	15	85
Italy	20	9	91
Spain	13	<5	>95
Netherlands	11	90	10
Belgium	7	87	13
Austria	5	41	59
Portugal	3	<5	>95
Denmark	3	81	19
Greece	2	<5	>95
Sweden	2	21	79
Finland	1	45	55
<i>Ireland</i>	<i>1</i>	<5	>95
Luxembourg	0	n/a	n/a
EU-15	180	28	72

Construction and demolition waste was identified as a priority waste stream in 1991 as part of the *Priority Waste Stream Programme*. The objectives of this programme were to respond to the waste management hierarchy, which is:

1. Prevention or reduction
2. Re-use
3. Recycling or materials recovery
4. Energy recovery
5. Disposal in a safe manner

A construction and demolition project group was set up in 1992, and included representatives from the building industry, material producers, wholesale and trade organisations, architects, consumers, recycling and recovery organisations, waste management organisations, environmental protection agencies, local and regional authorities, Member States, European Free Trade Association (EFTA), and the European Commission.

One of the key objectives of the programme was to identify and quantify the amount of construction and demolition waste throughout the Member States. Table 3.3 outlines the construction and demolition waste arisings and the percentages re-used or recycled.

In the report to the European Commission, Symonds *et al.* (1999) identified the following:

- 'Core' construction and demolition waste was estimated to be in the region of 180 million tonnes per annum (Table 3.3).

- This equates to approximately 480kg per person per year.
- Only 28% of the construction and demolition waste stream across the EU-15, as a whole is being reused or recycled.
- If you add construction waste ('non-core'), road planings and excavated soil and rock to this figure (180 mt), it more than doubles the total weight and volume of material to be managed.

Table 3.3 illustrates that the five Member States; Germany, the UK, Spain, Italy and France, who have the largest share of the overall construction market (Table 3.2) account for nearly 80 per cent of the total 'core' construction and demolition waste.

Figure 3.5 illustrates the largest contributors to construction and demolition waste in Europe.

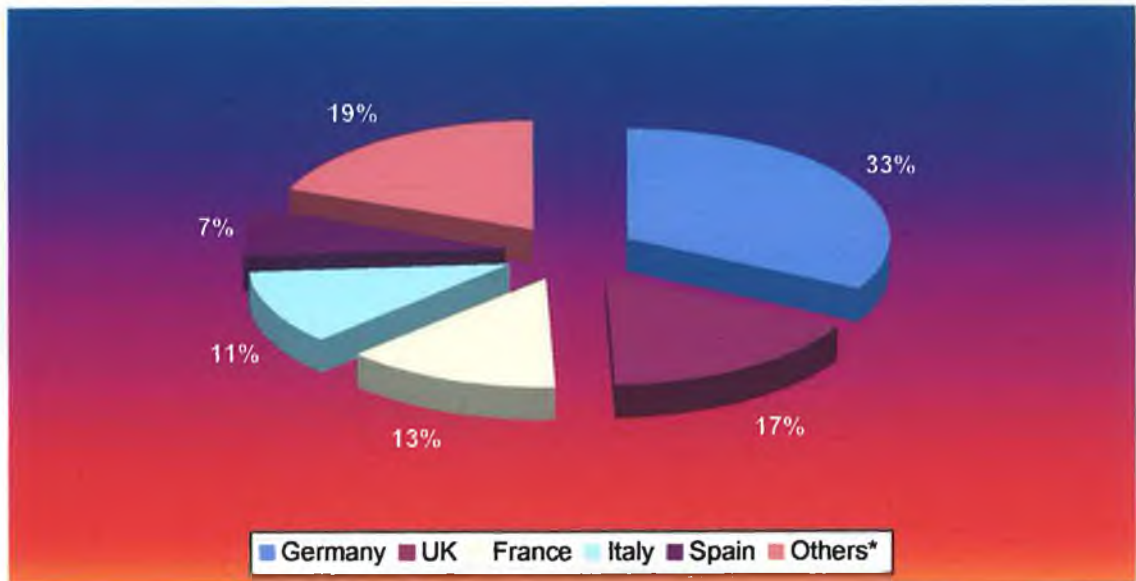


Figure 3.5 Largest contributors to construction and demolition waste in Europe

(Adapted from Symonds *et al.*, 1999)

*Others represent the Netherlands, Belgium, Austria, Portugal, Denmark, Greece, Sweden, Finland, Ireland and Luxembourg.

To clarify the accuracy of these results, it is important to identify where they originated from, i.e. research reports and studies.

3.4.3 Individual Breakdown of Largest Contributors

Germany

Taking the quantities from Table 3.3, Germany produces 59 million tonnes of construction and demolition waste per annum, recycling 17 per cent and incinerating or landfilling the other 83 per cent. Kohler (1994) and additional data from the recycling industry forms the

basis for these figures. Further research by Brooks *et al.* (1994) reported that construction and demolition waste amounts to 19 per cent of the total waste stream in Germany.

United Kingdom

The UK produces 30 million tonnes of 'core' construction and demolition waste per annum, with 45% of this being recycled and 55% landfilled. These figures are derived from research reports published by Arup Economics and Planning (1991) and Howard Humphreys and Partners (1994). Howard Humphrey's 1994 estimate of 70 million tonnes of total construction and demolition waste being produced each year was generally accepted by the Department of the Environment as the best estimate possible at that time. During 1997, a pilot study of construction and demolition waste crushers in three English regions was carried out by Arup Economics and Planning. This study estimated that 67 million tonnes of construction and demolition waste was being produced each year. The recycling estimate for 'core' construction and demolition waste was 45%, which is lower than the Howard Humphrey's 1994 estimate of 63%.

France

France produces 24 million tonnes of construction and demolition waste per annum. The primary source for this figure is a 1998 report, '*Guide des Dechets de Chantiers de Batiment*' (as cited in Symonds *et al.*, 1999). This report covered the building and renovation sector in great detail, but it did not extend to civil engineering projects.

Italy

Italy produces 20 million tonnes of construction and demolition waste per annum. These figures were derived from a 1998 CRESME report, *'Il Mercato delle Demolizione in Italia'* and a 1997 report, *'Report on the State of the Environment'* prepared by the Ministry of the Environment (as cited in Symonds *et al.*, 1999).

Spain

The estimate of 13 million tonnes per annum was based on an estimate of 'core' construction and demolition waste arisings on a per capita rate of 325kg/year (as cited in Symonds *et al.*, 1999). This is due to the fact that no official statistics were available.

It can be seen from these figures that construction and demolition waste is a huge problem across Europe. The difficulty in quantifying this waste stream accurately means that the full extent of the arisings is not shown in Table 3.3 and many of the estimates may be an understatement.

Ireland

Ireland props up Table 3.3 with Luxembourg. The estimate of 1 million tonnes of 'core' construction and demolition waste was produced by M. C. O'Sullivan & Co. Ltd., based on the *1995 National Waste Database Report* (EPA, 1996). The *1998 National Waste Database Report* (EPA, 2000) identified a dramatic increase of construction and demolition waste from 1995 to 1998 (Table 3.5), from 1.32 million tonnes to 2.7 million tonnes per annum.

It can be seen from these figures that there is great difficulty in accurately quantifying the total amount of construction and demolition waste arising in the EU-15. Research carried out in the different countries only give 'best estimates' of the actual figures.

A recent report from the European Environment Agency (Brodersen *et al.*, 2002) reviewed selected waste streams in the EU-15. Seventeen countries were asked to submit information on five waste types including construction and demolition waste. There were seven replies for construction and demolition waste. This was where additional information was available (national reports, extracts from reports or corrections to previously submitted information) which was not previously submitted to the OCED / Eurostat or Environment DG. Data availability was limited for some of the waste fractions, especially glass, plastics, insulation and mixed waste. As a consequence, data for these fractions were excluded from the report's findings.

Table 3.4 illustrates the most recent information concerning the total quantities of construction and demolition waste in selected EEA countries. A comparison of Table 3.3 and 3.4 will illustrate some differences in the quantities estimated. This is due to the fact that the EEA Report (Brodersen *et al.*, 2002) is a more recent report with updated figures and more importantly, it does not quantify construction and demolition waste as 'core' materials.

Table 3.4 Total quantities of construction and demolition waste per country and capita (adapted from Brodersen *et al.*, 2002)

Country	Year	Quantity (1 000 tonnes)	Quantity (kg per capita)
Austria	1996	25 392	3 155
	1999	7 500	930
Denmark	1994	2 433	466
	1995	2 559	490
	1996	3 088	591
France	1997	3 427	656
	1991	13 700	236
Germany	1992	25 000	430
	1990	121 178	1 485
	1993	131 645	1 613
Greece	1996	219 921	2 695
	1991	1 718	164
Ireland	1996	1 809	173
	1995	1 320	429
Italy	1998	2 705	763
	1995	14 311	250
Netherlands	1997	20 397	357
	1995	13 700	885
Spain	1996	13 650	882
	1994	22 000	555
UK	1999	20 628	521
	1990	70 000	1 205

3.4.4 Waste flows and key trends in Ireland

The gross value of construction output was estimated at approximately €19.5 billion for 2001 or around 20 per cent of Gross National Product (GNP). There has been a major expansion in construction output from 1993 to 2000. The industry has experienced a slowdown in output in 2001 with the rate of growth falling 2 per cent. The Construction Industry Federation (CIF) predicts that the industry will show a further decline in growth rate of 2.5 per cent for 2002 but expects the industry to have positive growth of about 4 per cent in 2003. Employment in the industry is currently at 185 000 with a further 75 000 people employed in the construction materials/materials providers and within the construction profession. Given the huge influence that the construction industry has on the Irish economy, it is not surprising that some areas have been neglected in the past. One such area is the production of construction and demolition waste and its impact on the environment.

The Environmental Protection Agency (EPA) has the responsibility for collating data to determine accurate and reliable figures for the waste arisings in Ireland. The EPA is committed to publishing national surveys every three years to establish key trends in the amount of waste being produced. The *National Waste Database Report, 1995* (EPA, 1996) provided the first attempt at such a survey. The report was primarily based on surveys and questionnaires received from local authorities, industry, waste contractors and recycling organisations. It presented national waste statistics for the year 1995 along with an inventory of waste disposal and recovery facilities throughout the country.

The most recent report from the Environmental Protection Agency concerning waste arisings is the *National Waste Database Report, 1998* (EPA, 2000). This provides the most accurate and reliable information on waste arisings in Ireland, to date. There has been an improvement in the quality of information collected by the EPA since the 1995 report due to the fact that there are a greater number of waste facilities and waste producers becoming more familiar with waste terminology and waste reporting in general.

From this report, it is estimated that the national waste arisings for 1998 were 80 012 678 tonnes. Of this, approximately 64.6 million tonnes (82 per cent) originated from agricultural sources with the municipal and industrial sectors accounting for over 15 million tonnes of waste (18 per cent) produced in 1998 (Figure 3.6).

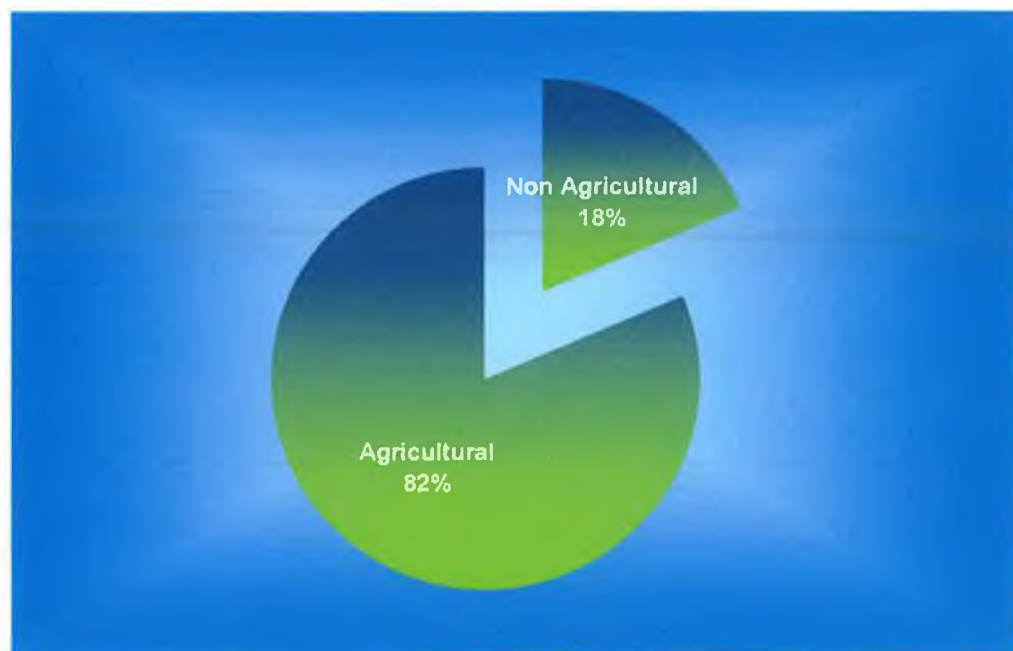


Figure 3.6 Estimated national wastes arising in 1998 (EPA, 2000)

A comparison of best estimates of waste arisings for 1995 and 1998 are presented in Table 3.5. It can be seen from Table 3.5 that construction and demolition waste increased significantly from 1 318 908 tonnes per annum in 1995 to 2 704 958 tonnes per annum in 1998. Improved reporting by local authorities and industry can account for a percentage of the increase in waste quantities as they give a more accurate picture of how much waste is being produced. The main reason for the large increase in construction and demolition waste is that this sector is producing waste in line with economic growth. The 'building boom' that has continued since 1995 has led to an increase in construction activity, which in turn, has led to an increase in the production of waste.

Table 3.5 Comparison of estimated arisings in Ireland for 1995 and 1998 (EPA, 2000)

Waste Category	1998		1995	
	<i>Tonnes/ annum</i>	(%)	<i>Tonnes/ annum</i>	(%)
Agricultural	64 578 724	80.7	31 000 000	73.4
Manufacturing	4 876 406	6.1	3 540 226	8.4
Energy, Gas & Water Supply	448 674	0.6	351 849	0.8
Mining & Quarrying	3 510 778	4.4	2 200 002	5.2
Hazardous Waste	370 328	0.5	243 754	0.6
Municipal Waste	2 056 652	2.6	1 848 232	4.4
End-of-Life Vehicles/Scrap Metal	187 484	0.2	52 154	0.1
Construction & Demolition Waste	2 704 958	3.4	1 318 908	3.1
Urban Wastewater Sludges	50 586	0.6	851 380	2.0
Drinking Water Sludges	38 988	0.0	58 095	0.1
Dredge Spoils	734 000	0.9	784 600	1.9
TOTAL	80 012 678	100.0	42 249 200	100.0

The amount of construction and demolition waste being produced in 1998 is likely to be much higher than 2.7 million tonnes (EPA, 2000). The lack of accurate and reliable reporting and tracking of the construction and demolition waste stream does not allow for a comprehensive analysis of this waste stream. This problem is highlighted in Table D-1 (Appendix D), taken from the *National Waste Database Report 1998*, which summarises information reported by local authorities on construction and demolition waste management in their functional areas. The report acknowledges that there are considerable gaps in information at local levels and recommends that a national study be established to identify reliable and accurate statistics for the construction and demolition waste stream.

Table 3.6 summarises the waste flows in Ireland in 1998 for non-agricultural wastes outlining the percentages disposed and recovered.

Table 3.6 Waste flows in Ireland for non-agricultural reported wastes in 1998 (EPA, 2000)

Waste Category	Arisings <i>Tonnes/ annum</i>	Disposal <i>(%)</i>	Recovery <i>(%)</i>	Unspecified <i>(%)</i>
Manufacturing	3 680 013	48.6	51.4	47.0
Energy, Gas & Water Supply	448 674	84.0	16.0	0.0
Mining & Quarrying	3 510 778	99.6	0.4	0.0
Hazardous Waste	370 328	37.0	54.4	8.5
Municipal Waste	2 056 652	91.4	8.6	0.0
End-of-Life Vehicles/Scrap Metal	187 484	4.0	96.0	0.0
Construction & Demolition Waste	2 704 958	56.7	43.3	0.0
Urban Wastewater Sludges	50 586	93.3	5.9	0.8
Drinking Water Sludges	38 988	100.0	0.0	0.0
Dredge Spoils	734 000	94.6	0.0	1.9
TOTAL	14 040 047	73.2	26.6	0.2

It can be seen from Table 3.6 that 56.7 per cent of construction and demolition waste is been disposed of and that 43.3 per cent is being recovered. These percentages are based on information reported to the Environmental Protection Agency (EPA), which estimates that 1 171 572 tonnes of waste going to landfill was recovered in 1998. This consisted of construction and demolition waste reported to be received at Dunsink (931 572 tonnes) in Fingal and Kinsale Road (240 000 tonnes) in Cork City. This material was recovered by putting it to beneficial use on the landfill sites either as a construction material for the construction of roads and berms or as cover and capping material. These figures can only be taken a 'best estimates' as there are no accurate and reliable recycling and recovery figures available in Ireland at the moment.

3.4.5 Waste flows and key trends in Connaught

The *National Waste Database Report 1998* (EPA, 2000) highlighted the difficulties in assessing the quantities of construction and demolition waste being produced in the Connaught region. Table 3.7 illustrates this point by outlining the information submitted by the relevant local authorities for the preparation of the *National Waste Database Report 1998* (EPA, 2000).

Table 3.7 Summary of waste flow and landfilling information reported to the EPA by Connaught local authorities for construction and demolition waste for the preparation of the *National Waste Database Report, 1998* (adapted from EPA, 2000).

Local Authority	Arising in FA*	Imported into FA	Exported from FA	Managed within FA	Reported landfilled in FA
Galway Corporation	0	0	0	0	0
Galway County Council	0	0	0	0	1 050
Leitrim County Council	0	0	0	0	0
Mayo County Council	0	0	0	0	2 500
Roscommon County Council	13 300	0	0	13 300	0
Sligo County Council	60 000	0	0	60 000	0

* *Functional Area*

The Waste Management Plan for the Connaught Region 1999-2004 (MCOS/COWI) offers the best source of information from which to estimate the quantity of construction and demolition wastes arising in the Connaught region. The present estimate for non-agricultural waste generation in the Connaught region is 596 054 tonnes of municipal and

industrial waste per annum. Table 3.8 outlines the different waste types and the estimated quantities.

Table 3.8 Quantities of non-agricultural waste arisings in the Connaught region (MCOS/COWI, 1998)

Waste Type	Connaught Region (tonnes/annum)
Household Collected	133 115
Household Delivered (bulky)	4 606
Other Household	11 395
Commercial	53 162
Industrial Sludges	4 070
Industrial	116 993
Construction/Demolition Waste	201 510
Ash/Incineration Residue	0
Contaminated Soil	0
Litter/Street Sweepings	8 345
Water Treatment Sludge	1 263
Wastewater Treatment	13 540
Mining & Quarrying	46 672
Healthcare	1 384
Subtotal	596 054
Agricultural	9 952 626
Total	10 679 952

Priority wastes including tyres, end-of-life vehicles, electrical equipment waste, packaging waste, batteries and accumulators, PCB's and waste oils are not included in Table 3.8. The figures used in Table 3.8 were extrapolated from the *Proposed Hazardous Waste Management Plan, 1999* (EPA, 1999) and from figures in the *Connaught Waste Management Strategy* (MCOS/COWI, 1998).

3.4.6 Waste flows and key trends in Galway

The *Galway Waste Management Strategy Study Report, 1998* (MCOS, 1998) provides the best estimates for County Galway. The strategy study was intended to provide a basis for informed decision making by each authority as to the most appropriate options to achieve optimum management over the next 20 – 25 years. Table 3.9 and Figure 3.7 outline the quantities of non-agricultural wastes arising in County Galway. The figures are based on landfill surveys conducted by Galway local authorities, MCOS/COWI, questionnaires and information obtained from the *National Waste Database Report, 1995* (EPA, 1996).

Table 3.9 Quantities of non-agricultural waste arisings in County Galway (MCOS, 1998)

Waste Type	% of Waste Stream	Tonnes/annum
Household	25.00	56 369
Commercial	15.51	34 962
Industrial	18.45	41 627
Construction & Demolition	29.95	67 510
Street Sweepings	0.25	555
Sewage Sludge	1.96	4 400
Mining & Quarrying	8.88	20 000
Total	100	225 423

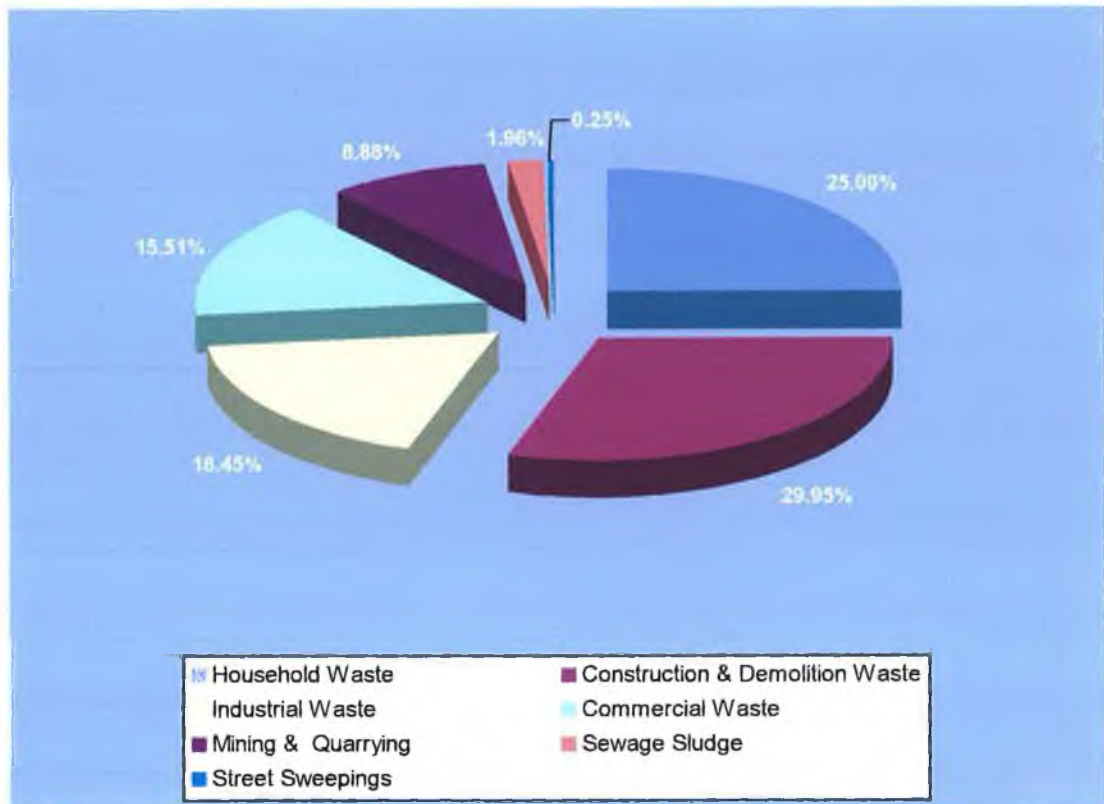


Figure 3.7 Estimated quantities of non-agricultural wastes arising in County Galway (MCOS, 1998)

The best estimate for construction and demolition wastes arising in County Galway of 67 510 tonnes/annum accounts for 29.95 per cent of the non-agricultural wastes arising in this area. The report states that an estimated 22 300 tonnes/annum were used in recent years in land reclamation activities principally in the docks area. This outlet has been closed for the past 3 years. The report also states that only one company, Barna Waste Ltd., operates a recycling and transfer station at which they take in and process approximately 18 000 tonnes of predominantly construction and demolition waste per annum (now licensed to receive 30 000 tonnes per annum).

3.5 Conclusions

The aim of this chapter was to identify the main characteristics of the construction and demolition waste stream. This was achieved by addressing four related aspects:

1. The nature of construction and demolition waste.
2. The source of construction and demolition waste.
3. The composition of construction and demolition waste.
4. The quantity of construction and demolition waste being produced.

The main conclusions arising from exploring these aspects were that:

- There are numerous classifications for the nature and source of the construction and demolition waste stream. The most up-to-date classification put forward by Symonds *et al.* (1999) provides an acceptable definition of the origin and nature of construction and demolition waste in Europe.
- The source of construction and demolition waste is dependent on the nature of the construction activity and site type. Symonds *et al.* (1999) again provides a comprehensive categorisation of the various site types including: 'demolish and clear' sites; 'demolish, clear and build' sites; 'renovation' sites; 'greenfield' sites; 'road build' sites; and 'road refurbishment' sites.

- The composition of the construction and demolition waste stream is highly variable and is also dependent on the nature of the construction activity. Accurate data is difficult to ascertain but estimates provided by various sources indicate that the inert fraction could possibly account for up to 90 per cent plus of the construction and demolition waste stream in Ireland.
- The annual waste production estimates provided by various reports illustrate the extent of the problem facing the European Community as a whole. Taking into the account the difficulty in accurately quantifying the construction and demolition waste stream, it could be assumed that many of figures proposed may be an understatement of the actual arisings. This is especially relevant in Ireland where the *National Waste Database Report, 1998* (EPA, 2000) recognised that there currently exists a lack of accurate and reliable reporting and tracking of construction and demolition waste, which does not allow for a comprehensive analysis

It has being identified that the construction industry is facing an enormous problem, highlighted by the huge quantities of construction and demolition waste being produced each year. The next chapter will take the logical step in trying to find a solution to this problem by investigating previous research carried out into the recycling and reuse of construction and demolition waste materials

Chapter 4 : The Potential of Construction and Demolition Waste for Recycling and Reuse

4.1 Introduction

This chapter will focus on previous research carried out in the area of construction and demolition waste materials recycling and reuse. It will examine findings that demonstrate the potential of these materials to be recycled and reused successfully.

4.2 History

The reuse and recycling of construction and demolition waste materials is not a new concept. For thousands of years, civilisations have built on top of one another, with new societies plundering relics of the past. A classic example of this is in Rome, Italy. In the early years of the Roman Empire, some 2 500 years ago, the Romans used Etruscan³ building materials and slave labour to construct enormous temples, baths and domes. The marble sheathed Colosseum was built by some 40 000 slaves in just eight years. After the fall of Rome, approximately 1 200 years later, the Catholic Church began recycling many Roman building materials. When marble was needed to build a castle, palace or church, someone was dispatched to the Colosseum to pull down a piece of marble, brick, stone and transport it to the new building site.

De Pauw *et al.* (1994) reported that the Romans used fragments of tiles and bricks as aggregates and mixed these with calcined limestone (lime) and pozzolanic materials, such as volcanic ash, to produce early cement materials. Examples of this can be seen in the

³ Pre-Roman civilisation

oldest city in Belgium, Tongeren and in the concrete channels of the Eifel water supply to Cologne (Schulz and Hendricks, 1992).

Crushed brick concrete with Portland cement was used in Germany from 1869 for the manufacture of concrete products and systematic investigations on the effect of cement content, water content and grading of crushed brick have been carried out since 1928 (Schulz and Hendricks, 1992). However it was not until the immediate aftermath of the Second World War that direct applications of these materials were realised.

The end of the Second World War left Germany with an estimated 400 to 600 million cubic metres of brick rubble. This had two effects:

1. There was an enormous demand for building material in order to begin reconstruction.
2. The removal of the rubble from the destroyed cities involved large site clearance costs.

It was decided to reuse this rubble to meet these two problems head-on. To aid this massive undertaking, many technical and economic guidelines were published between 1945 and 1960. The main standard was *DIN 4163 Ziegelsplittbeton*, 1951, which regulated the use of recycled masonry rubble, generated from material bigger than 30mm, as a base material for concrete. There were a vast number of articles published [*The German Society of the Use of*

Rubble issued a total of 437 publications listed in Heller, 1958 (as cited in Schulz and Hendricks, 1992)] during this period to expand the knowledge in the use of these materials.

Rubble-recycling plants in the Federal Republic of Germany produced approximately 11.5 million cubic metres of crushed brick aggregate by the end of 1955, with which 175 000 dwelling units were built (Heller, 1958 as cited in Schulz and Hendricks, 1992). The statistics compiled by the *Association of German Cities* show that by the end of 1956, approximately 85 per cent of all building rubble in the German Federal Republic had been cleared. In two-thirds of all municipalities, clearance was complete at the beginning of 1957, with only about one million cubic metres remaining in fifteen large cities in the Federal Republic (Heller, 1958 cited in Schulz and Hendricks, 1992). By 1960, practically all of the rubble was recycled and/or reused.

In the U.K., rubble was also recycled after the Second World War, although to a lesser extent than in Germany. The reuse of masonry rubble, originating from the demolition of military defensive structures, were utilised as aggregates in applications such as in blocks for chimneys, in fire-resistant coverings of steel construction, in the production of building stones or blocks for interior walls and in floors.

After this post-war period, there was a pause in the study of reusing and recycling construction and demolition waste materials until the 1970s when the publication of many articles in the U.S. prompted renewed interest in Europe. There is evidence, however, that the use of masonry rubble was widespread during the fifties and sixties in Belgium from

the specifications of the time [*Cahier des charge – Type No. 104: Entreprises de Travaux de Batiments, 1963* (as cited in Schulz and Hendricks, 1992)]

4.3 1970s Research

4.3.1 United States

In the seventies, a significant amount of research was initiated in USA and Europe into the possible reuse of construction and demolition waste materials. In the USA, most of the research carried out concentrated on the recycling of concrete and pavement materials. Marek *et al.* (1971) examined the potential of recycling pavement and structural concrete rubble. Recycling pavement rubble was identified as a logical alternative to transporting natural aggregates from other localities, sometimes over long distances. Bargman (1972) identified construction and demolition waste as one of the four waste streams that made up the recoverable solid waste stream. He stated that construction and demolition waste had little recovery potential, except for fill purposes.

“..for all practical purposes, however, recycling or material recovery of these wastes is nil, and there is little prospect for increasing their use”.

(Bargman, 1972)

This view was supported by Wilson (1975), who examined the resource potential of demolition debris in the United States. He concluded that good quality broken concrete was no longer generally in demand as hard fill, although he did recognise that there were many reports in the literature of concrete stating that it was being recycled into new pavement and other types of construction (*Roads and Streets*, 1971; Sadler, 1973; Briggs, 1973).

Jones (1973) further supported Wilson and Bargman's view by stating:

"...concrete represents by far the largest tonnage of construction material...74 per cent in 1971...For all practical purposes, the recycling of concrete is non-existent."

(Jones, 1973)

Further research was carried out to examine potential and hypothetical new technologies and applications, which when applied to resource recovery from demolition wastes, could be economically feasible (Wilson, 1975). It was reported that markets existed for scrap iron, steel, aluminium, copper and glass and that the markets for wood, concrete, and plastic were insignificant. It concluded that wood waste and concrete had enormous potential for recycling and reuse, e.g. wood waste could be used for paper pulp, mulch, particleboard and fuels and concrete could be used as a substitute for natural aggregates as it was proven to be a feasible source of base and fill material for paving in several operations in the U.S.

Saylak *et al.* (1976) investigated the recycling of old asphalt pavements and concluded that a good possible source of both quality aggregates and asphalt cement was through the reuse or recycling of building and paving construction materials. Wilson *et al.* (1976) identified that the existing markets for wood, concrete and plastic were insignificant (thus corroborating his previous research) but recognised that concrete offered potential for reuse as aggregate in areas where natural aggregate was scarce and where the transportation costs of natural aggregates offset the cost of crushing the concrete.

4.3.2 Europe

In the UK, the most prolific researcher in the area of construction and demolition waste was E.R. Skoyles. His work was based on a pilot project organised by the Building Research Establishment (BRE). Two studies were carried out in the 1970s; the first one was to determine the incidence and nature of the losses (Skoyles, 1974; Skoyles and Hussey, 1974) and the second one was to devise and test an accounting system to enable wastes to be monitored while work was in progress (Skoyles, 1976a,b,c; 1978).

In both studies combined, data had been gathered from 114 sites, though not all materials were studied on all sites. The earlier study concluded that the average losses of the principal building materials were higher than the norms used in practice by contractors and that there was great variability in waste between apparently similar sites. The average overall percentage for waste on building sites was calculated at 10 per cent, though this could rise to 20 per cent for certain materials on different sites. The second study aimed at producing an accounting system that could enable the contractor/quantity surveyor to measure the waste as it occurs.

He concluded that in the United Kingdom, waste on building sites represented a considerable loss of the nation's resources. In the housing sector alone the losses, if applied to the 1974 housing output, would have been sufficient to provide about another 13 000 dwellings per year. In the industry as a whole, it was calculated that if every firm were able to reduce its waste of common traditional materials by only 10 per cent, approximately £30 million (1975 prices) could be saved on the cost of materials alone (Skoyles, 1976a,b,c).

Other contributors to the study of construction and demolition waste at this time were Abbot (1970), Dunning (1972) and Wyatt (1978). They all indicated that waste was a problem and that an improvement in materials control was the key to its alleviation within the building firm.

4.4 1980s Research

4.4.1 United States

Research in the United States continued to be mainly concerned with the potential reuse/recycling of asphalt and pavement material for use in the rehabilitation and maintenance of the transportation system (Epps, 1980; Dallaire, 1980; Jimenez, 1980; and the Transportation Research Board, 1988).

Clifton *et al.* (1980a,b) expanded this research into investigating the use of waste materials and by-products in construction. He identified that the level of use of recovered material depends on the specific material and the geographical region. Taking used bricks as an example the research identified that the market for used bricks varied across the U.S., with most of the recovered brick in the New England region being reused, whereas used brick had little or no value in the Midwest region. He supported previous research carried out in the 1970s (Bargman, 1972; Jones, 1973; Wilson 1975) by stating that that only an insignificant portion of the available concrete, wood, gypsum, asphalt, and plastics from demolished buildings and highways was being recycled. Asphaltic concrete⁴ was identified as one demolition waste that was increasingly being recycled (due in no small part to the extensive research in this area). He recommended that the technology of separating the materials present in the rubble needed to be improved to prevent contamination. The lack of data was also highlighted as a factor that was limiting the recycling rates.

⁴ Used as a road surfacing material

4.4.2 Japan

In Japan, extensive research was carried out into the use and properties of recycled aggregate concrete (Kashino and Takahashi, 1988; Ikeda *et al.*, 1988; Yanagi *et al.*, 1988; Kasai *et al.*, 1988). Kawamura and Torii (1988) examined the reuse of recycled concrete aggregate for pavement. Recycled aggregates were not widely used for new pavement construction in Japan at this time. It was found that the recycled aggregate from old pavement had more favourable physical properties as a concrete aggregate for concrete paving than that from an old building. This led to the conclusion that based on the mechanical properties of the concrete made from recycled aggregate, the recycled aggregate from old pavement can be used as a concrete aggregate for the light-traffic pavement or car-parking areas.

4.4.3 Europe

In Europe, research efforts began to intensify with work coming from most of the Member States. Hansen and Narud (1983) studied the strength of hardened concrete made from recycled concrete and reached the conclusion that there should be little practical difficulty in producing recycled structural concrete of the same strength as old concrete provided the strength is uniform throughout a structure to be demolished. If this is not the case, low strength concrete of uniform quality, such as frequently used for foundations and non-load bearing structures, could be produced from a recycled aggregate, regardless of the quality of the original concrete from which the recycled aggregates is derived. Hendricks (1985) reported that the first use of recycled aggregate concrete in the Netherlands was in Amersfoort in 1984 where such concrete was used in partition walls in an apartment

building. In 1985, coarse recycled aggregate concrete was used for a lean mix course and concrete pavement at Volkel Airport, in the Netherlands (Hendricks, 1985). From 1985, the use of aggregates for the production of new concrete for general construction purposes has been permitted in the Netherlands

Schulz (1988) reviewed developments in West Germany with regard to producing concrete with recycled rubble. This review was based on a pilot project started in West Berlin in 1987 which reused 5 000 tonnes of processed rubble and investigated if the existing recycling plants were capable of processing these materials. It was concluded, from an economical point of view, that processed rubble should be utilised to the highest degree and that the mixing of recycled and natural aggregates should be considered as a viable alternative. Bauchard (1988) investigated the use of aggregates, made from demolition materials, in road construction. Extensive applications of these aggregates in the Paris and the Nord-Pas-de-Calais regions since 1976 had confirmed that there was scope to expand to a wider use, in particular in pavements intended for low-traffic levels, thus agreeing with findings in Japan by Kawamura and Torii (1988).

Alternative uses for construction and demolition waste were being investigated around this time and Hansen (1989) demonstrated that crushed concrete fines made an excellent cat litter, which was free from odour (probably due to the presence of small quantities of slaked lime in the fines). This was in line with previous work by Berger and Carpenter (1981), which suggested that crushed concrete fines could be used for neutralisation of acid soils or wastewater.

An interesting development was discovered by Scott (1985, 1986) which reported on an 'accident' that occurred on an overpass in Austria. During the resurfacing of the overpass, an area of 'sick' forest beneath was heavily coated with gravel dust to a depth of approximately 2mm. Years later, the coated area displayed vigorous and renewed health, contrasting with the adjacent uncoated forest area which remained 'sick'. It was assumed by the author that this accidental coating supplied lime to fertilise the soil and neutralise the acid rain and he suggested two possible benefits:

1. An abundant material (gravel dust), which is not the product of fossil fuels, can rejuvenate ailing forests.
2. One large application extended the effect over a period longer than one year without burning the nourishment system of the trees.

The author concluded that perhaps this beneficial accident could spur commercial interests in the timber industry and farming to explore the possibility of achieving reduced costs and improved yields by applying gravel such as was suggested by Julius Hensel in the 1890s.

In the U.K., Lindsell and Mulheron (1985) reviewed the wide range of aggregate products, which can be manufactured depending of the type of demolition debris being processed and the capabilities of the recycling plant. The materials were classified into four main categories:

1. Crushed demolition debris – mixed crushed concrete and brick that has been screened and sorted to remove excessive contamination.
2. Clean graded demolition debris – crushed and graded concrete and brick with little or no contamination.
3. Clean graded brick – crushed and graded brick containing less than 5% concrete or stony material and little or no contamination.
4. Clean graded concrete – crushed and graded concrete containing less than 5% brick or stony material and little or no contamination.

Four main uses for these classifications were identified for recycled concrete / masonry:

1. General bulk fill.
2. Fill for drainage purposes.
3. Sub-base material in road construction.
4. Aggregate for new concrete.

The authors concluded that the inclusion of recycled aggregates in the construction of road sub-bases appears to be widely accepted in most countries provided that the normal grading requirements are met and the level of contaminants are acceptable.

4.5 1990s Research

4.5.1 United States

The 1990s witnessed an intensification of research activities especially in Europe where a number of important reports were published. In the U.S., research expanded to consider alternative applications of construction and demolition waste other than road construction. Apotheker (1990) reported on the results of two studies by the Massachusetts Institute of Technology in the late 1970s and subsequent research carried out by C.T. Donovan and Associates who identified the following potential end-markets for construction and demolition waste materials:

1. Dirt / soil to be used as soil, soil conditioner, landscaping and landfill cover.
2. Bricks could be used for masonry applications, landscaping and ornamental stone.
3. Cinder blocks, concrete and rocks used for fill and roadbeds.
4. Asphalt to be used for road and bridge resurfacing.
5. Tar-based materials could be mixed with used asphalt for resurfacing.
6. Wood could be used for fuel, landscaping, composting bulking agent, animal bedding and manufactured building products.

O’Federle (1993) reported on the potential for materials recycling in the building industry in the U.S., citing the example of the highway construction industry. This had led to a widespread knowledge on the recycling of concrete from roadways for use as aggregate in new concrete or as a fill or base material. The reasons identified for the lack of success in recycling waste materials from the building construction industry were due to the quality and lack of proven applications. Typically, concrete from roads was preferred by recyclers due to the lack of contamination in the concrete received as outlined by Ravindrarajah (1987):

“Waste concrete from the demolition of buildings is generally contaminated with a variety of materials such as reinforcing steel bars, bricks, gypsum, wood, plastics and glass. By contrast, the waste concrete from highways and from construction activities is free from contaminants”

(Ravindrarajah, 1987)

The property difference between virgin and recycled aggregate was also identified as a major impediment (O’Federle, 1993). The author concluded that recycled concrete has reduced concrete strength and is less durable than new concrete, dramatically reducing the potential of using recycled concrete as an aggregate. The most common use for recycled aggregate and masonry rubble was found to be as a base or fill material. The problems of recycled construction and demolition waste wood were also addressed. The wide variations in the physical and chemical characteristics of wood generated during construction operations make it challenging to find suitable end-markets. These variations are related to

different wood species, and treatments including pressure-treatment, lamination (e.g. plywood) or fire-treatment. The recycling of wood wastes is further complicated due to the fact that some of these treatments are considered hazardous. Typically, the pressure-treated, fire-treated and creosote impregnated wood can be ground for fuel (Gitlin, 1991). The remainder of the wood can be shredded for mulch or compost or chipped for use as a landscaping material.

The progress of recycling concrete and masonry in the USA was examined by Kibert (1993). Recycled concrete/masonry was classified according to Lindsell and Mulheron (1985) and the relationships between these applications and the classifications of recycled concrete / masonry was tabulated in Kibert (1991, cited in Kibert, 1993) as follows (Table 4.1):

Table 4.1 Suitability of Recycled Aggregates (Kibert, 1993)

Recycled Aggregate Category	General Bulk Fill	Fill in drainage projects	Material for road construction	New concrete manufacture
Crushed demolition debris	Suitable	Usually suitable	Not usually suitable	Not suitable
Graded mixed debris	Suitable	Usually suitable	Suitable in some cases	Suitable in some cases
Clean graded brick	Highly suitable	Suitable	Usually suitable	Suitable in some cases
Clean graded concrete	Highly suitable	Highly suitable	Suitable	Usually suitable

This research concluded that the use of recycled construction materials is generally desirable both from an economic and environmental standpoint confirming previous research from Buck (1976 & 1977) and Halverson (1981).

Dulcy *et al.* (1994) identified building rubble as having the greatest potential for reuse as it has been successfully used as sub-base and base material for pavement and as a fill material. Potential uses include aggregates for new concrete, soil modifier or raw material for brick manufacturing. Again the issue of contamination is mentioned which supports the findings of O'Federle (1993). Crushed concrete fines are identified as a potential raw material for brick manufacture while recycled wood waste has potential end products including boiler fuel, bulking agent for sewage treatment plants, landscaping mulch, landfill cover and manufactured building products. Further research into recycled wood waste discovered that the manufacture of stay-in-place insulated wall forms have the potential to recycle meaningful quantities of secondary wood fibre from construction and demolition waste (Frank, 1994). Falk (1994) expanded this research by looking at the potential technologies for the development of building products from recycled wood waste. The spectrum of potential wood waste that could be converted into housing products included: full-sized used timber salvaged from buildings; wood resulting from demolished buildings; old wooden pallets; scrap from new construction sites; old wooden utility poles; railroad ties; preservative-treated wood waste from treating facilities; and building construction.

Highway construction research continued with emphasis on the demonstration of successful applications. One such application was in the New York Metropolitan Area, where recycled Portland cement was used as an aggregate in sub-base courses and fill (Wheeler, 1996).

The material was first used in 1982 and became a standard application where nearly 100 per cent of the material placed as sub-base for state highways in 1996 consisted of recycled Portland cement concrete aggregate (RPCCA). Alternative uses were also examined, such as the use of waste materials in waste containment applications (Swyka, 1996).

Construction and demolition waste, when primarily consisting of inert materials, can be used as-is for fill, screening berms, or daily cover. Under New York state regulatory relief initiatives, the material was considered for use in the final layer of final cover in landfills. This was subject to close scrutiny due to the uncertainties with contamination problems.

4.5.2 Australia

As research in the U.S. began to focus on higher-level applications for construction and demolition waste, other countries began to follow suit while still concentrating on low-level uses. In Australia, MacSporran *et al.* (1994) [citing research by Tucker *et al.* (1993)], reported that it was not uncommon to have recovery rates of 60 to 80 per cent for waste concrete.

This was followed up by research carried out into the recycling of construction and demolition waste materials in roadworks and other local government activities (Bakoss and Ravindrarajah, 1999). It was found that uses for recycled concrete pavement were still essentially low level and included: all sub-base pavement patching, footpath crossing

construction, granular pavement patching, kerb and gutter pads. Recycled aggregates were used as the drainage medium in subsoil and for hardcore on building sites. In addition to unbound road base and sub-base applications, other potentially major uses for recycled construction and demolition waste were identified:

- Low value alternatives for general fill, under slab fill, and drainage material.
- Construction of new lightly trafficked concrete pavement.
- Lean concrete sub-base for highways and airports and concrete shoulders.
- Aggregate for new low grade concrete.
- Bituminous products such as crushed asphaltic concrete pavement, or milled bituminous pavement produced as a result of road pavement profiling.

4.5.3 Japan

In Japan, the focus was turning from the laboratory stage to practical applications of construction and demolition waste materials. Kasai (1993) reported on the present state of the reuse of demolished concrete in 1993, and found that the degree of reuse was approximately 48 per cent (approximately 12 million tonnes). This was mainly used for road bases and a small amount of coarse aggregate while most of the fine aggregates were also applied to backfills. In order to demonstrate practical applications, the Ministry of

Construction in Japan in 1992, initiated a 5-year technical development project entitled '*Development of technology for restriction and accelerated reuse of construction by-products*'. A pilot project was undertaken by the Tokyo Metropolis to demonstrate the reuse of demolished concrete for peripheral constructions of the conference halls in the city centre. Complimentary to this study was the market development of research carried out by the *Eastern Japan Cement Products Association* from 1991 to 1992 into the application of recycled aggregate for precast concrete products (Kasai, 1993).

Other contributors to research in Japan at this time were Yagishita *et al.* (1993); Kikuchi *et al.* (1993); Sano *et al.* (1993) and Suzuki (1995).

4.5.4 Europe

In Europe, research into the potential of construction and demolition waste materials continued both on a broad European level and from individual countries. The establishment of the *Priority Waste Streams Programme* by the European Commission in 1991 increased the focus on this area and encouraged extensive research throughout the Member States.

Whitbread *et al.* (1991) investigated the occurrence and utilisation of mineral and construction wastes in the UK in a report commissioned by the Department of the Environment under the Geological and Minerals Planning Research Programme. It was discovered that quite a high proportion of waste arisings were crushed for uses such as site fill. Recycling to produce graded aggregates was much less extensive. A large proportion of road planings (estimated at 80 per cent) were found to be reused in some form of

secondary use, but virtually none were recycled back into asphalt for use on road surfaces. Secondary uses included footpaths, farm roads, car parks and in some cases the planings were crushed, graded and reused as sub-base aggregates but this practice was not found to be widespread.

Hansen (1992) examined the recycling of demolished concrete and masonry in Europe. It was found that clean graded crushed concrete met the requirements for fill and was used frequently in the construction of foundations for houses, garages and other light buildings while inferior materials had applications such as landscaping, levelling or the construction of acoustic barriers, provided there is no risk of contamination of groundwater (Mulheron, 1986). The example of the U.K. was used where the specification of crushed concrete as granular fill has provided a wide range of applications such as:

- Drainage works, permeable backing to earth retaining structures, material for filter drains, and backfill to pipes and above pipe surround material.
- Earthworks such as fill to structures, drainage layers, reinforced concrete structures, bedding material for buried steel structures and unbound or cement-lime bound capping layers.
- Road base and sub-base layers.

Schulz and Hendricks (1992) examined the recycling of masonry rubble with a view to suitable practical applications. Through a historical review of past applications (most notably during the Second World War), the research concluded that although the

composition of rubble and demolition and recycling technologies may have changed over the years, the experience gained during the post-war years was still applicable, particularly in respect of recycling masonry rubble for use as aggregate for production in new concrete.

Schulz (1993) continued his research by examining the processing of building rubble as concrete aggregate in Germany. It was identified that valuable demolition rubble was still being reused for secondary purposes such as sub-base for roads and noise protection walls. In order to set a target to increase the use of construction and demolition waste materials in high-level applications, the concept of a closed-loop system was introduced. This is where the recycled material has to serve its original purpose. This may have set an unachievable target but the idea was to aim for reuse on the highest level possible. From a technical and economical point of view, the use of crushed concrete and masonry as concrete aggregate was identified as the maximum level of reuse possible at that time. Other research in Germany (Nicholai *et al.*, 1993; Rahlwes, 1993) supported Schulz's findings concluding that it was a viable aim from an environmental and economical point of view to continue with low-level applications while investigating practical applications of high-level applications.

In France, Morel *et al.* (1993) reported that approximately 25 million tonnes of waste materials was being produced every year with an estimated 10-15 million tonnes being potentially recyclable. Only 20-30 per cent of this potential is being realised with recycled aggregates only accounting for less than 1% of the national production of aggregates. The use of recycled aggregates in France was found to be limited to roadworks and landfilling

(90 per cent as aggregates, 10 per cent with binders) and to a lesser extent in concrete mixes (Symonds / ARGUS, 1995). Other interesting research in 1993 came from Denmark, Austria, Belgium, Spain and the U.K.

Kristensen (1993) investigated the recycling of clay bricks in Denmark and found through a novel process of re-burning⁵; the bricks could be recycled to be used as concrete aggregate, as filling materials and as cushion courses as well as tennis court gravel.

In Spain the recycling of demolition materials only attained a significant level for the construction of the Olympic site facilities at Barcelona. Recycled materials were used to build Olympic city's streets and highway system, the base and sub-base, as well as the protective rock fill structures of the encircling coastline (Morel *et al.*, 1993).

In the U.K., Collins (1993) examined the reuse of demolition materials in relation to specifications in the U.K. It was found that although 40 per cent of demolition waste (approximately 11 million tonnes) is recycled in the U.K. (highest in Europe at the time), most of it was for low-grade applications. Higher-grade utilisation such as in concrete has been discouraged by a lack of suitable specifications.

⁵ At the Masonry Centre at the Danish Technological Institute, experiments were carried out on bricks that have been re-burned. The process used normal brick kilns resulting in the separation of the bricks and the easy removal of mortar resulting in whole, hard-burned bricks, quicklime and sand and half-bricks and brick-bats.

The City of Vienna investigated the possibilities of reusing construction waste through research carried out by Maydl (1994). The following fields of application for recycled concrete and brick masonry were identified:

- Unbounded (loose): gravel substitution for road construction, gravel substitution for pipe trenches, substrate for green roofs (crushed brick rubble).
- Cement-bounded: concrete aggregates (substitutes natural sand and gravel); in situ concrete as well as concrete hollow block for walls; covering of tennis courts (crushed brick rubble); cement stabilised soils; fine aggregate for mineral waterproofings of landfill sites (cement stabilised, only fine sand from crushed mortar).

Examples of the successful reuse of recycled concrete in Austria were the:

- Recycling of damaged concrete slabs of Austrian highways and the reuse as aggregates for the new concrete.
- Filling material for pipe trenches.
- Reuse of recycled clay brick masonry as aggregate for concrete blocks for masonry walls.

- Reuse of crushed clay bricks as aggregates in substrates for green roofs (planted with grass).

Maydl (1994) concluded that following practical examples in Denmark and the Netherlands, it was clearly demonstrated that recycled materials could be used in new structures, substituting for primary materials.

Danish research in 1994 stated that in principle, all masonry and concrete waste has the potential to be recycled and reused (Lauritzen, 1994). It was stressed that to develop a market for recycled materials as a substitute for primary/natural raw materials, it was necessary to satisfy the given technical specifications and be economically competitive. Potential uses identified for the reuse of brick and rubble are listed in Table 4.2.

Table 4.2: Examples of possibilities for reuse of brick and concrete waste material

[adapted from Lauritzen (1994)]

Application	Project example	Waste material
Aggregate in new concrete	Concrete roads	Crushed concrete
	Runways, taxiways and aprons	Crushed concrete
	Concrete pavement in general	Crushed concrete
	Concrete sewage pipes	Crushed concrete
	Concrete culverts	Crushed concrete
	Bridges	Crushed concrete
	Harbour constructions	Crushed concrete
	Buildings:	
	• Foundations	Crushed concrete/brick
	• Floors	Crushed concrete/brick
• Horizontal divisions	Crushed concrete/brick	
• Walls	Crushed concrete/brick	
	Foundations in general	Crushed concrete/brick
Aggregate in new asphalt	Base course materials in pavements and yards	Crushed concrete
Unbound base course	Bicycle lanes	Crushed concrete/brick
	Pavements	Crushed concrete/brick
	Field roads	Crushed concrete/brick
	Forest roads	Crushed concrete/brick
	Internal building site roads	Crushed concrete/brick
	Primary roads	Crushed concrete/brick/asphalt
	Secondary roads	Crushed concrete/brick/asphalt
	Runways, taxiways & aprons	Crushed concrete/brick/asphalt
	Parking lots & other yards	Crushed concrete/brick/asphalt
Fill material	Cable trench	Crushed concrete/brick

Collins (1994) continued his research by investigating the efficient use of mineral resources in construction in the U.K. The U.K. was to the forefront of reusing waste materials at this

Table 4.3: Materials as waste in construction and arising from demolition and their potential for reuse, recycling and/or waste minimisation (Guthrie and Mallet, 1995)

Waste Material Type	Potential* for reuse	Potential for recycling	Potential for minimisation
Primary aggregates (sand, gravel, rock)	3	N/A	2
Natural secondary aggregates (minestone, slate, china clay, sand etc.)	3	N/A	2
Concrete	3	3	3
Masonry (stone)	3	3	3
Bricks	3	3	3
Tiles/pipes	3	1	3
Soils	3	1	3
Timber	3	3	2
Glass	1	3	2
Paper/cardboard	0	3	2
Metals	1	3	2
Plastic	1	3	3
Oils	0	3	3
Chemicals (paints/solvents)	0	2	3
Plaster/gypsum products	0	1	3
Asbestos	0	0	N/A

*Potential assessed as: N/A = Not Applicable, 0 = None, 1 = Low, 2 = Intermediate, 3 = High

In 1999, a report to the European Commission entitled *Construction and Demolition Waste Management Practices and their Economic Impacts* (Symonds *et al.*, 1999) was published, which examined each Member States' approach to construction and demolition waste management. The findings of the 1995 report (Symonds/ARGUS, 1995) were discussed and it was established that not much had changed in the intervening years, with the road construction industry providing the most viable markets. The report concluded that the inert

fraction of the construction and demolition waste stream had a high potential for reuse and recycling as aggregates in certain lower-grade applications, most notably engineering fill and road sub-base.

4.5.5 Ireland

In 2001, the B4 Taskforce (established by the Forum for the Irish Construction Industry in 1999) produced a report on the development and implementation of a voluntary construction industry programme to meet the government's objectives for the recovery of construction and demolition waste. This report provided the first attempt at an in-depth analysis of the construction and demolition waste management situation in Ireland. It concluded that the current construction and demolition waste management practices in Ireland are unsustainable and that the recycling and/or reuse of construction and demolition waste provides an unique opportunity to preserve valuable resources and reduce the depletion of finite aggregates. A number of recommendations were outlined in the report on ways to improve the current situation and this is currently under review (July 2002) by the Department of the Environment and Local Government.

4.6 Recent European Research

Recent European research (Hendricks and Janssen, 2001) has reported that construction and demolition waste has different applications depending on the processing technology.

Without any processing, concrete rubble can be used for hard standing, bank protection, fill and raising areas, road construction and noise barriers and embankments. After removal of contaminants through selective demolition, screening and/or air separation and size reduction in a crusher to aggregate sizes, concrete rubble can be used as aggregate in a asphaltic concrete, road sub-bases, and in concrete containing secondary concrete aggregates. After washing, recycled concrete aggregates may be used as a replacement for gravel in concrete. This represents the highest level of application of secondary aggregate.

The will to recycle construction and demolition is not enough as there are a number of constraints. These include the contamination of the construction and demolition waste stream and the lack of standards and/or specifications. The issue of contamination has been addressed by various authors (Ravindrarajah, 1987; O'Federle, 1993; Dulcy *et al.* 1994), who promoted the concept of source separation as a solution. The issue of specifications and/or standards for construction and demolition waste materials is a more complex issue.

4.7 Specifications

There is a universal acceptance in the construction industry that properly formulated specifications are needed to safely permit the use of products derived from secondary and recycled materials. Throughout Europe, there is a debate as to whether specifications should permit the use of all material irrespective of their source or should they be specifically designed for secondary and recycled materials. This debate is based on a number of issues, including the contamination and leaching characteristics of the proposed product. This has led to a number of different approaches being adopted by various Member States. Austria, Denmark, Germany and the Netherlands have all developed some standards specifically for secondary and recycled materials with the Netherlands also adopting performance specifications (Symonds *et al.*, 1999). The U.K. and Ireland make limited provision for the use of some secondary and recycled materials in road construction. The U.K. is making progress in the development of their specifications. Good general guidance is given in '*BS 6543: 1985 British Guide to the Use of Industrial By-products and Waste Materials in Building and Civil Engineering*', (although this standard is rarely quoted in contract documents). The *Highways Agency Specification 1998* permits the use of crushed concrete for pavement construction if it complies with the 'quality and grading requirements of BS 882'. Unbound applications of recycled aggregates are covered in the *Highways Specification and BRE Digest 276* (Hobbs, 1996).

France, Italy, Portugal and Finland do not make special provision for the use of secondary and recycled materials. In practice, most national bodies in the EU are awaiting guidelines from the European Standards body, CEN Technical Committee 154, whose objective is the

development of performance specifications that permit the use of products derived from recycled materials. This is a lengthy process and most experts agree that the industry cannot wait this long for formal standard to be finalised. This means that interim measures are required as has been done in Denmark, Germany, the Netherlands and to some extent in the U.K. It must be noted that the Member States with the highest recycling/reuse percentages are the ones with some form of accepted standards and/or specifications.

4.8 Conclusions

The aim of this chapter was to investigate previous research carried out into the recycling and reuse of construction and demolition waste materials to discover if there was an answer to the extensive waste problem facing the industry. The historical development of this research clearly showed that there is a solution. The conclusions are as follows:

- The reuse and recycling of construction and demolition waste materials is not a new concept. It has seen significant development since the 1940s right through to the present day. Research carried since the 1970s has identified construction and demolition waste as a priority waste stream, which has an enormous potential for recycling and reuse.
- The most frequently used applications are of a 'low-grade' nature, i.e. general fill, drainage material, lightly trafficked concrete pavement etc. This is generally due to a lack of specifications and contamination problems.
- The inert fraction of the construction and demolition waste stream has, in theory, the potential to be fully recycled and/or reused. If this is applied to the estimated composition of construction and demolition waste in Ireland, that would imply that 90 per cent of this waste is potentially recyclable or suitable for reuse.

- The closed-loop concept introduced in the 1990s (Schulz, 1993) is a laudable goal, where the recycled material aims to serve its original purpose or to the highest level of reuse possible. This ideal may be somewhat off, but it establishes a worthy goal.

Recent research (Hendricks and Janssen, 2001) has emphasised the effect of the processing technology used on the potential end products. The next chapter examines this technology and investigates the infrastructure required to provide the solutions to the construction and demolition waste problem.

Chapter 5 : Construction and Demolition Waste Recycling Facilities

5.1 Introduction

This chapter will investigate the role of materials recovery infrastructure in the recycling and recovery of construction and demolition waste materials. It will examine the design considerations and outline the various technologies available for the development of construction and demolition waste recycling facilities.

5.2 Materials Recovery Facilities (MRFs)

Materials Recovery Facilities rose to prominence in the USA in the 1980s when a number of facilities were constructed across the country (Beck and Associates, 1991). Rising waste quantities and decreasing landfill space across the U.S. led to an investigation into alternative waste management ideas. Throughout the 1980s in the U.S., incineration was touted as being the most viable way of diverting solid waste away from landfill, but concerns over the environmental impacts and the high costs associated with these incinerators, led to a re-think. The concept of a centralised facility capable of handling different waste streams was proposed. This had strong appeal in the battle against rising waste quantities and decreasing landfill space.

The early MRFs were primarily concerned with processing the municipal solid waste stream. The development of construction and demolition waste recycling facilities was first proposed in the 1970s in the U.S., where it was felt that on-site material separation was impracticable for economic and logistical reasons and that a feasible alternative would be

the establishment of a central facility to handle the construction and demolition waste stream (Wilson *et al.*, 1976). Almost a decade later, the first recognised construction and demolition waste recycling facilities began operation across the U.S.A.

Throughout the 1990s, construction and demolition waste materials were recognised as having a number of disposal options (Howard Humphreys and Partners, 1994):

- Landfill: landfill disposal and engineering
- Low-Level Processing: on site uses
- High-Level Processing: salvage and secondary aggregates
- Unlicensed Processing: agricultural improvement and illegal dumping.

Symonds *et al.* (1999) expanded on this by investigating alternative processing options.

Two main options were identified:

1. *On-site processing*

On-site processing involves the reuse of materials on-site for the original intended purpose; or on-site processing to recover high value saleable materials; or recycling on-site for a low-value purpose (including non-essential land-raising). The methods that could be used for on-site processing are crushing, shredding, chipping, grinding and pulverising and may involve several different types of processing technologies.

2. *Off-site processing*

Off-site processing would involve the re-use off-site for original purpose; or off-site processing to recover high value saleable materials; or recycling off-site for a lower-value purpose (including non-essential land raising).

Dolan *et al.* (1999) concluded that despite the advantages of on-site processing, e.g. reduced transportation costs, reduced waste disposal fees and treating the waste at its source, it may be impractical to process materials at the site due to increased labour, space restrictions or lack of pick-up services, thus promoting the use of a central processing facility. Contrary to the thinking of the 1970s, the separation of construction and demolition waste is now actively promoted on construction sites throughout the world and forms an integral part of the successful recycling and/or reuse of construction and demolition waste materials. The central facility is no longer viewed as a drop-off centre but rather a link in the waste management chain, which involves source separation, appropriate processing technologies and the production of quality end products. Taking this into account the design and layout of a construction and demolition waste recycling facility is of the utmost importance to ensure the success of the operation.

5.3 Design Factors

There are several factors that need to be taken into consideration when establishing a construction and demolition waste recycling facility (Peng *et al.*, 1997):

1. Good site and site location
2. Proper equipment
3. Experience in construction and demolition waste recycling operations
4. Trained supervisors and employees
5. Knowledge of secondary materials markets
6. Business/financial capacity
7. Knowledge of environmental and safety regulations

Elaborating on these factors, Peng *et al.* (1997) outlined the basic requirements of a facility without addressing the technologies involved:

5.3.1 Site and site location

For a nominal operation, an allocation of 0.8 hectares (ha) would be a minimum requirement for materials handling and throughput. This would be divided into 0.4 ha for equipment and at least 0.4 ha for storage of processed materials. The site must have adequate space for the construction and demolition waste processing equipment, an area for the incoming waste materials, and space for the processed materials. The location is important in that it must be in reasonable proximity to the construction operations and a suitable distance away from residential/commercial areas in order to minimise environmental impacts such as noise and dust nuisances.

5.3.2 Proper equipment

Experienced construction and demolition waste operators have learned that it pays to have the proper equipment for the job, preferably equipment made specifically for construction and demolition waste recycling operations or for a similar business such as quarrying operations. The equipment must be able to be maintained by the operators. This includes good knowledge of the equipment, technical information and access to spare parts.

Functional equipment is absolutely essential because of the tight operating margins of construction and demolition recycling. The equipment needs to be reliable, have a high throughput and must be able to produce secondary materials of sufficient quality to meet market demands.

5.3.3 Experience in construction and demolition waste operations

Construction and demolition waste is a waste stream that has components of real value mixed in with materials with little or no value. Understanding the equipment, separation techniques, quality control issues, and other essential features of construction and demolition waste is the key to the success of the recycling business. The recovery rate of secondary materials or percentage of the incoming waste stream converted to secondary materials can determine the success of a construction and demolition waste operation. A high recovery rate indicates a successful operation able to technically handle the problems of separating mixed materials. Some materials, such as concrete, masonry and rock may need to be cleaned to meet the quality requirements of the secondary materials market.

5.3.4 Trained employees

The employees of a construction and demolition waste recycling operation must be well trained to operate equipment, understand the general business, recognise the value of the various materials, and be able to function safely in a hazardous environment. The employees also need to be trained as a team to maximise their productivity, maintain availability of equipment and produce a high quality product.

5.3.5 Knowledge of secondary materials markets

The primary goal is to maximise the throughput of materials to earn tipping fees and sell the recovered materials to the secondary materials markets. In order to ensure a continuous intake of construction and demolition waste materials, the operator has to develop relationships with demolition and general contractors. This is to ensure that the

construction and demolition waste recycling facility is the preferred disposal option for the contractors.

5.3.6 Business and financial capacity

Start-up costs are always significant, because the entire system must undergo a trial period during which productivity will be low. Additionally, markets for products may only be partially developed resulting in the initial slow sale of the operation's output.

5.4 Design Criteria

Integrated into these basic requirements are certain fundamental design criteria that are critical to the development of a successful MRF (Beck and Associates, 1991). These include:

- Flexibility – to be able to respond to changes in the waste stream and market conditions, so that if new markets open up, or existing ones close down, the processing system can accommodate the changes.
- Expandability – to be able to handle increasing amounts or types of materials.
- Simplicity – because unnecessary complexity can lead to operational problems later. Conveyors crossing over and moving materials unnecessarily may create problems in materials flow; or trying to sort too many things in too small an area may produce contamination.

- Reliability – to avoid shut-down of the facility due to equipment problems, it may be better to have redundancy of systems, i.e. two or more smaller sized pieces of equipment rather than one larger one.
- Quality – to ensure marketability of the processed materials, the MRF must be able to produce high quality materials, which meet market specifications.
- Integration – the MRF should be integrated into other recycling or planned diversion programs, such as source reduction and recycling, rather than replace them.
- Location – proximity to transportation infrastructure, and adequate space and buffers from conflicting uses and other related issues should be considered. Use of existing solid waste facilities, whether it be space or landfill or the redesign of an existing transfer station can ease the pressures of locating the MRF.

In addition, other design issues should be addressed at the beginning of the planning process (Beck and Associates, 1991):

1. Sizing – the size and scale of the facility should reflect the amount of material, which will move through the facility.
2. Layout – the layout of the facility should be designed to reduce congestion from: truck traffic and loader movement; handling problems from incoming vehicles;

weighing stations; unloading areas; in-feed conveyors; sorting stations; processing equipment; and residue management. Access to the equipment for ongoing maintenance is also critical.

3. Building – the building size, expandability, aesthetics, durability, energy use (for lighting and heating/cooling), and visitor access are key factors. Adequate storm water run-off collection and landscaping are key factors for the area around the MRF.
4. Sorting – the materials received at the MRF will be unloaded from a variety of truck types and contain a variety of material types. These materials will have to be sorted into marketable categories. The primary goal of the operation is to ensure the efficient flow of materials through the facility. To be efficient, a MRF must keep the materials moving, and reduce double handling.
5. Processing – for the most part, the materials sorted at MRFs are sorted into piles; either loose on the floor, or into surge hoppers or bunkers, where they are sorted until processing (baling, granulating, crushing etc.). This reduces the likelihood of system shutdown if some of the processing equipment fails. At some facilities, however, the material is conveyed directly to the next processing step, without storage.

6. Contamination – generally the highest degree of contamination results from processing of mixed wastes; the more source separated the input materials, the lower the contamination. The mixing of only selected material types allows for a greater degree of sorting, and can result in a higher recovery rate for materials. The higher quality output can result in easier marketing and a higher value for the end product.

7. Staffing – the level of the staffing needed to process the materials through the facility varies depending on the degree of mechanisation. A highly mechanised facility will require less labour, but some hand sorting is still required and allows for greatest flexibility in processing.

Having satisfied all these design factors, the key component of a successful operation is the selection of the appropriate processing system incorporating suitable equipment. This is not an easy task, as there are a number of choices available to the operator.

5.5 Processing Equipment

The selection of the processing equipment is critical to ensure a system will work efficiently and productively. There are three main groups of construction and demolition waste recycling equipment to choose from (Symonds *et al.*, 1999):

- Conveying equipment
- Crushing / reducing equipment
- Screening/separating equipment

Within these categories there are a number of options available: (Flitz *et al.*, 1993a,b):

5.5.1 Conveying Equipment

This type of equipment needs to be extremely durable due to intensive impact at the main in-feed point. Options include:

1. Heavy-duty steel-apron conveyors (Photograph 5.1);
2. Toughened conveyors; and
3. Pan-type conveyors



**Photograph 5.1 Heavy-duty steel-apron conveyor in operation
(Copenhagen Recycling Centre, Denmark)**

5.5.2 Crushing/Reducing Equipment

There is a number of options available including:

- **Jaw Crusher**

‘Jaw’ crushers are typically shaped like a wedge, in which one of the faces moves relative to the others, producing a ‘chewing’ action, which grinds the material into progressively smaller pieces as it passes towards the narrow end. Material is fed into the wide end (at the top), and falls out the narrow end. The narrow end can be set to a range of openings to determine the nature of the resultant material (photograph 5.2). They are specifically designed to efficiently accept, crush and discharge Portland cement concrete or other

similar recyclable materials. The units are designed for recycling and can easily tolerate pipes, steel, rebar, manhole lids etc. Compressible materials (wood, plastic etc.) will tend to jam up the jaws and severely reduce throughput. Jaw crushers are ideal for reducing steady streams of large rubble material. Typically material is fed via an adjustable vibrating grizzly feeder and this assures that the large volume of fines normally encountered will bypass the jaw crusher efficiently.



Photograph 5.2 'Jaw' crusher' in operation (DemCon 20/20 Project, Cork)

- **Impact crusher**

An impact crusher uses a high-speed rotor inside a container, into which material to be crushed is fed. There is typically four or six 'hammer plates' mounted on the rotor which break the material against 'face plates' set at operator-determined positions on the inner surface of the container. The 'cutting' action is very like that on a conventional cylinder landmower. The throughput is greatly affected by the clearance between the rotating

'hammer plates' and the fixed 'face plates', and the rate of wear on the plates varies greatly according to the hardness of the material being processed (photograph 5.3).



Photograph 5.3 Impact crusher on the Spillepeng Landfill site in Malmo, Sweden

The choice between an impact crusher and a 'jaw' crusher is the operator's, and it depends on the use to which the crushed material will be put. An impact crusher will produce an aggregate with a smaller range of sizes, and although they are substantially cheaper to buy on a size-for-size basis, their running costs are much higher, particularly with very hard materials like some reinforced concretes. In general impact crushers tend to be designed for higher throughputs than 'jaw' crushers. A Dutch investigation [Civieltechnisch Centrum Uitvoering Research en Regelgeving (CUR), 1986 as cited in Symonds *et al.*, 1999] concluded that jaw crushers provide the best grain distribution of recycled aggregate for concrete production and that impact crushers provide better grain-size distribution of

aggregate for road construction purposes. It was also discovered that jaw crushers perform better than impact crushers because they can be set at 1.2 – 1.5 times the maximum size of original aggregate and will only crush a small proportion of the original aggregate particles in the old concrete. Impact crushers will crush old mortar and original aggregate alike and thus produce a coarse aggregate of lower quality. Schroeder (1982) concluded that jaw crushers should be used for the processing of lightly reinforced concrete while heavy impact crushers of various designs appear to be the best choice for normal heavily reinforced concrete.

- **Hammermills**

For wood wastes, a vertical or horizontal hammermill is typically used because it can produce a consistently sized product. For bulky wood waste, a stump grinding machine or low-speed shredder is used as a primary reducer and coupled with a secondary hammermill for further refinement

- **Stump grinder**

Stump grinders are primarily used for crushing wood waste. The principle is that one type of grinder uses tool steel-winged teeth bolted to a rotor that cuts the material against the impact bars. Other types included a large chipper disc arrangement and an impeller that throws material against teeth mounted on free-spinning rollers.

- **Rotary shear shredders**

These are ideal for primary reduction of bulky wood material, such as pallets, crates and stumps (75-100mm diameter). Shear shredders are low-speed, high-torque machines that rip and tear material apart. In addition to wood waste, the larger units can be used for construction and demolition waste reducing concrete, steel drums, white goods and furniture (photograph 5.4).



Photograph 5.4 A rotary shear shredder in operation

(SSI Shredding Systems Inc., USA)

- **Screw shredders**

These units can process bulky wood material, including tree stumps, brush, logs, scrap lumber, clean wood, pallets, trees, and yard trimmings. Material is first broken down between two parallel slow-running screws with opposing threads situated at the top of the grinder. The threads catch the corner of the material and draw it down between the threads. Once per revolution, the threads meet so material that has not already been crushed is

sheared by the cutting edges of the threads. This equipment is versatile and has low operating and maintenance costs.

5.5.3 Screening / separating equipment

This equipment is used to split construction and demolition waste materials into various size fractions and to segregate different materials. Vibratory equipment such as grizzly feeders or shaker screens are common. Disc screens and trommels are other conventional types of mechanical screening/separation equipment. Various types of magnets are used to remove steel items from the waste stream. Flotation tanks are sometimes used to take advantage of the specific gravity difference between wood (which floats) and rock (which sinks). As construction and demolition waste processing evolves, air separation of material into light and heavy fractions will be used more often. Equipment options include:

- **Grizzly screen**

It consists of a feed hopper with a vibrating bottom deck made up of evenly spaced steel bars (photograph 5.5). The spaced bars move the oversize material forward into the crusher while the undersize material falls through the bars, thus keeping the crushing chamber free of excess fines. These feeders are ideal for feeding rubble and mixed construction and demolition waste to the primary crusher. They are capable of withstanding the heavy impact generated when dumping construction and demolition waste material into the hopper. The vibrating action tends to automatically meter the feed so the crusher receives a consistent quantity of material, which is a key factor in maintaining high crusher throughput rates.



**Photograph 5.5 A 'grizzly' screen incorporated into a mobile crushing system
(Construction Equipment Co., USA)**

- **Disc screen**

This is used to size wood chips. The equipment consists of a series of parallel shafts (6-10) that run perpendicular to the flow of in-feed material. Attached to each shaft are discs that are positioned in such a way that they are midway between the discs on each opposing shaft. The spacing between the opposing shafts and their associated discs form the openings through which undersize material (75-150mm) can pass. Each shaft rotates in the same direction, causing the oversized fraction to ride the length of the screen on top of the screen surface.

- **Trommel**

This is basically a large, rotating cylindrical screen placed on its side and slightly elevated on the material feed end. An advantage is that the materials fed into it are self-distributing (photograph 5.6). A negative aspect is that they are larger than other screens and at any one time only use 20-30 per cent of their entire screen surface. The material is size-separated as it comes in contact with the screen surface while spiralling down through the chamber. The

degree of elevation of the angle of the drum (4-10 degrees) is responsible for controlling the speed at which material moves through the screen.



Photograph 5.6 A trommel in operation (Powerscreen Ltd., U.K.)

Rotational velocity of the drum determines how material behaves while in the cylinder. Behaviour refers to how material reacts to the speed of revolution. Material will exhibit either a cascading, cataracting or centrifugal action. When cataracting, material rises along the screen and drops when gravity overcomes the cylinder's centrifugal forces. This results in particles falling the maximum distance possible (this is the preferred action).

- **Vibratory screen**

Used in sand and gravel industries. Classified, either as high speed or low speed and are either inclined or horizontal models. The screen surface is housed in a rectangular box, which may contain one or more multiple material separations and a multiple deck is used to perform what is known as sizing (photograph 5.7).



Photograph 5.7 A vibratory screen (Armico Ltd., Lebanon)

According to a Japanese study [Building Contractors Society of Japan (B.C.S.J), 1978], coarse materials are separated more effectively by inclined screens vibrating at low frequencies and large amplitudes, while horizontal screens vibrating at high frequencies and small amplitudes are more effective in separating fine materials. Dutch results (Boesman, 1985) indicate that for separating lightweight material, adapted flat sieves are the best, giving little loss of the stony materials whilst removing some 80 percent of the wood.

- **Magnetic separator**

Used to remove ferrous metal from a moving bed of material. A large magnet, either permanent or electromagnetic is mounted in a frame. Surrounding the magnet is either a rubber belt or steel drum with vanes that travel around the magnet (photograph 5.8). This equipment is typically installed above a bed of material in an in-line or cross-belt fashion.

In construction and demolition waste recovery operations, the suspended cross-belt style is frequently used.



Photograph 5.8 An overhead magnetic separator (Dings Co., USA)

- **Float-sink tank**

A float tank is a gravity separator using water as a medium. In construction and demolition waste operations, it is used to separate wood from rubble-based material. Before entering the tank, the material is screened to remove fines and is spread out to minimise bed depth. On entering the tank, rubble materials will sink and the wood fraction will float. Rubble material is scraped from the bottom of the tank by a drag chain conveyor that inclines up and out over the tank lip. Floating material is moved by a skimmer over an in-tank barrier, deposited onto a short screen to drain, and then discarded. Product quality problems can occur. Plastics and paper debris can remain in the wood fraction and sometimes, saturated woody material will sink along with the rubble.

A combination of the float sink technique and directly applied water jets can separate lightweight contaminants from heavier bulk materials. The so-called 'Aquamator' is based

on this principle. It was developed by UBA/BMFT in West Germany and is briefly described by Pietrzeniuk (1984) [as cited in RILEM Report No. 6 *Recycling of Demolished Concrete and Masonry*. Edited by T.C. Hansen (1992)]. Flitz *et al.* (1993b) discovered that with large amounts of rubble material, the water would tend to clean the product, which is beneficial. The float-sink technique is not effective for separating mixed materials that contain numerous materials, i.e. wallboard, insulation, wood, rubble, ceiling tiles, because they contain more fibrous contaminants, which will become saturated.

- **Manual picking station**

This is an elevated platform with a conveyor, usually a slider belt, and a catwalk along both sides of the belt (photograph 5.9). The conveyor is usually 1.2-1.5m wide in order to keep material burden depth to a minimum. At about 3-4 metre intervals on each side of the conveyor, there is a place for a sorter to stand beside one or two chutes. Chute openings of about 2m² are appropriate for construction and demolition waste materials. Each picker manually removes specified items from the conveyor and places them in the appropriate chute.



Photograph 5.9 Manual Picking Station in operation at the Barna Waste facility in Galway

- **Air classifier**

This is a density separator using air as a medium. A vertical or horizontal airflow is used to separate dense material from less dense material. In a horizontal unit, feed material is dropped into a chamber where a horizontal stream of air deflects the light material so that it crosses a fixed splinter and discharges separately from the heavy material. Vertical units lift the light material on a rising column of air for discharge out the top and heavy material discharges at the bottom. This method is more desirable than the float method because woody waste remains dry and float-sink tank maintenance and need for wastewater treatment and disposal are eliminated. The air classifier will require the use of a bio-filter control system to properly treat and dispose of dust (Schlauder and Brickner, 1993).

As can be seen, there are a number of different equipment options available for the processing of construction and demolition waste materials. The selection of the appropriate type and size of equipment is dependent on the following:

- Throughput requirements, i.e. daily tonnage
- Characteristics of the incoming material
- Definition of the materials ideal particle size and distribution after processing
- The integration of equipment into the overall processing system.

5.6 Processing System

Having chosen the equipment, it needs to be integrated into a processing system.

Lindemann Recycling Equipment Ltd. has designed several construction and demolition waste processing plants in Europe and the USA to manage waste streams ranging from 500-1500 tonnes/day (Perez, 1994). They identify the three key steps in the processing system as the:

1. Initial screening of the system
2. Manual sorting of the recyclables
3. Processing the recovered material for specific market needs

5.6.1 REMEX example

An example of facility implementing these three key steps is the REMEX system in Germany (Symonds *et al.* 1999). REMEX is a leading German operator of construction and demolition waste recycling centres and accepts construction and demolition waste from contractors (they do not act as demolition contractors). The features of this process are as follows:

Inert fraction

1. The inert fraction is weighed and inspected, and placed into one of the following stockpiles:
 - Broken bricks and tiles
 - Reinforced concrete
 - Non-reinforced concrete
 - Mixed construction and demolition waste

2. Broken bricks, tiles, reinforced concrete and non-reinforced concrete are screened through a pre-sieving process to remove the 0-45mm fraction, which is divided into 0-4mm and 4-45mm. The remaining material then goes to an impact crusher.

3. Material coming out of the impact crusher passes through a magnetic separator to remove ferrous metals before being sieved to divide it into 0-45mm and >45mm.

4. The >45mm fraction is placed onto a temporary stockpile for re-crushing, while the 0-45mm fraction is sieved into sub-fractions of 0-4mm, 4-8mm, 8-16mm, 16-32mm, and 32-45mm. These sub-fractions can be re-combined into mixes defined by the end user.
5. The choice of an impact crusher over a 'jaw' crusher reflects the fact that it produces a more consistent and predictable aggregate, with sharper edges on the individual granules.
6. On emerging from the crusher, instead of being sieved into the sub-fractions, described above, the 0-45mm fraction can be passed through an air classifier, washed, passed through a further metal separator and screened through with a vibrating screen or a free-fall screen. This produces a range of washed, sorted and quality-graded materials. Any oversize materials (more common with 'jaw' crushers) can be sent back to the crusher for re-processing.

Mixed fraction

1. In the Remex system, mixed construction and demolition waste is generally subjected to hand sorting even before it is screened and passed through a magnetic separator for the first time. This is followed by further manual (or in some cases automated) sorting to remove plastics, paper, wood and other non-ferrous metals.

2. The mixed construction and demolition waste is then passed through a 'jaw' crusher and magnetic separator before being passed through an air separator, which removes light materials (small pieces of paper and plastics which escaped the earlier sorting processes and the 0-4mm fraction of the inert material). The 4-45mm fraction can then be sieved or screened, as with the brick, tile and concrete waste.

The REMEX system illustrates that the proper plant and equipment integrated into an appropriate processing system is essential for a successful operation. Another question that arises is what level of technology is applicable to a given facility. This is the next step in ensuring a construction and demolition waste recycling operation is feasible.

5.7 Processing Technologies

The processing strategy for construction and demolition waste and thus the equipment sorting and size reduction, is primarily determined by the composition of the construction and demolition waste materials and the end uses for the recovered materials. A wide range of technologies can be applied to construction and demolition waste recycling and there has been extensive research to identify suitable systems (Frondistou-Yannas and Itoh, 1977; Donovan, 1991; Curro, 1991; Hansen, 1992; Schlauder and Brickner 1993; Brummer and Stampfli, 1993; Flitz *et al.*, 1993a,b; Perez, 1994; McMahon, 1997; Peng *et al.*, 1997; Dolan *et al.*, 1999).

Symonds *et al.* (1999) provides the most definitive categorisation of the processing technologies used in construction and demolition waste recycling throughout Europe. They are:

- Level 1 'Low' Technology – comprises mobile crushing and sorting plant, and is only really suited to the processing of inert construction and demolition waste.
- Level 2 'Intermediate' Technology – involves metal removal and more complex sorting and sieving facilities, and is therefore capable of dealing with mixed (mainly) inert construction and demolition waste.
- Level 3 'High' Technology – addition of hand sorting, washing plant and facilities for other construction and demolition waste streams (such as wood) to Level 2

plant, and can deal with any (mixed and contaminated) construction and demolition waste if required.

Symonds *et al.* (1999) outlines the best available estimates of the number of fixed and mobile construction and demolition waste recycling centres in the EU-15 (Table 5.1). Fixed construction and demolition waste recycling centres in this context means places where bulky construction and demolition waste, particularly concrete waste, is received, crushed, stored and sold. It does not include centres, which deal with any other individual waste streams such as municipal wastes, or road recycling activities.

Table 5.1 Fixed and mobile construction and demolition waste crushing and sorting plants (adapted from Symonds *et al.*, 1999).

Member State	Total No. (est.)	Comments
Germany	Up to 1000	This estimate (from the Bundesverband der Deutschen Recycling-Baustoff-Industrie) appears high.
UK	Approx. 50-100	A total of 360 crushers are listed but this includes all quarry crushers.
France	About 50	This refers to fixed centres.
Italy	About 60-110	The number of specialist recyclers with fixed plants is estimated not to exceed 10. The other 50-100 are small mobile crushers.
Spain	About 6	These are mobile crushers at fixed sites.
Netherlands	120	Roughly 20 are on construction sites with the other 100 on fixed construction and demolition waste recycling centres.
Belgium	92	80 crushers/recyclers and 40 sorting facilities in Flanders. None in Brussels. 12 recycling plants in Wallonia.
Austria	150	Crushers roughly 2:1 ratio of fixed to mobile.
Portugal	N/a	Few if any crushers.
Denmark	About 30	Crusher's ratio roughly 1:1 fixed to mobile.
Greece	N/a	Almost certainly no crushers.
Sweden	10	8 mobile and 2 fixed.
Finland	10	Refers to concrete/masonry collection facilities, number of fixed/mobile crushers not known.
Ireland	<8	<6 mobile and 2 fixed in preparation.
Luxembourg	N/a	No data received from Luxembourg
EU-15	About 1500	Typically capacity is 100 000 tonnes/year per crusher, but most machines are operating well below this figure.

Level 1 technology is utilised in Spain, Portugal, Greece and Southern Italy. This technology is prevalent here due to the low landfill prices and cheap primary aggregates

and as a consequence, very few crushers are available to produce construction and demolition waste-derived aggregates.

A combination of Level 1 and Level 2 technology is more common in the U.K., France, Italy and Belgium, where the recycling of inert construction and demolition waste is carried out.

Level 3 technologies can be witnessed in Germany, Denmark and the Netherlands. In these Member States, construction and demolition waste management has been integrated into the overall waste management issue and economic instruments have followed a stricter code of command and regulation

The construction and demolition waste processing industry is going through a learning process and new processing techniques are being developed to reduce processing costs and generate high-quality recovered material. More and more operations are using intermediate to high technology to recover a greater proportion of the waste stream.

5.8 Conclusions

The aim of this chapter was to investigate the infrastructure (MRFs) required to process the construction and demolition waste stream. This was achieved by examining the various design factors and issues associated with such a development. The different equipment options were discussed with particular emphasis on how to integrate them into a successful processing system. The main conclusions are:

- Considerable investment and knowledge is required to establish a construction and demolition waste recycling facility.
- The main design factors to be considered at the inception stage are: site location; proper equipment; experience in construction and demolition waste operations; trained staff; knowledge of end-markets; business/financial capacity; and knowledge of environmental and safety regulations.
- There is a wide range of technologies available but the most effective are a combination of conveying equipment, reducing/crushing equipment and screening/separating equipment.
- The processing system used is largely determined by the composition and the throughput of the material being accepted at the facility.

- There are primarily three levels of technology available for the processing of construction and demolition waste: low, intermediate and high technology. Combinations of these levels have been used successfully throughout Europe. The application of these technologies depends on the economic viability of their use and the potential end-markets.

This chapter has illustrated the basic requirements for the design of a construction and demolition waste recycling facility. The next step is to establish what conditions are necessary to ensure the success of the development and operation of a construction and demolition waste facility. It was decided that the best way to identify these parameters was to visit and examine facilities of best practice throughout Europe.

Chapter 6 : Case Studies of Best Practice Facilities

6.1 Introduction

In order to investigate the successful operation of a construction and demolition waste recycling facility, it was decided to examine three case studies that demonstrate best practice throughout Europe and Ireland. This examination involved an extensive literature review, followed by correspondence to relevant parties and finally site visits to the facilities. The Policy Document *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002) has identified the need for eighteen construction and demolition waste recycling facilities in Ireland to establish the necessary infrastructure to achieve the targets set out in *Changing Our Ways* (DoELG, 1998).

The three case studies identified as representing current best practice in Ireland and Europe were:

1. The DemCon 20/20 Project in Cork is the subject of the first case study. This project was first identified in the *National Waste Database Report 1998* (EPA, 2000) and in subsequent publications such as *B4 Taskforce Report 2000* (B4 Taskforce, 2001) and *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002). It was funded under the European LIFE Programme⁶ to demonstrate construction and demolition waste management best practice in co-operation with Loftus Civil Engineering; Clean Technology Centre (Cork Institute

⁶ The LIFE Programme is EU financial instrument that specifically supports the development and implementation of Community environmental policy.

of Technology); Fehily, Timoney and Co. (Consulting Engineers); Cork Corporation; and Cork County Council.

2. The second case study examined was the Copenhagen Recycling Centre in Denmark. This was initially identified as best practice example during a waste management, water and renewable energy conference in Dublin Castle in October 2000 (co-organised by the Irish Energy Centre and Green Innovation (Denmark). Subsequent research discovered that this facility was the largest recycling facility in northern Europe and one of its primary functions was the recycling and reuse of construction and demolition waste materials. The *B4 Taskforce Report 2000* (B4 Taskforce, 2001) identified this facility as a best practice facility and recommended that this operation be used as a example for any such developments in Ireland.

3. The third case study examined was the Sysav Facility in Malmo in Sweden. Again the *B4 Taskforce Report 2000* (B4 Taskforce, 2001) identified this facility as an excellent example of an integrated waste management solution, which successfully recycles and reuses construction and demolition waste materials.

6.2 Case Study 1 – DemCon 20/20 Project in Cork, Ireland

6.2.1 Background

The DemCon 20/20 Project was co-funded by the LIFE Programme of the European Commission and in co-operation with Cork Corporation, who had commenced a major project to recycle construction and demolition waste as part of its commitment in meeting the objectives and targets of the *Cork Waste Management Strategy* (Cork Corporation, 2001). The project is a public/private partnership involving the following partners: Loftus Civil Engineering; Clean Technology Centre (Cork Institute of Technology); Fehily, Timoney and Co. (Consulting Engineers); Cork Corporation; and Cork County Council.

The Clean Technology Centre in the Cork Institute of Technology undertook a preliminary study, to quantify the amount of construction and demolition waste generated in the Cork Region. The study estimated that the quantity of construction and demolition waste was in the order of 300 000 tonnes in 1995, with potential to rise to 550 000 by the year 2001 (Murphy, 1997).

The projects' main aim is the demonstration of a successful management programme and innovative promotion of material reuse. The project is concentrating on the investigation and development of markets and the innovative use of materials to solve both landfill problems as well as saving natural resources.

In order to ensure the success of the project, a number of stages were set out:

1. Detailed survey of construction and demolition waste. Personal contact with construction and demolition waste contractors, waste handlers etc. to encourage the use of the facility.
2. Development of a management programme including logistics, a system of charges and open dialogue with relevant parties.
3. Operation of a recycling system to provide materials and identify end products (to be carried out by Loftus Civil Engineering).
4. Construction of an amenity site on the landfill site using recycled materials from construction and demolition wastes.
5. Demonstration of an effective recycling regime for construction and demolition wastes.

6.2.2 Site Location

The Kinsale Road Landfill is situated on 66 hectares (ha) of the Tramore Valley to the east of the South City Link Road and to the north of the South Ring Road in Cork. The site area comprises three zones; a restored area to the northeast; an active landfill area to the south; and an area reserved for recycling-related activity bordering on the South Link Road to the west.

The landfill site is owned by Cork Corporation and has been in operation since the early 1960s. A waste licence was approved by the EPA in February 2002 and determines the conditions under which the landfill is operated. Recently an application has been made by Cork Corporation for a reviewed waste licence, which would extend the lifetime of the landfill.

6.2.3 Scope of Licensed Activities

Approximately 266 700 tonnes of waste were generated in the city of Cork in 1997 (Cork Corporation, 2001). The two largest elements of this total were construction and demolition waste (125 000 tonnes) and municipal solid waste (140 700 tonnes). In response to this the *Cork City Waste Management Plan 1999-2004* (Cork Corporation, 2001) put particular emphasis on two specific waste streams:

- Construction and demolition waste and
- Paper/cardboard.

Of the 125 000 tonnes of construction and demolition waste entering the Kinsale Road Landfill in 1997, 44.1 per cent was being disposed (Table 6.1). The reasons for choosing construction and demolition waste as a priority waste stream were:

- It was the single largest waste stream entering the landfill facility at the Kinsale Road, using up a large area landfill space.
- The technology to recycle this material is relatively inexpensive and technically quite simple.

**Table 6.1 Waste entering the Kinsale Road Landfill Site in 1997
(Cork Corporation, 2001)**

Waste Type	Quantities Deposited (tonnes)	% of Total Waste Deposited
Household	54 075	19.1
Commercial	62 973	22.2
Industrial Non-Hazardous	23 292	8.2
Industrial Non-Hazardous Sludges	12 000	4.2
Park and Public Cleansing	6 000	2.1
Construction & Demolition Waste	125 000	44.2
TOTAL	283 340	100.0

The *Cork City Waste Management Plan 1999-2004* also estimated the projected growth in construction and demolition wastes arising from 1997 to 2004 (Table 6.2).

Table 6.2 Projected growth in construction and demolition waste 1997-2004
(Cork Corporation, 2001)

Year	Quantity of construction and demolition waste (tonnes)	Data source/comment
1997	125 000	Baseline*
1998	134 375	Projected**
1999	144 453	Projected**
2000	149 942	Projected***
2001	155 640	Projected***
2002	161 554	Projected***
2003	167 694	Projected***
2004	174 066	Projected***

* Based on the waste quantification surveys undertaken at each of the landfills in the Cork Region in 1997.

** Assuming a 7.5% growth rate until the year 1999, which includes for the potential impact of successful waste avoidance measures.

*** Assuming a 3.8% growth rate after the year 1999, which includes for the potential impact of successful waste avoidance measures.

Landfill surveys have indicated that the amount of this material which was delivered to the landfill site in 1998 was approximately 240 000. This is a significant increase on the amount landfilled in 1997 (125 000 tonnes) and is considerably more than what was projected for in 1998 (134 375). This indicates that the figures stated in Table 6.2 are relatively low estimates for the quantities of construction and demolition waste being produced in Cork City and its surrounds.

6.2.4 Processing System

Construction and demolition waste has been traditionally accepted free-of-charge at the Kinsale Road Landfill where it was used as daily cover material for the active face of the landfill (i.e. the part of the landfill which is accepting waste inputs at a given time). The heterogeneous nature of this waste, however, means that it tends to occupy large amounts of void space unless it is crushed or otherwise pre-treated before deposition. With landfill space becoming increasingly scarce, and therefore valuable, it was recognised as an unsustainable practice to continue filling landfills with an inert material, which has a great deal of potential for reuse and recycling.

To exploit this potential, the recycling facility uses a processing system which comprises segregation, crushing and screening equipment and produces a granular material, the size of which can be tailored to suit the planned end-use or market.

The procedure for processing construction and demolition waste is as follows:

1. All construction and demolition waste is weighed and recorded on the weighbridge on entering the landfill.
2. The carrier is then directed to the construction and demolition waste processing area.
3. The construction and demolition waste is then tipped onto a waste inspection area.

4. The material is sorted into piles, i.e. inert construction and demolition waste, wood waste, metals etc.
5. The inert material is then transferred into the 'jaw' crusher by an excavator to reduce the size of the material (photograph 6.1)
6. Material coming out of the crusher passes through a magnetic separator to remove ferrous metals before being screened.



Photograph 6.1 Construction and demolition waste being transferred to the 'jaw' crusher on the DemCon 20/20 project

7. The material passes through a screen and is divided into three different fractions depending on their end use (photographs 6.2 and 6.3).



Photograph 6.2 Screening of construction and demolition waste materials on the DemCon 20/20 project



Photograph 6.3 Screening of material into three separate fractions on the DemCon 20/20 project

8. The material is then stockpiled on site for subsequent use (photograph 6.4) in landfill engineering works, i.e. capping of landfill and construction of access roads (photograph 6.5).



Photograph 6.4 Stockpiles of construction and demolition waste on the DemCon 20/20 project



Photograph 6.5 Use of processed materials in the construction of landfill access roads

The project demonstrates how construction and demolition waste materials can be used to enhance the landscaping of the area and how materials (i.e. concrete, masonry, brick and fine materials/soil) can be used in the restoration of the Kinsale Landfill Site in advance of the development of the regional park. Most of the construction waste is been used in its primary state as topsoil but the demolition waste material has to be ground down into fractions.

6.2.5 Environmental Impacts

The main environmental impacts are the dust and noise nuisances created by the processing of construction and demolition waste. This is mitigated somewhat by the fact that the construction and demolition waste recycling areas are surrounded by stockpiles of materials, either processed or awaiting processing, where they act as acoustic barriers. The location of the construction and demolition waste recycling facility within the confines of an already established landfill ensures that any negative environmental impacts are minimal.

The environmental benefits of the project are as follows:

- Reduction of wastes landfilled.
- Demonstration and piloting of a major recycling scheme.
- Contribution towards the provision of a public amenity park.
- Provision of statistics on the composition of construction and demolition waste.
- Reduction of energy consumption due to transport.
- Job creation.

- Protection of adjacent rural environment by minimising/eliminating fly tipping.
- Creates symbiotic relationships with other recycling facilities proposed for municipal waste and non-hazardous industrial waste.
- Creates a valuable recycled product from a waste material, thus supporting the waste management hierarchy.
- Becomes an integral part of the planned recycling centre at the landfill while being portable so that it can be moved to the next landfill site developed for the city with minimum financial impact.

6.2.6 End-markets

While the technical aspects have been relatively straight forward, the greatest challenge has been to successfully put in place a programme to promote an ongoing construction and demolition waste supply, and to identify and promote innovative outlets for the fractions which have been recycled.

The main advantage of this project is that it already has an established market for its products. The processed construction and demolition waste materials are being used as engineering features in the finishing of the adjacent landfill and the transformation of this landfill into a major amenity area of approximately 50 ha. In the case of the Kinsale Road Landfill in Cork City, the requirements for such an operation were initially estimated at 650 000 tonnes comprising:

- Granular material = 300 000 tonnes
- Topsoil = 100 000 tonnes

- Mixed soils/clays = 220 000 tonnes
- Lower quality mixed material lines = 30 000 tonnes

This total has risen to 800 000 tonnes of topsoil and various types of granular material. This is to ensure that the transformation of the landfill into an amenity area complies with EPA requirements, i.e. the landfill must be sufficiently capped.

The next site visit was to the Copenhagen Recycling Centre in Denmark, which is the largest construction and demolition waste recycling facility in northern Europe.

6.3 Case Study 2 - Copenhagen Recycling Centre, Denmark

6.3.1 Background

The Copenhagen Recycling Centre was opened in May 1996. This marked the establishment of an integrated waste management system with an annual capacity of 1 million tonnes. The recycling centre has an area of 100 ha with three 7.5 ha special facilities for construction and demolition waste, green waste composting and contaminated soil treatment (Photograph 6.6 and 6.7). The rest of the site is fully permitted and is to be used as a landfill, although no waste will be accepted until the landfill currently serving Copenhagen has reached its capacity.

At the initiative of the Municipality of Copenhagen, two limited companies were established in co-operation with private companies for the purpose of processing construction and demolition waste, and to process contaminated soil. Today the municipality and the two companies manage the recycling centre as partners. One company, Rastof-og Genanvendelse Selskabet of 1990 A/S (RGS 90), process the construction and demolition waste and operates the compost plant. The other company, Hovedstadens Jordrens, processes the oil-contaminated soil and work as consultants, evaluating contaminated sites.

6.3.2 Site Location

The Copenhagen Recycling Centre functions as a unified central plant, receiving the greater part of all construction and demolition waste, waste from parks and gardens and contaminated soil. The location of the plant (approximately 5 kilometres from the city centre) provides easy access from all over the region, which leads to a reduction in transportation costs and associated environmental impacts. The main purpose of the recycling centre is to comply with the legislation on safe disposal of solid waste, but also to provide new improved solutions to waste management problems. A time schedule has been established with the purpose of transforming the recycling centre into a recreational area; a planned transition from processing plant to nature reserve. It is estimated that all depots will have reached their capacity by 2020 and then the area will be handed over to the public to form a recreational area close to the centre of Copenhagen.



Photograph 6.6 Aerial view of Copenhagen Recycling Centre



Photograph 6.7 Aerial view of Copenhagen Recycling Centre

6.3.3 Scope of Licensed Activities

The reprocessing and recycling of waste is the primary business area of the company today.

This involves:

- Reprocessing and recycling of construction and demolition waste. This process takes place in the Copenhagen Recycling Centre, with approximately between 600 000 and 800 000 tonnes per annum being processed for recycling.
- Composting of garden and park waste, which amounts to between 60 000 and 100 000 tonnes per annum being processed.
- Recycling of industrial waste, e.g. slag from incineration and used products for sandblasting.
- Operation of slightly contaminated soil depots.
- Operation of biological soil treatment plant as contractors for Hovedstadens Jardenes A/S.

RGS 90 process construction and demolition waste in three plants on Zealand: the Copenhagen Recycling Centre, Sanderogdgaard Genbrugscenter at Hornbaek and the transfer station at the northern port of Copenhagen. The main activities are carried out at

the Copenhagen Recycling Centre. The plant covers an area of approximately 7.5 ha, which is leased from the Municipality of Copenhagen.

6.3.4 Processing system

The activities of RGS 90 are distributed over a number of plants all over Denmark. The main activities, however, take place at the Copenhagen Recycling Centre. RGS 90 A/S was founded in May 1991 with the purpose of recycling building and construction waste at a high quality and environmental level. The company consists of seven departments, which all operate in raw materials and recycling, and at present the organisation employs a staff of over 120.

For the main part, the waste has been sorted at the source before arrival (photograph 6.8) at the Copenhagen Recycling Centre, and is received as:

- Pure soil
- Soil with a content of concrete/tiles/asphalt
- Asphalt/tiles
- Building waste for sorting and crushing

These categories are based on the treatment that the waste will subject to and resultant end products. The remaining waste categories will go through a process by which recycled materials are removed, possibly for further processing, before they are sold. Mixed construction and demolition waste is also accepted at the centre but at a higher cost (Photograph 6.9).



Photograph 6.8 Inert material delivered for processing at the Copenhagen Recycling Centre



Photograph 6.9 Mixed waste delivered to the Copenhagen Recycling Centre

The processing methods include direct delivery to the crusher for concrete waste and pre-crushing by a mobile jaw crusher for the ferrous reinforced concrete. The mixed waste is separated initially by mobile cranes/grabs with the resultant fractions going through the processing system, which includes size reduction methods (photograph 6.10), hand sorting and screening with a powerscreen and a rotary drum sorter.



Photograph 6.10 Size reduction methods at the Copenhagen Recycling Centre

Photographs 6.11 and 6.12 show the processing plant in operation. The treatment results in the materials being refined into recycled products, processed externally, incinerated or used for landfill. Of the material received, approximately 95 percent is recycled with only 5 percent of the incoming waste being removed for incineration or landfill.



Photograph 6.11 Processing plant in operation at the Copenhagen Recycling Centre



Photograph 6.12 Processing plant in operation at the Copenhagen Recycling Centre

6.3.5 Environmental Impacts

The main environmental impacts associated with the processing of construction and demolition waste are noise and dust. There are no commercial or residential properties in close proximity to the operations, which helps minimise the environmental impact on the surroundings. The facility is under strict regulation by the Danish EPA and the local municipalities. The environmental impact arising from the transportation to and from the centre is reduced by storing both primary and secondary materials on site. The hauler is able to transport the construction and demolition waste materials from the construction site to the recycling centre and then collect either primary or secondary materials for transport back to the construction site.

The positive environmental impacts of the activities are as follows:

- Processing of recyclable materials implies less material going to landfill.
- Replacement of virgin materials. Secondary materials produced to specify quality for use in building applications, i.e. road construction.
- Any fraction of the construction and demolition waste stream that cannot be reused and/or recycled and is not hazardous, is transported to the incineration plant to be used as combustible waste for energy.

6.3.6 End markets

A quality control system is in operation through ongoing technical and environmental documentation. The recycled products that are produced include:

- Crushed concrete, 0-32mm
- Crushed tiles, 0-32mm
- Crushed asphalt/tiles, 0-32mm
- Crushed concrete/tiles, 0-32mm
- Screened recycled soil
- Screened topsoil
- Composting products

The three best-selling products are crushed concrete, crushed asphalt/concrete (photograph 6.13) and crushed concrete/tiles. These materials successively replace raw materials in the building of roads and squares/car-parks etc.



Photograph 6.13 Crushed asphalt/concrete stored adjacent to the processing operations at the Copenhagen Recycling Centre

The construction and demolition waste facility also provides various kinds of virgin materials for sale to reduce the transportation costs and associated environmental impacts. Each truck that delivers construction and demolition waste also departs with virgin or recycled materials for use on various projects.

The next site visit was to the Sysav facility in Malmo, Sweden where an integrated waste management service is in operation.

6.4 Case Study 3 – The Sysav Facility in Malmo, Sweden

6.4.1 Background

Sysav is a comprehensive public waste management company taking care of all kinds of waste in Scania Region of southern Sweden (approximately 520 000 inhabitants). Sysav is owned by nine municipalities in southern Sweden and they are responsible for the collection and transportation of waste to Sysav's facilities (photograph 6.14). A number of different methods are employed to handle all types of waste:

- Combustible waste from both household and industrial sources is brought to the waste-to-energy plant, where the waste is converted into energy and is used for heating water. It is incorporated in the district-heating network in Malmo, and has sufficient capacity for approximately one quarter of Malmo's requirements.
- At the Spillepeng landfill, wood waste is shredded and used as fuel chips in the production of heat.
- Garden and park waste is stored and processed for three years and produces a nutrient compost which has a quality standard label.
- Construction and demolition waste is processed, primarily concrete and reinforcement but also materials that can be used as fuel.

- The landfill consists of bio-cells for the depositing of waste materials not suitable for treatment. During the degradation process of the waste materials, gases are formed consisting of methane and carbon dioxide. These gases are piped to the waste-to-energy plant and used in the production of electricity and in district heating.



Photograph 6.14 Aerial view of the Sysav Facility in Malmo

6.4.2 Site location

Sysav's main area of activity is in the Spillepeng area along the river Sege, approximately 5 kms north of Malmo city centre.

6.4.3 Scope of Licensed Activities

The Sysav/Skanska Recovery Project at Spillepeng (Project 447) involved the re-utilisation of construction and demolition waste materials for use in the extension of the Spillepeng landfill. For a period of eight months at the Spillepeng site, 150 000 tonnes of waste concrete was crushed and screened into new products for use in road constructions. The waste concrete originated from the demolition of buildings and bridges in the area (photograph 6.15). Besides the recovered concrete, some 1 500 tonnes of reinforcement steel has been separated and returned to the steel industry as a raw material. Sysav Project 447 has processed and recovered large quantities of construction and demolition waste by using re-constructed crushing plant (Photograph 6.16).



Photograph 6.15 Construction and demolition waste stored for processing at the Spillepeng site.



Photograph 6.16 Processing system in operation at the Spillepeng site.

6.4.4 Processing system

The processing system worked as follows:

1. A crusher mounted on an excavator reduced the largest blocks to approximately 1 metre in size.
2. Using a wheel-mounted loader, the demolition concrete was tipped into the feeder where it is crushed by the primary crusher.
3. By using the feeder, the operator was able to control and guide the flow of material into the crusher. The concrete was crushed along with the reinforcement steel, up to a length of 5 metres.

4. In the primary crusher, most of the reinforcement steel was freed from the concrete.
5. The concrete was crushed to a fraction between 0-300mm. Using an overhead magnet conveyor system, the reinforcement steel was separated from the crushed concrete.
6. The material was transported on a conveyor system to the screening station, where it was screened into three fractions:
 - 0-90mm sub-base course (all material larger than 100mm are re-crushed in a secondary crusher to produce a 0-90mm sub-base course);
 - All materials less than 50mm are sorted to be used as a base course; and
 - The intermediate fraction, 50-100mm, is placed in storage before being crushed again to produce a 0-25mm product in the fine crusher facility.
7. The separated iron was loaded into containers and is taken to a fragmentation plant and the reinforcement steel was recycled and became new raw material for the steel industry.
8. The recycling/recovered construction and demolition waste materials were used as sub-base in road applications (photograph 6.17).

6.4.5 Environmental impacts

The Sysav facility is regulated by various waste licences and permits for the different activities. The company follows the ISO 14001 standard, which evaluates the environmental impact of each operation. The localisation of the site to areas with heavy industry minimises any environmental impact to the surroundings. The positive environmental impacts of the activities are as follows:

- Processing of recyclable materials implies less material going to landfill. This leads to economic benefits for the construction industry as they incur reduced charges.
- Replacement of virgin materials. Secondary materials produced to specify quality for use in building applications, i.e. road construction.
- Any fraction of the construction and demolition waste stream that cannot be reused and/or recycled and is not hazardous, can be incinerated as combustible waste for energy.

6.4.6 End-markets

The Spillepeng project conducted durability tests on the recycled materials and discovered that recycled concrete used in traileed sections performed better than crushed stone used on a referenced section of road. Recent research has discovered that the concrete undergoes a cement reaction resulting in the increased durability of the material. In the base course, the cement reaction is even more pronounced than in the sub-base course, resulting in reduced tracking and the possibility of making more slim line constructions (Sysav, 2002).



Photograph 6.17 Use of recovered material in road applications

Other initiatives include the development of a recycled building materials store, *Malmo Aterbyggdena* (Photograph 6.18).



Photograph 6.18 View of the inside of the recycled building materials store, Malmo Aterbyggdena

The enterprise has been operating, in cooperation with the City of Malmo, since 1997. Buildings materials such as tiles, bricks, windows etc. are restored and stored for resale (Photographs 6.18, 6.19 and 6.20). These materials have become popular in restoration work, providing unique architectural features and landscaping features. The example of the restored bricks illustrates the viability of the enterprise. The resale value of the bricks is much higher than the cost of virgin bricks, but this not prevented considerable sales of the restored bricks to both private and professional people alike. To demonstrate the use of these materials, Sysav incorporated recycled bricks, tiles, doors, window, and floorboards into the construction of its head office at the Spillepeng Facility in 1999. This recycled

building provides an excellent example of the use of recycled materials in the construction/renovation process (photograph 6.21).



Photograph 6.19 Recycling/restoration of bricks at the Malmo Aterbyggdena store



Photograph 6.20 Storage yard at Malmo Aterbyggdena



Photograph 6.21 Use of recycling building material at Sysav's head office

Another initiative at SYSAV is the use of incineration ash (slag) in road applications. This material is processed at the Spillepeng Landfill (photograph 6.22) and research is being carried out into its suitability in road applications and its associated environmental impacts.



Photograph 6.22 Processing of incinerator ash (slag) at the Spillepeng Landfill

6.5 Conclusions

The three case studies provide an invaluable insight into the practical aspects of recycling/reusing construction and demolition waste materials. The main conclusions can be summarised as follows:

- All three case studies were operated in some form of public/private partnership agreement.
- The site location on all three sites was similar. Each construction and demolition waste recycling was located within a 5 km distance from the relevant city centres. Each facility was directly linked to a major transportation route.
- The processing systems were almost identical in all three facilities. Each operation utilised separation, crushing and screening techniques to produce viable end products. The Copenhagen Recycling Centre operated the highest level of processing (Level 2-3), followed by Sysav (Level 2) and DemCon 20/20 (Level 1-2).
- The environmental impacts of the three sites were under strict regulatory control by the respective environmental agencies.
- All three facilities had established end-markets. The Copenhagen Recycling Centre and the Sysav Facility have developed markets for recycled/recovered materials, i.e. in road applications, architectural salvage, in construction works. The DemCon 20/20 project

produces material for lower grade applications, i.e. landfill engineering works and capping.

The examination of the case studies identified a number of conditions that are common to each of the best practice facilities as follows:

- Site Location
- Scope of licensed activities
- Processing systems
- Environmental impacts
- End-markets

The next chapter investigates these conditions elaborating to establish a set of best practice indicators for the successful operation of a construction and demolition waste recycling facility.

Chapter 7 : Best Practice Indicators for the Successful Operation and Development of a Construction and Demolition Recycling Facility.

7.1 Introduction

The aim of this chapter is to identify a set of best practice indicators for the development of a successful construction and demolition waste recycling facility.

The most recent policy statement issued by the Department of the Environment and Local Government on waste was *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002). This policy statement identified the lack of infrastructure available in Ireland for the successful treatment of waste. One of the recommendations outlined in the policy statement was the development of eighteen construction and demolition waste recycling facilities across the country. There is a lack of guidance for these proposed facilities. The establishment of a set of best practice indicators represents a unique opportunity to make a significant contribution to knowledge for the construction and waste industry

7.2 Best Practice Definitions

The preparation of the various regional waste management plans throughout Ireland has assessed the different waste management options, i.e. recycling, recovery, thermal treatment and landfill, under two primary headings:

- Best Available Technology Not Entailing Excessive Cost (BATNEEC)
- Best Practicable Environmental Option (BPEO)

BATNEEC is defined by the Environmental Protection Agency as follows:

“The technology in question should be Best at preventing pollution and Available in the sense that it is procurable by the operator of the activity concerned. Technology itself includes techniques and the use of techniques, such as training and maintenance. NEEC sets out the balance between environmental benefit and financial cost”.

(EPA, 1996)

The Agency has published a series of BATNEEC notes designed to provide guidance to those applying for Integrated Pollution Control (IPC)⁷ licences. The objective of these notes is to identify the types of technologies that will be used by the Agency to define BATNEEC for a licensable activity. In the identification of BATNEEC, emphasis is placed on pollution prevention techniques, including cleaner technologies and waste minimisation, rather than end-of-pipe treatment.

Under the EU Directive (96/61/EC) on Integrated Pollution and Prevention Control (IPPC), the concept of Best Available Technology (BAT) is set to replace BATNEEC. BAT is defined by EU Directive 96/61/EC as:

“The most effective and advanced stage in the development of activities and their methods of operation which indicates the practicable suitability of particular techniques for providing the emissions and the impact on the environment as a whole”.

(EU Directive 96/61/E)

⁷ Under the Environmental Protection Agency (Licensing) Regulations, 1994, the licensing function of the Agency commenced on 16 May 1994 and applies to all major industrial sectors listed.

The BATNEEC definition will apply until the IPC regime is phased out. BAT not only covers the technology used but also the way in which the installation is operated, to ensure a high level of environmental protection as a whole. BAT takes into account the balance between the costs and environmental benefits and the economic viability of the technique.

The definition of Best Practicable Environmental Option (BPEO) is similar and is outlined as follows:

“ The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefit or least damage to the environment as a whole, at an acceptable cost, in the long term as well as the short term ”.

(12th Report of the Royal Commission on Environmental Pollution, 1988)

The BPEO for a particular waste stream will include different waste management methods, as each component material of the waste stream will merit distinct management options. Evolving from these definitions is the concept of best practice indicators (DETR, 1999). Best practice indicators recognise that each project/case is unique and is dependent on a number of variables. Some of these variables can be consistent throughout a number of profiles and will provide the basis for a set of best practice indicators. This will promote a more focused investigation of the case/project to support measures of established best practice.

7.3 Best Practice Indicators

Through an extensive literature review and associated site visits, it was discovered that a number of common conditions exist which provide the basis for a set of best practice indicators for the successful operation of a construction and demolition waste recycling facility. They are as follows:

1. Site Location
2. Ownership
3. Regulation and enforcement
4. Scope of licensed Activities
5. Quantity and composition of accepted materials
6. Processing technology
7. End-markets
8. Construction industry and local authority involvement
9. Tipping fees and charges

Within each one of these common conditions exist a number of indicators, which demonstrate best practice in the development and operation of a construction and demolition waste recycling facility.

7.3.1 Condition 1 - Site location

One of the main design factors taken into consideration is the site location. The following indicators play an important role in the operation of the facility:

Indicator 1.1 - The site should be of the appropriate area for the operation. Peng *et al.*

(1997) recommended a minimum area of 0.8 ha for a small operation. The use or redesign of existing solid waste facilities for use as a construction and demolition waste recycling facility is the preferable option.

Indicator 1.2 – The sites' proximity to the construction/demolition activities is important to reduce transportation costs and associated environmental impacts. Ideally the facility should be situated on the outskirts of a city with easy access to the transportation infrastructure.

Indicator 1.3 - Proximity to residential and/or commercial developments. The operation must be a suitable distance away from residential/commercial properties to minimise its environmental impacts, i.e. noise and dust.

7.3.2 Condition 2 - Ownership

Ownership is also an important consideration at the design stage. The initial investment requires a considerable financial capacity (depending on the size of the facility). Good management is required to ensure financial stability and enable expansion if appropriate.

The three main options available are:

- Public/private partnership
- Private ownership
- Public ownership

All three case studies identified in Chapter 6 utilised the public/private partnership arrangement to good effect. This is being actively promoted by the Irish government to encourage the development of waste management infrastructure (DoELG, 2002), under the National Development Plan 2002-2006. It must be noted that each of the three options could be considered suitable if the following indicators can be achieved:

Indicator 2.1 – Financial investment for capital cost

Indicator 2.2 – Financial stability for proposed expansion

7.3.3 Condition 3 - Regulation and enforcement

The regulation of the facility incorporates the various licenses and permits which determine the level of operational management carried out in any particular facility. This regulation can also be applied to the geographical region or country to establish if it provides a 'level playing field' for all operators. The enforcement of these regulations is the responsibility of the licensing authorities, i.e. EPA, local authorities. The two main indicators are:

Indicator 3.1 - The regulation of the construction and demolition waste recycling facility to ensure it operates in an environmentally safe manner, with appropriate technologies producing a quality product. This will involve compliance with the relevant licenses and permits.

Indicator 3.2 - The regulation of all regional operators to ensure that all construction and demolition waste is sent to a fully permitted and licensed facility for processing, thus preventing illegal dumping.

7.3.4 Condition 4 - Scope of licensed activities

The scope of the licensed activities outlines the type and quantity of waste that is acceptable at the facility. The various methods of processing are addressed and an important factor is the alternative disposal options available to the operator. This is translated into the following indicators:

Indicator 4.1 - The licensed capacity of the facility. This outlines the type and quantity of waste acceptable at the facility.

Indicator 4.2 - The alternative disposal options available to the facility. The main disposal options are energy recovery, incineration without energy recovery and landfill (with landfill being the least favoured by the waste management hierarchy).

7.3.5 Condition 5 - Composition and quantity of material being accepted

The facility should aim to operate at full capacity with the majority of the materials being source separated before delivery/collection. The following indicators will establish the level of compliance with this condition:

Indicator 5.1 – The quantity of material accepted at the facility, calculated on a yearly basis must be comparable to the capacity of the licensed facility. Ideally, a facility should be operating at full capacity.

Indicator 5.2 - The percentage of materials accepted that are source separated and of good quality. Source separated construction and demolition waste materials are preferable due to the ease of processing, enabling the production of a better quality secondary material.

Indicator 5.2 – The percentage of the delivered/collected waste stream that is inert, hazardous or mixed. The inert fraction is the most easily recoverable providing ease of processing for viable markets.

7.3.6 Condition 6 - Processing technology

The processing technology or system should be modular in design in order to adapt to changing circumstances, i.e. increased/decreased quantities of accepted materials. There are a number of factors affecting the performance of a processing technology, which are summarised by the following indicators:

Indicator 6.1 - The processing technology must be appropriate to the quantity and type of material being received, i.e. Level 1 technology will not be able to process mixed construction and demolition waste. The equipment needs to be appropriate to the task, be reliable and have a high throughput.

Indicator 6.2 – Good quality control measures are required to ensure a viable end product that will meet required specifications.

Indicator 6.3 - The employees must be well trained to operate equipment, recognise the value of various materials and work safely in a hazardous environment.

7.3.7 Condition 7 - End-markets

To ensure the viability of a construction and demolition waste recycling operation, there needs to be end markets or end uses. If these do not exist, the materials will accumulate after processing and become waste again. The following indicators outline the various options:

Indicator 7.1 - The presence of existing markets for secondary materials gives the operation a competitive advantage. The level of these markets can range from low-grade applications such as fill and landfill engineering works to high-grade applications such as the replacement of primary materials in construction applications.

Indicator 7.2 - The development of potential markets will provide the facility with alternative end uses, thus encouraging a more competitive market. Potential markets will depend on secondary materials being of sufficient quality and price to compete with the primary materials market. The use of secondary materials should be especially encouraged in regions where there is a lack of accessible primary materials.

Indicator 7.2 - The use of existing specifications and standards for recycled/recovered materials are required to promote the use of these secondary materials. Engineering professionals are reluctant to use secondary materials without the guarantee of appropriate specifications and standards.

7.3.8 Condition 8 - construction industry and local authority involvement

The involvement of the construction industry and the relevant local authorities is vital to ensure the success of a recycling facility. The following indicators would signify a positive pro-active approach by the relevant authorities:

Indicator 8.1 - The delivery of source separated construction and demolition waste materials in large quantities, which would enable efficient processing at a lower cost producing a better quality end product.

Indicator 8.2 - The use of the secondary materials in construction applications would provide a market for the recycling facility.

Indicator 8.3 - The integration of the construction and demolition waste recycling facility into the overall regional waste management strategy.

7.3.9 Condition 9 - Tipping fees and charges

The economic feasibility of a construction and demolition waste recycling facility depends primarily on the value ascribed to the materials, the cost of processing, and the market price of the primary raw material. The following indicators illustrate this:

Indicator 9.1 - The cost of landfilling in a region will determine the highest tipping fees and charges. The tipping fees and charges should not be greater than the relevant landfill charges (unless the waste stream was banned from landfill altogether). This will encourage the recycling and recovery of the waste materials.

Indicator 9.2 - The cost of processing the materials to produce a quality end product will be reflected in the charges incurred. Mixed construction and demolition waste is more difficult to process and will incur a higher charge than for source separated inert construction and demolition waste. The secondary material needs to be able to compete with the primary material on quality and price.

Indicator 9.3 - The resale value of the secondary material will affect the original charges and fees. This resale cost must be comparable with the cost of primary materials to encourage its use.

7.4 Interdependence of Identified Conditions

Nearly all of the conditions/indicators are interlinked in some way. Examples of this are:

- The appropriate site area is dependent on the capacity of the facility and the proposed estimates for a particular geographical region.
- The financial stability of the operation will be primarily based on the number of end-markets that exist for the processed materials and the fees charged.
- The regulation of the facility determines the scope of the licensed activities by determining its processing and storage capacity. The enforcement of the regulations is dependent on the involvement of the construction industry and relevant local authorities.
- The alternative disposal options are determined by the overall regional waste management strategy.
- The processing technology is determined by the proposed capacity, the actual quantities accepted, the composition and the quality of the waste entering the facility. The proposed end-market will determine the quality required to ensure the secondary will meet specifications.

- The existence of end-markets relies on the involvement of the construction industry and the relevant local authorities.
- The fees and charges will be determined by the existing landfill charges and the cost of processing. Again this will depend on the type and quality of material delivered, i.e. are the materials source separated or mixed?

7.5 Grading/Marking Scheme

In order to simplify the assessment process, each condition is made up of two or three best practice indicators. These indicators are graded as suitable (1) or unsuitable (0). This will form the basis for a checklist assessment (Table 7.2) of a construction and demolition waste recycling facility. This implies that the maximum allowable mark for each condition is as follows (Table 7.1):

Table 7.1 Grading system for best practice conditions

Condition	Maximum allowable mark
1. Site Location	3
2. Ownership	2
3. Regulation and enforcement	2
4. Scope of licensed activities	2
5. Quantity and composition of accepted materials.	3
6. Processing technology	3
7. End-markets	3
8. Construction industry and local authority involvement.	3
9. Tipping fees and charges	3
Total	24

**Table 7.2 Best Practice Indicators for the Development and Operation of a
Construction and Demolition Waste Recycling Facility.**

Condition	Indicator	Rating 0 or 1
1. Site Location	1.1 Appropriate area and access 1.2 Proximity to construction/demolition activities 1.3 Proximity to residential/commercial areas.	
2. Ownership	2.1 Financial stability 2.2 Finance for expansion	
3. Regulation and enforcement	3.1 Licenses and permits 1.1 Regulation of illegal dumping	
4. Scope of licensed activities	1.1 Appropriate capacity to Regional estimates 1.2 Alternative disposal options	
5. Accepted materials	5.1 Quantity accepted versus capacity 5.2 Quality of materials accepted 5.3 Composition of materials accepted	
6. Processing technology	6.1 Appropriate technology and equipment 6.2 Quality control measures 6.3 Staff	
7. End markets	7.1 Existing 7.2 Potential 7.3 Specifications and standards	
8. Construction industry/ Local Authority involvement	8.1 Delivery and on site separation 8.2 Use in construction applications 8.3 Regional plan integration	
9. Fees and charges	9.1 Landfill and facility fees 9.2 Processing costs (including transportation) 9.3 Resale value	

7.6 Limitations

The limitations of this form of assessment are as follows:

- The grading system is open to interpretation and is dependent on a number of variables. Take for example, Condition 1 – Site location, Indicator 1.3 – Proximity to construction/demolition activities. What determines good proximity? i.e. if the facility were located within 5 km of the main construction/demolition activities, then it would be graded as suitable. If it was located 20 km away, then it would be graded as unsuitable, but throw in the variable of having no primary materials resource in that geographical region, then the distance becomes less important because there is no competition.
- It is not a definitive list of all the factors involved in the development and operation of a construction and demolition waste recycling facility. To establish all the factors involved, a number of facilities would need to be monitored over a set time-span, i.e. 5 years, to establish the performance indicators. This would then identify what made one facility more successful than another comparable facility.
- Some of the conditions were identified as having a number of different variables associated with them. This was illustrated by having three indicators for certain conditions, i.e. site location, accepted materials, processing technologies, end markets, construction industry/local authority involvement and fees and charges.

This may provide the basis for a hierarchy of importance but would need further investigation over a more prolonged period.

- The indicators are not based on the actual studied performance over a specified timeframe of any construction and demolition waste recycling facilities.

7.7 Conclusions

The main aim of this chapter was to outline a number of conditions that are required to aid in the successful development of a construction and demolition waste recycling facility.

The conclusions are as follows:

- The current definitions of best practice (BATNEEC and BPEO) do not examine the operational management of a facility. They are concerned with the environmental impact of an operation and its associated costs. The development of the BAT concept is a positive step as it aims to address the technology used as well as the ongoing operation, to ensure a high level of environmental protection.
- The establishment of best practice indicators provides a useful tool for the developer in the examination of a proposed or existing development. The best practice indicators can be used at the inception stage to investigate the feasibility of a small or large-scale facility or during operation to investigate the current practices and provide some improvements.
- The grading/marking scheme is intentionally simple to ensure that the checklist is user-friendly.
- The conditions and indicators listed is not a definitive list. The development and operation of a construction and demolition waste recycling facility is dependent on a number of variables and the checklist identifies the most common ones.

The next chapter will provide a descriptive overview of the development of the Barna Waste Ltd. facility leading to an examination of its operational effectiveness and economic viability in subsequent chapters.

Chapter 8 : The Development of the Barna Waste Ltd. Waste Transfer and Recycling Facility.

8.1 Introduction

The aim of this chapter is to provide a descriptive overview of the development of the Barna Waste Ltd. Waste Transfer and Recycling Facility. The Barna Waste Ltd. Facility is the central case study in the thesis and will be analysed from an operational and economic point of view in the following chapters.

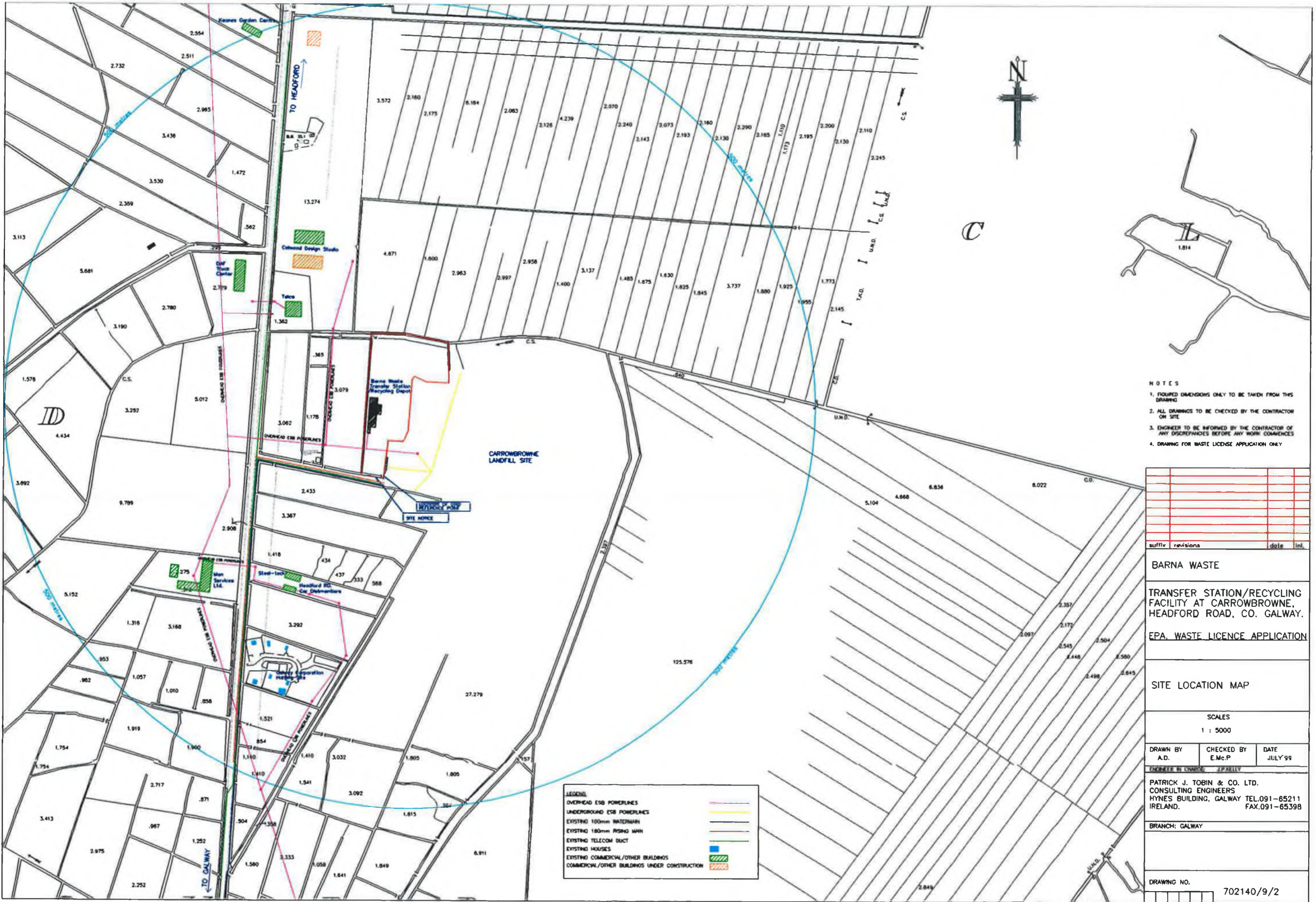
8.2 Background

Barna Waste Ltd. is a waste contracting business, which was founded in 1978. Sean Curran purchased Barna Waste Ltd. in 1989. The company moved premises in 1993 to its current location at Carrowbrowne, Headford Road, Galway (Site Location Map – Drawing No. 7021140/9/2).

8.2.1 Planning Background

The current Barna Waste Ltd. site is located within the functional area of Galway County Council, and as such is subject to the planning regulations of that authority. The following is the planning history of the Barna Waste Ltd. Facility:

1993 – In March 1993, planning permission was granted to Barna Waste Ltd. for the development of a waste material recycling facility at Carrowbrowne, Co. Galway.



- NOTES**
1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
 2. ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
 3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
 4. DRAWING FOR WASTE LICENCE APPLICATION ONLY

suffix	revisions	date	int.

BARNA WASTE

TRANSFER STATION/RECYCLING FACILITY AT CARRWBROWNE, HEADFORD ROAD, CO. GALWAY.

EPA, WASTE LICENCE APPLICATION

SITE LOCATION MAP

SCALES
1 : 5000

DRAWN BY A.D.	CHECKED BY E.Mc.P.	DATE JULY 99
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PATRICK J. TOBIN & CO. LTD.
CONSULTING ENGINEERS
HYNES BUILDING, GALWAY TEL.091-65211
IRELAND. FAX.091-65398

BRANCH: GALWAY

DRAWING NO. 702140/9/2

- LEGEND**
- OVERHEAD ESB POWERLINES
 - UNDERGROUND ESB POWERLINES
 - EXISTING 100mm WATERMAIN
 - EXISTING 180mm RISING MAIN
 - EXISTING TELECOM DUCT
 - EXISTING HOUSES
 - EXISTING COMMERCIAL/OTHER BUILDINGS
 - COMMERCIAL/OTHER BUILDINGS UNDER CONSTRUCTION

1996 – In October 1996, planning permission was granted for an extension of the premises, incorporating the building of a 91.2 m² lean-to-extension.

1998 – In March 1998, planning permission was granted to Barna Waste Ltd. for the continuance of the use, for a further ten years, of the existing facility at Carrowbrowne.

1998 – In September 1998, planning permission was granted for the extension of the waste recycling facility at Carrowbrowne, by the construction of a 1600 m² building, 10.5 metres high, to facilitate the covered segregation of waste material.

1999 – In November 1999, permission was granted to use some 600 m² of the existing permitted Waste Recycling Facility Building as a Transfer Facility for non-recyclables for disposal off site, and for the transfer of municipal waste from smaller to larger vehicles for disposal off site.

2000 – In April 2000, permission was granted to roof 1980 m² of existing yardage permitted for waste recycling to cover permitted sorting bays and waste skips, and to cover areas permitted for bulk recycling, so that all loading and unloading prior to recycling will occur under roof cover.

2000 – In December 2000, Barna Waste Ltd. was granted a waste licence for a waste transfer and recycling facility from the Environmental Protection Agency (EPA).

2001 – In August 2001, Barna Waste Ltd. was granted a waste permit from Galway County Council for the site adjacent to the existing facility.

2002 – In January 2002, permission was granted to roof 1440 m² of concrete hardstand. This roof cover encloses the manual picking station.

2002 – Currently, a decision is pending on an application for a composting facility for the site adjacent to the existing facility.

8.2.2 Waste Licence

Part IV of the Waste Management Act, 1996 provides for the stringent system of integrated waste licensing by the EPA in respect of all significant waste recovery and disposal activities. This is to ensure that high environmental standards apply to the establishment, management, operation, closure and aftercare of licensable waste facilities. Licensing obligations have been imposed on a phased basis since May 1997 and full application took effect from 1st of October 1999. To grant a licence the EPA must be satisfied that (www.epa.ie):

- The applicant must be a “fit and proper person” to hold a waste licence (i.e. is technically qualified and has a satisfactory legal record).
- The activity concerned will not cause any environmental pollution (as defined in Section 3 of the Waste Management Act, 1996).
- Emissions from the activity will comply with any relevant standard or emission limit value.

- The best available technology not entailing excessive cost (BATNEEC) will be used to minimise emissions.
- The applicant can discharge all financial commitments and liabilities likely to arise from the licensed activity (including remediation and aftercare).

The detailed procedures in respect of a waste licence application processing are set out in the Waste Management Act, 1996 and associated regulations.

Barna Waste Ltd. was granted a waste licence (Register No. 106-1) by the EPA in December 2000, becoming the first fully licensed waste contractor in Connaught. The licence enables the facility to carry out the waste activities listed in section 8.4.

8.3 Site Location

The existing site is located in the townland of Carrowbrowne, Co. Galway, approximately 6 km north of Galway City. The townland of Carrowbrowne has population of approximately 628 persons (1996 Census). The site is situated on the N84 Galway-Castlebar Road, adjacent to the disused Carrowbrowne Landfill Facility, as shown on site location map, Drawing No. 702140/9/2. The entire site covers an area of approximately 1.65 ha. The Barna Waste facility shares a common boundary with the Carrowbrowne Landfill site (on the east side). The landfill site covers an area of approximately 15.4 ha.

The land surrounding the Barna Waste site is situated in the Corrib Basin, which is flat, featureless and low-lying. Most of the land is part of an extensive tract of peat bogland,

bordered on the north, east and south sides by limestone hills, and on the west side by Lough Corrib. The River Clare flows through the region to the north of the site into Lough Corrib.

The existing residential developments in the area surrounding the Barna Waste site are shown on Drawing No. 702140/9/2. There are three private dwellings and a Galway Corporation halting site within a 1 km radius of the site. There are a number of commercial/industrial premises adjacent to the site along the N84. These businesses include the DAF Truck Centre; Tolco Antiques; MAN Services (Truck Centre); and Car Dismantlers (Scrap Yard).

The Barna Waste site is accessible from Galway City and other areas via the N84 Galway – Castlebar road. Due to the close proximity of the townland of Carrowbrowne to Galway City and to the Carrowbrowne Landfill, the site has an agreement with Galway Corporation allowing the use of both the Carrowbrowne Landfill watermain and the adjacent Carrowbrowne Landfill leachate lagoon, which connects to the Galway Corporation sewerage main.

8.4 Scope of Licensed Activities

8.4.1 Waste activities licensed

The Facility is licensed for the following waste disposal activities, in accordance with the Third Schedule of the Waste Management Act, 1996:

Class 11. Blending or mixture prior to submission to any activity referred to in a preceding paragraph of this Schedule.

Class 12. Repackaging prior to submissions to any activity referred to in a preceding paragraph of this Schedule.

Class 13. Storage prior to submission to any activity referred to in a preceding paragraph of this Schedule, other than temporary storage, pending collection, on the premises where the waste concerned was produced.

This activity is limited to the temporary storage of compacted wastes, enclosed in ejector trailers prior to disposal to landfill.

The facility is licensed for the following waste recovery activities, in accordance with the Fourth Schedule of the Waste Management Act, 1996.

Class 2. Recycling or reclamation of organic substances, which are not used as solvents (including composting and other biological transformation processors).

Class 3 Recycling or reclamation of metals and metal compounds.

Class 4. Recycling or reclamation of other inorganic materials.

Class 12. Exchange of waste for submission to any activity referred to in a preceding paragraph of this Schedule.

This activity is limited to the repackaging of the different segregated waste streams from the transfer/recycling facility and the Civic Waste Facility.

Class 13. Storage of waste intended for submission to any activity referred to in a preceding paragraph of this Schedule, other than temporary storage, pending collection, on the premises where such waste is produced.

This activity is limited to the storage of waste prior to recovery.

The main aim of the waste licence and its licensed activities is to ensure that all operations are carried out in an environmentally safe manner. The implementation of an

Environmental Management System (EMS) is a key component in fulfilling these obligations. Barna Waste Ltd. must submit an Annual Environmental Report to the EPA to demonstrate compliance with the conditions of the waste licence.

8.4.2 Licensed quantities and composition of waste accepted at the facility

The waste licence (106-1) outlines the waste categories and quantities that are acceptable at the Facility (Table 8.1).

Detailed records are kept at the facility on the category and quantity of waste being accepted and this is submitted as part of the Annual Environmental Report. Details are also kept of any waste brought off-site to identify the final destination of the various waste streams.

Table 8.1 Waste Categories and Quantities acceptable at Barna Waste Facility

[Schedule G: Waste acceptance (Table G.1) (Waste Licence 106-1)]

Waste Type	Maximum tonnes per annum
Household	55 500
Commercial and Industrial	40 500
Construction and Demolition	30 000
Total	126 000

8.4.3 Current activities

The weighbridge has been fully operational since February 2001 and records have been kept on all wastes arriving and departing the facility since that time. Table 8.2 lists the type and quantities of waste accepted at the facility over a 15-month period.

Table 8.2 Waste received – 12th February 2001 to the 14th May 2002**(adapted from Barna Waste Ltd. on-site waste records)**

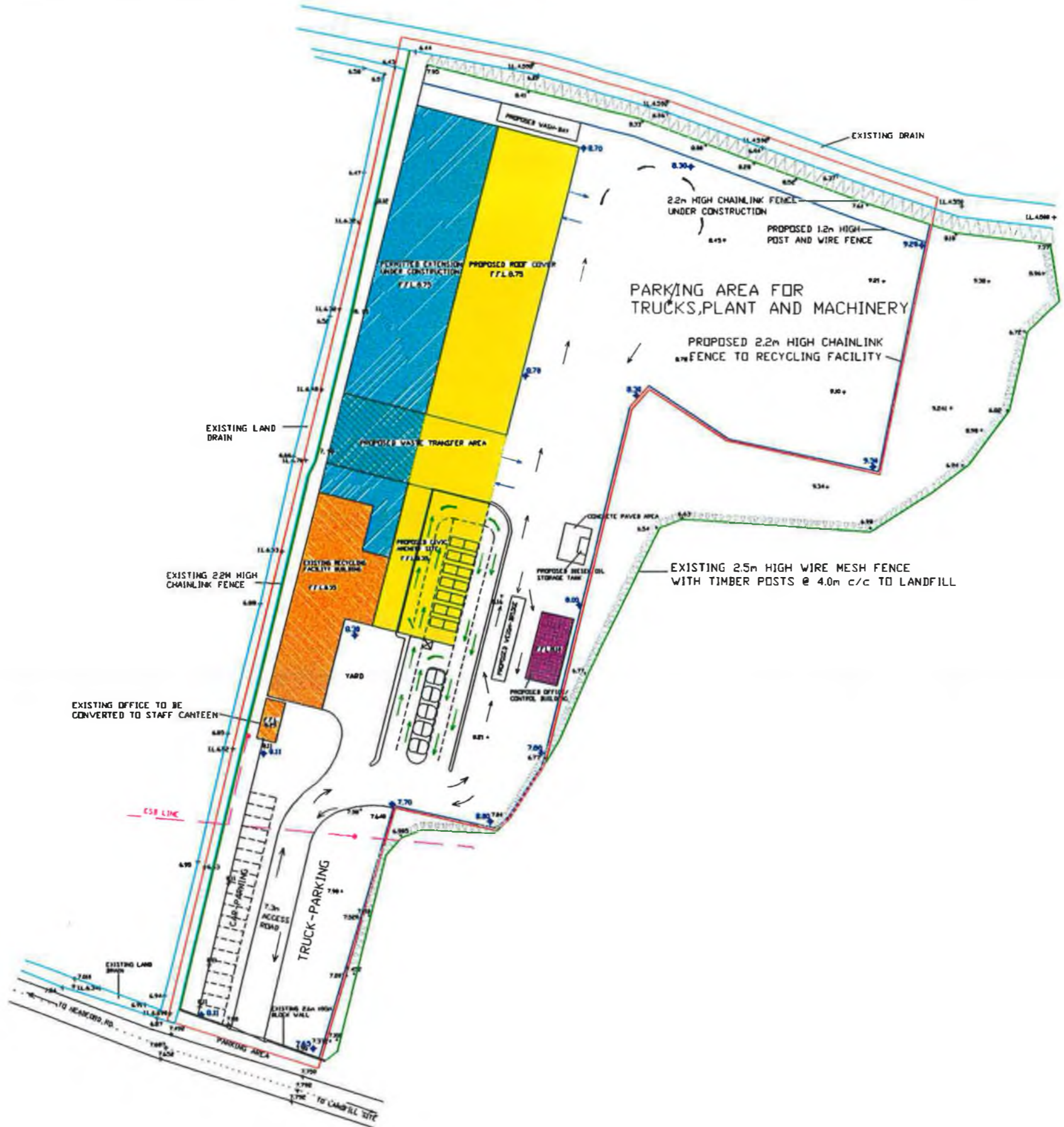
Description	Quantity in tonnes	Percentages (%)
Cardboard	1021.36	2.0
Commercial	14853.30	28.0
Construction and Demolition Waste	25498.62	48.0
Domestic	9849.72	19.0
Recyclables	1786.79	3.0
Total	53009.79	100.0

8.5 Processing System

8.5.1 General site layout

The layout of the facility has developed since its original inception at the time of the waste licence application. Drawing No. 702140/9/4 shows the original layout (as submitted in the waste licence application to the EPA) and this has developed with the addition of new hardstands and associated roof cover as outlined in Drawing No. 702140/9/24. The proposed future construction is outlined in Drawing No. 702140/9/29 and includes additional roof cover to the existing hardstands to permit the full enclosure of the main waste transfer building. In all cases, the design of the layout took into consideration the following criteria:

1. Ease of traffic flow within the site (photograph 8.1).



LEGEND

- EXISTING BUILDING PERMITTED BY PLANNING REF. 65804, 96/832 AND 97/3096
- EXTENSION UNDER CONSTRUCTION PERMITTED BY PLANNING REF. 96/2056
- PROPOSED ROOF COVER TO EXISTING YARDAGE PERMITTED. PLANNING APPLICATION UNDER CONSIDERATION AT PRESENT. PLANNING REF. 99/427
- PROPOSED WASTE TRANSFER AREA SHOWN CROSS HATCHED PLANNING APPLICATION UNDER CONSIDERATION AT PRESENT. PLANNING REF. 99/204
- PROPOSED OFFICE/CONTROL BUILDING SUBJECT TO PLANNING
- + 9.38 EXISTING GROUND LEVELS
- ◆ 7.60 PROPOSED GROUND LEVELS
- EXISTING FENCE/FENCE UNDER CONSTRUCTION
- PROPOSED FENCE

- NOTES**
1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
 2. ALL DIMENSIONS TO BE CHECKED BY THE CONTRACTOR ON SITE
 3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
 4. ALL LEVELS TO ORDNANCE DATUM SEVEN HEAD
 5. DRAWING FOR WASTE LICENCE APPLICATION ONLY.

SUFFTY	REVISIONS	DATE	BY

BARNA WASTE
TRANSFER STATION/RECYCLING FACILITY AT CARRWBROWNE, HEADFORD ROAD, CO. GALWAY.
E.P.A. WASTE LICENCE APPLICATION

SITE LAYOUT PLAN SHOWING EXISTING BUILDING, PERMITTED EXTENSION UNDER CONSTRUCTION, PROPOSED ROOF COVER TO EXISTING YARDAGE PERMITTED AND PROPOSED OFFICE/CONTROL BUILDING

SCALE

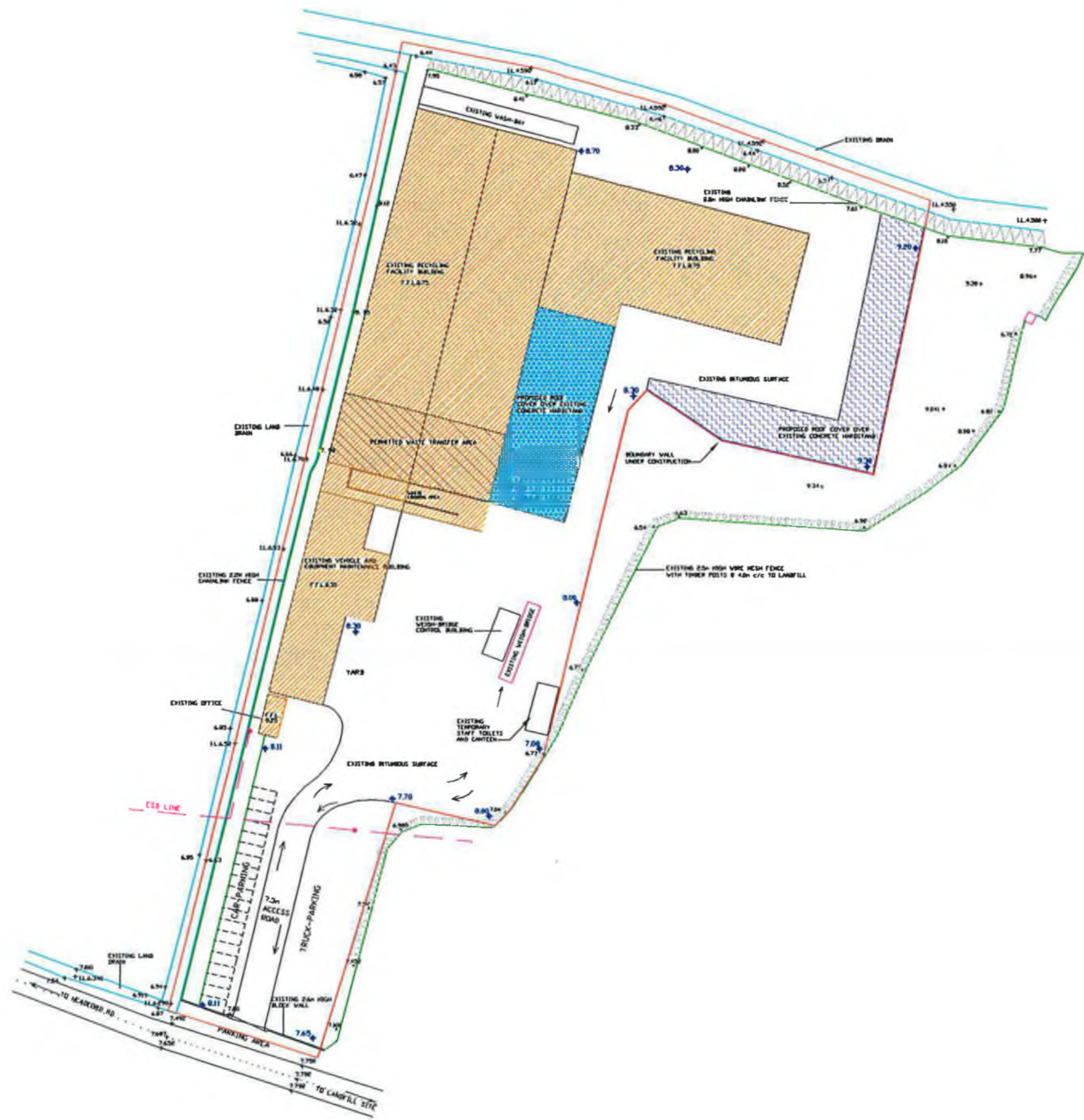
DRAWN A.D.	CHECKED BY E.McP.	DATE JULY '99
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ENGINEER IN CHARGE J.P. KELLY

PATK. J. TOBIN & CO. LTD
CONSULTING ENGINEERS
HYNES BUILDING GALWAY TEL-(091-85211)
IRELAND FAX-(091-85388)

BRANCH GALWAY

DRAWING NO. 702140/8/4



LEGEND

- EXISTING BUILDING PERMITTED BY PLANNING REF. 85/004, 96/832, 97/3696, 98/2056, 99/427 AND 01/379
- WASTE TRANSFER AREA SHOWN CROSS HATCHED PERMITTED BY PLANNING REFERENCE 99/427
- PROPOSED ROOF COVER OVER EXISTING CONCRETE HARDSTAND, PERMITTED UNDER PLANNING REF 01/738
- PROPOSED ROOF COVER OVER EXISTING CONCRETE HARDSTAND, PLANNING UNDER CONSIDERATION
- +9.38 EXISTING GROUND LEVELS
- ◆7.60 EXISTING FINISHED YARD LEVELS
- EXISTING FENCE
- BOUNDARY WALL UNDER CONSTRUCTION
- EPA LICENCE BOUNDARY

NOTES

1. DIMENSIONED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL DIMENSIONS TO BE CHECKED BY THE CONTRACTOR ON SITE
3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
4. ALL LEVELS TO ORDNANCE DATUM MALIN HEAD
5. DRAWING FOR I.P.M. WHERE LICENCE USE ONLY.

SUFFIX	REVISIONS	DATE	BY

BARNA WASTE Ltd.

WASTE TRANSFER/RECYCLING FACILITY AT CARROWBROWNE, HEADFORD ROAD, CO. GALWAY.

SITE LAYOUT PLAN SHOWING EXISTING BUILDINGS AND HARDSTAND AREA

SCALES
1 : 500

DRAWN K.G.	CHECKED BY E.McP.	DATX MAY 2002
ENGINEER IN CHARGE J.P. KELLY		

PATK. J. TOBIN & CO. LTD
CONSULTING ENGINEERS
HYNES BUILDING GALWAY
IRELAND
TEL-(091)652111
FAX-(091)653988

BRANCH GALWAY

DRAWING NO. 702140/8/29



Photograph 8.1 Entrance to the Barna Waste facility

2. Sufficient road areas within the site to accommodate queuing of vehicles and to avoid traffic queuing on the public road.
3. Availability of the weighbridge to heavy vehicles using the Facility.
4. Sufficient room for landscaping and screening of the site.

8.5.2 Layout of the buildings

The layout of the buildings is shown on Drawing No. 702140/9/24. The following buildings/services are present on site:

- Existing office/canteen
- Transfer building (photograph 8.2) incorporating areas for:
 - Waste transfer of commercial, industrial and domestic wastes
 - Cardboard baling
 - Sorting



Photograph 8.2 View of waste transfer building on the Barna Waste site

- Maintenance building and maintenance yard (photograph 8.3) for equipment storage
- Concrete hardstands for waste handling and transfer and C&D W storage
- Vehicle wash bay

- Weighbridge and associated office (photograph 8.4)
- Foul water drainage network including a full retention oil separator, holding tank and pumping station, flow-meter and sampling chamber
- Surface water drainage network including grit trap, bypass oil separator, shut-off valve and sampling chamber
- Galway Corporation's Carrowbrowne Landfill watermain
- Connection to Galway Corporation's Carrowbrowne Landfill leachate lagoon and sewer
- Bituminous hardstand surface covering entire site (except concrete hardstands)



Photograph 8.3 View of maintenance building and yard on the Barna Waste site



Photograph 8.4 View of weighbridge and associated office on the Barna Waste site

8.5.3 Schedule of plant and equipment

The facility has a number of waste processing machines, as detailed below:

The current plant consists of:

- 3 track excavators, 2 of which have grab arms for waste handling
- 2 fork lifters
- Erin Finger screener (photograph 8.5)
- Extec stone shredder/crusher
- Timber shredder with magnetic separator (photograph 8.6)
- Baler for cardboard
- A manual picking station (photograph 8.7).



Photograph 8.5 Erin Finger Screener 125T on Barna Waste site



Photograph 8.6 Timber shredder on Barna Waste site



Photograph 8.7 Manual picking station in operation at the Barna Waste facility

There are also a number of on-the-road vehicles for waste collection and transfer. These include:

- 5 skiploaders
- 2 hook vehicles
- 3 skipeaters
- 4 tractor units
- 8 No. 30 m³ ejector trailers for the transfer of waste
- A tipper vehicle
- A sludge tanker
- 2 refuse collection vehicles

Table 8.3 lists the various capacities of the plant and equipment (relevant to construction and demolition waste processing) currently on site at the Barna Waste Facility.

Table 8.3 Capacities of construction and demolition waste processing equipment at the Barna Waste facility (adapted from TES Consulting Engineers, 2002)

Equipment	Description	Capacity
Extec Stone/Wood Shredder 3600s	Capable of dealing with a variety of materials. Main use is for the crushing of construction and demolition waste.	100 tonnes/hour 800 tonnes/day
Erin Fingerscreener FS 165	Capable of dealing with a variety of materials. Main use is for the screening of construction and demolition waste.	40 tonnes/hour 320 tonnes/day
Manual Picking Station	Not in use at present. Main use is for the separation of mixed construction and demolition waste or oversize fractions.	Estimated to pick 12 tonne/day.
Case Porclain 688 with grab attachment	Used to mechanically separate mixed fractions and for loading of materials in crusher and screener.	30 tonnes/hour 240 tonnes/day
Volvo BM L160 Loading Shovel	Used within the transfer building to move various separated fractions to appropriate areas.	30 tonnes/hour 240 tonnes/day
Komatsu WA 200-1 Loading Shovel	Used to move recovered/processed materials to segregated bays for storage.	30 tonnes/hour 240 tonnes/day

8.5.4 Construction of the facility

The existing facility has been is a stage of continuous development for the past nine years. The development has been constructed in accordance with the relevant planning permissions. The internal site access roads/yards are finished with a bituminous surface with all waste handling and transfer carried out on concrete hardstands. Site access, car and truck parking, foul water drainage, surface water drainage, weighbridge facilities, ESB and water services are all present on site.

8.5.5 Operation of the Facility

The principle processes of the facility are:

1. The collection of domestic and commercial waste at the Transfer/Recycling Facility by Barna Waste Ltd. and private refuse collection vehicles, the loading of this waste into ejector trailers to provide for the bulk haul of the waste to the final disposal site (currently the Ballinasloe Landfill site).
2. The deposition and sorting of recyclable waste and household hazardous waste for collection and re-use or safe disposal elsewhere.
3. The treatment of construction and demolition waste and the recovery of soil, crushed stone, ferrous metal and timber.

On arrival on site, all waste is weighed in and relevant information regarding content, source, weight etc. is logged by the materials handling supervisor on site. Depending on the content, the waste will be directed and transferred to the designated area on site.

8.5.6 Processing of construction and demolition waste

The processing system has changed during the construction of the facility. Originally at the time of the waste licence application the following processing system was planned for construction and demolition waste materials (Drawing No. 702140/9/7).

- On arrival on site, all construction and demolition waste is weighed in and the relevant information regarding content, source, weight, is logged by the materials handling supervisor at the weighbridge office.
- The carrier is then directed to the construction and demolition waste processing area where it is tipped onto the floor.
- In this area, the load is tipped onto the floor and easily extractable material such as large items of wood are pulled out of the waste pile using a grab crane and transferred onto the hopper for treatment using the timber shredder. The timber shredder also includes a magnetic separator that facilitates the extraction of all ferrous metals from the crushed timber.
- The separated metal is collected in a skip for transfer to a scrap merchant.

- The remainder of the material is fed onto a conveyor, which feeds a finger screen via a hopper. This finger screen allows for the separation of the remaining material into fine and oversize fractions. The fines consist of primarily clay and soil and can be reused as fill material in the adjacent permitted site.
- The oversize fraction passes along a picking station where all salvageable material and residues are put into sorting bins. The oversize fraction continues on to a stone crusher where the material is crushed.
- The remaining material, which will incorporate predominately stone will be fed via a conveyor belt hopper into the stone crusher. The recovered crushed stone will be sold to the construction industry and may be used for fill material.
- All material recovered will be held in storage bays until such time that a load of sufficient size is available for consignment.
- In instances whereby a skip contains natural excavated material, uncontaminated soil or stone, then it shall be tipped at the relevant storage location for subsequent reuse or disposal at a site permitted to receive such material.
- A waste inspection area is provided in the waste transfer building for any loads that are unsuitable for direct processing and handling, i.e. hazardous waste.

- A waste quarantine area is provided (adjacent to the waste inspection area) inside the waste transfer building for safe storage of any materials not suitable for processing at the facility, i.e. hazardous waste. The material is stored for a short time in a bunded area until specialised waste contractors take the waste off site.

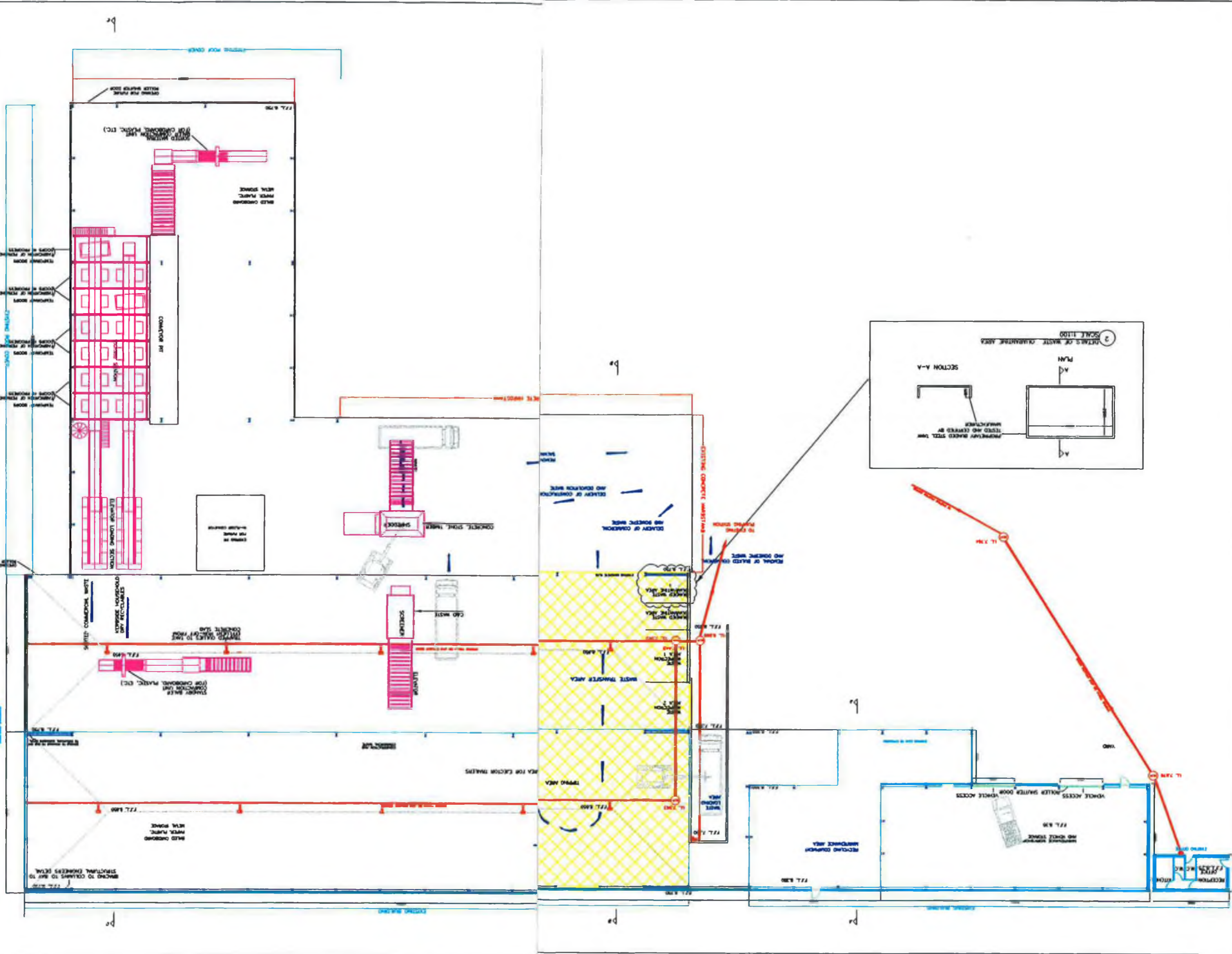
This processing system is using 'Level 2' to 'Level 3' technology (as defined by Symonds *et al.*, 1999) and is capable of processing all types of construction and demolition waste.

Due to the ongoing construction works, the full processing system for construction and demolition waste materials is not in operation. The current processing system is as follows (Drawing No. 702140/9/27):

- On arrival on site, all construction and demolition waste is weighed in and the relevant information regarding content, source and weight is logged by the materials handling supervisor at the weighbridge office.
- If the source of the material is known and the delivered material is separated and inert, it can be recovered without processing and deposited on the adjacent permitted site.
- All mixed or 'non-inert' construction and demolition waste is directed to the construction and demolition waste recycling area.

DRAWING NO.		DATE	
PROJECT NAME		DATE	
DRAWN BY		DATE	
CHECKED BY		DATE	
SCALE		DATE	
BARNY WASTE LTD. WASTE TRANSFER/RECYCLING FACILITY AT CLONBORNE, BEARFORD ROAD, CO. DUBLIN. FLOOR PLANS OF EXISTING RECYCLING FACILITY BUILDING			
PATE, J. TOON & CO. LTD. CONSULTING ENGINEERS 11, WINDMILL LANE, DUBLIN 18, IRELAND.			
BRANCH OFFICE 11, WINDMILL LANE, DUBLIN 18, IRELAND.			

- NOTES
1. FLOOR FINISHING ONLY TO BE TAKEN FROM THIS DRAWING.
 2. ALL DIMENSIONS TO BE CHECKED BY THE CONTRACTOR.
 3. ALL DIMENSIONS TO BE CHECKED BY THE CONTRACTOR.
 4. ALL DIMENSIONS TO BE CHECKED BY THE CONTRACTOR.
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- In this area, the load is tipped onto the floor and easily extractable material such as large items of wood are pulled out of the waste pile using a grab crane and transferred onto the hopper for treatment using the timber shredder. The timber shredder also includes a magnetic separator that facilitates the extraction of all ferrous metals from the crushed timber.
- The separated metal is collected in a skip for transfer to a scrap merchant.
- The remainder of the material is processed through the finger screen, which allows for the separation of the remaining material into a fine and oversize fraction. The fines consist of primarily clay and soil is reused as fill material on the adjacent permitted site. The oversize fraction is crushed and is used as fill material on the adjacent permitted site.
- Any remaining residual or mixed waste is sent to landfill.

The current processing system is constrained by the fact that the construction of the facility, i.e. the appropriate roof cover, has not been completed (June 2002). The system was devised in response to the quantities and composition of construction and demolition waste being received at the facility. At the moment, the composition of materials being received would be approximately 71 per cent inert and 27.4 per cent mixed with the source separated timber fraction accounting for 1.6 per cent (C. Balfe, *pers. comm*). This implies that the

actual amount of processing on site is minimal due to the fact that the majority of the inert material can be used as fill on the adjacent permitted site.

When fully completed the facility aims to have a processing system as outlined in Drawing No. 702140/9/12. This is based on the same fundamentals as the original system (Drawing No. 702140/9/7). The layout of the plant is slightly different to suit the construction developments of the facility, but the system remains the same with an improved picking station. This system will be ready for full implementation by the end of 2002.

The decision to upgrade to this type of system will be dependent on the a number of factors:

1. Economical viability
2. Operational effectiveness
3. Quantities of construction and demolition waste being received
4. Composition of construction and demolition waste being received

8.6 Environmental Impacts

8.6.1 Air

Dust emissions generated at the site are minimal because all operations are carried out under the cover of the facility buildings. However, dust monitoring is currently being carried out three times a year to ensure that the Barna Waste Ltd. site is not producing any adverse impacts on the environment. All results are sent to the EPA for inspection (Drawing No. 702140/9/3).

The nature and scale of the Barna Waste facility is such that no significant noise impact will arise. However, noise monitoring is being carried out on an annual basis to identify the following:

- A description of the ambient noise environment;
- Evaluation of the noise impact of the operation; and
- Identification and description of measures to mitigate noise impacts, where necessary.

Daily inspections are carried out by the Facility Manager to ensure that environmental nuisances are kept to a minimum.

8.6.2 Ecology

A survey of the habitat of the Barna Waste site was carried out as part of a submission of an environmental impact statement to the EPA. The results of the survey discovered that the habitats have been negatively affected both from leachate from the disused

Carrowbrowne landfill site, and by poaching and agricultural management practices. There are no liquid wastes coming from the facility and therefore any impact on the water quality is unlikely to be due to the activities of the site. All waste transfer areas are on concrete hardstands with the rest of the site covered with a bituminous surface and no waste will be left exposed for any long period of time. This ensures that there will be no long-term negative impacts on the flora and fauna of the surrounding area.

8.6.3 Surface water and foul water discharges

All surface water run-off from the facility (other than roof water) passes through a silt trap and class 1 full retention oil separator prior to discharge to the stream at the northern boundary of the facility. All roof waters shall be segregated and separately discharged to the surface water stream to the north of the site. A monitoring chamber is provided for the representative sampling of the final surface water discharge from the facility to the stream located at the northern boundary of the site. A shut-off valve is incorporated in the design to stop the discharge if so required.

All foul water passes through a silt trap and class 2 oil separator prior to discharge to the leachate treatment system in the adjoining Carrowbrowne landfill facility. The oil separator receives wastewater from the floors of the waste transfer building, the maintenance building and the vehicle cleaning facility. An inspection chamber is provided in connection with each pipe through which the foul water is been discharged. A monitoring point is provided for the representative sampling of the foul water discharge from the facility. A shut-off valve is incorporated in the design to stop the discharge if necessary. Adequate

capacity is provided upstream of the shut-off valve for the storage of the effluent. Drawing No. 702140/9/26 outlines the drainage network of the facility. Surface water and foul water monitoring is carried out quarterly and all results are submitted to the EPA for revision.

8.6.4 Landscape

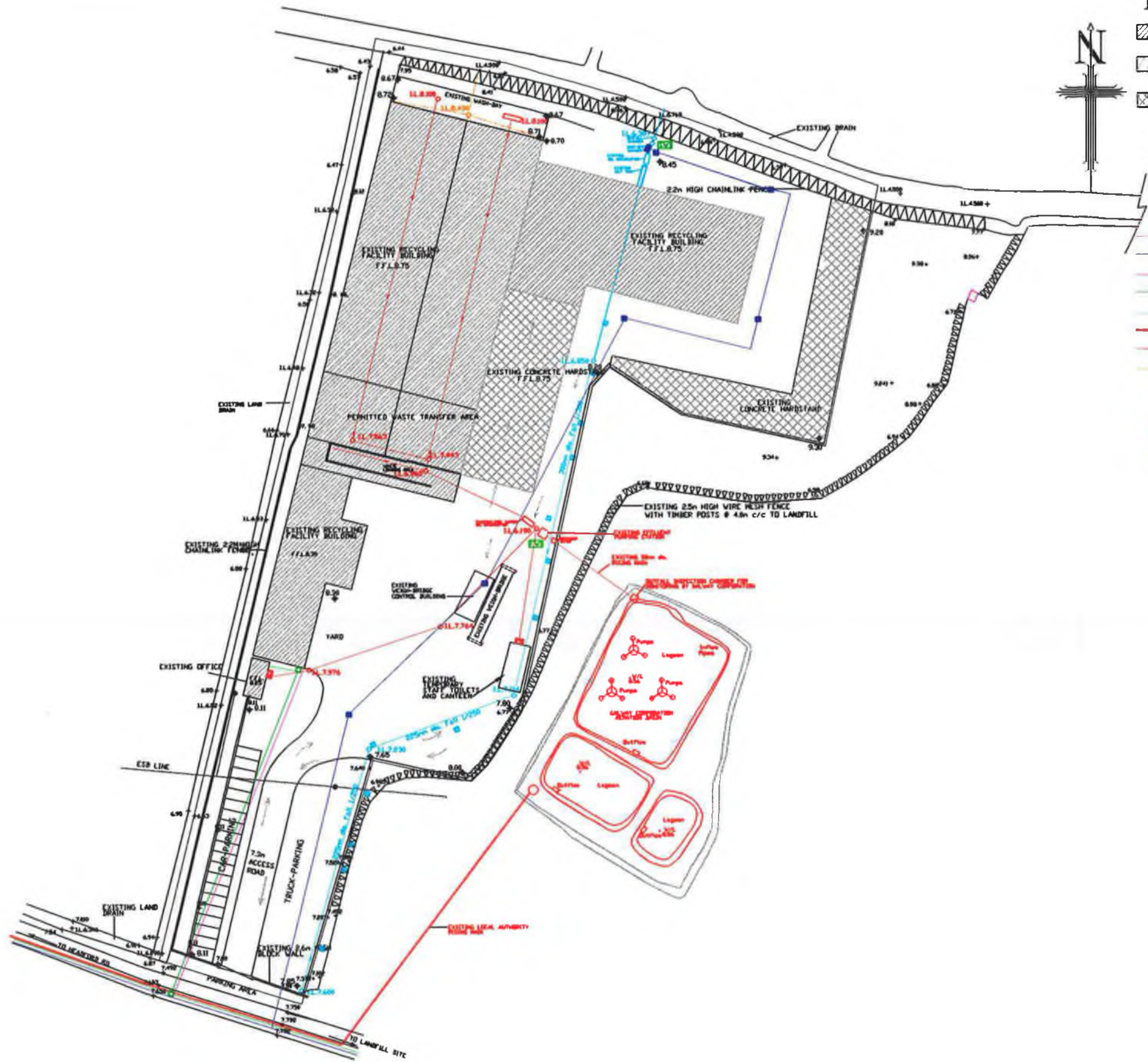
The facility is located on an industrial site adjacent to a disused landfill and therefore has no significant visual impact on the landscape. The appearance of the development is being enhanced by boundary planting and landscaping.

8.6.5 Human beings

The likely significant impacts on human beings of the development are visual impacts, noise and traffic impacts. All these impacts are being addressed in a pro-active manner to reduce the impact on human beings and in particular the local population.

8.6.6 Odour

Any odour nuisance to the surrounding area is monitored on a continuous basis by the Facility Manager. Each nuisance is registered and immediate action is taken by the site manager to investigate whether the odour emission is caused by the Barna Waste facility and if so, to take appropriate measures to immediately reduce the odour emissions. The cause for the odour emission will be investigated, and operational and/or managerial measures will be taken to ensure the future risks are minimised.



- LEGEND**
- EXISTING BUILDING PERMITTED BY PLANNING REF. 05804, 96/832, 97/5896, 98/2058, 99/427 AND 01/379
 - WASTE TRANSFER AREA SHOWN CROSS HATCHED PERMITTED BY PLANNING REFERENCE 99/427
 - EXISTING CONCRETE HARDSTAND
 - + 9.38 EXISTING GROUND LEVELS
 - + 7.60 EXISTING FINISHED YARD LEVELS
- SERVICES LEGEND**
- EXISTING 150mm DIA. EFFLUENT SEWER
 - EXISTING 100mm DIA. WATER MAIN
 - EXISTING 18mm DIA. WATER MAIN
 - EXISTING TELECOM DUCT
 - EXISTING 225mm/300mm DIA. SURFACE WATER DRAINAGE
 - EXISTING 180mm RISING MAIN
 - EXISTING 50mm dia. RISING MAIN
 - EXISTING 225mm DIA. ROOF WATER DRAINAGE
 - EXISTING FIRE HYDRANT
 - EXISTING SURFACE WATER GULLIES
 - ACCESS JUNCTION
 - SURFACE WATER DISCHARGE SAMPLING POINT
 - FOUL WATER DISCHARGE SAMPLING POINT

- NOTES**
1. DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
 2. ALL DIMENSIONS TO BE CHECKED BY THE CONTRACTOR ON SITE
 3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
 4. ALL LEVELS TO ORDNANCE DATUM UNLESS STATED OTHERWISE
 5. DRAWING FOR EPA WASTE LICENCE USE ONLY

SUFFIX	REVISIONS	DATE	BY
A	LAYOUT PLAN UPDATED	MAY 02	E.C.

BARNA WASTE Ltd.

WASTE TRANSFER/RECYCLING FACILITY AT CARRWBROWNE, HEADFORD ROAD, CO. GALWAY.

SITE PLAN SHOWING EXISTING LAYOUT OF DRAINAGE, WATERMAINS AND SERVICES

SCALE:

DRAWN E.C.	CHECKED BY E.M.P.	DATE FEB 2002
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ENGINEER IN CHARGE: J.F. KELLY

PATK. J. TOBIN & CO. LTD
CONSULTING ENGINEERS
HYNES BUILDING GALWAY IRELAND
TEL-(091-85211)
FAX-(091-85398)

BRANCH GALWAY

DRAWING NO. 702140/9/26

Other environmental nuisances such as litter, birds, flies and vermin are monitored by daily inspections of the site by the Facility Manager. Records are kept of any nuisances occurring and remedial action is undertaken immediately. A complaints register is also kept on site to enable neighbouring properties to voice their concerns if the facility is having any adverse environmental impact on its surroundings. All environmental monitoring records are available to the public for examination as part of the company's communications programme.

8.7 End markets

8.7.1 Waste permit

On the 28th of August 2001, Barna Waste Ltd. was granted a waste permit by Galway County Council under the powers of the Waste Management Act, 1996. The nature of the activity was specified as the:

“reclamation of land using soil, sub soil, rock, stone and concrete”

There were thirteen conditions attached outlining the company’s responsibilities in respect to the environmental impacts of the activity. With regard to the materials specified for use in the reclamation, the conditions stated that they must be uncontaminated. The permit is valid for three years from the 28th of August 2001 (Appendix E). This provides an existing adjacent end use for uncontaminated inert materials.

8.7.2 Current markets

Currently, all inert construction and demolition waste material delivered to site is weighed and recorded and then depositing on the adjacent site for fill purposes (photograph 8.8). The adjacent site is fully permitted by Galway County Council to accept unlimited inert material to be used as fill for development purposes. Barna Waste Ltd. actively promotes source separation on sites to prevent the delivery of mixed construction and demolition waste to the facility. This is reflected in the costs of accepting mixed construction and demolition waste and source separated construction and demolition waste:

- Mixed construction and demolition waste = €145/tonne

- Source separated timber = €35/tonne
- Source separated metals = €50/tonne
- Source separated inert fill = €5/m³ or approximately €11/tonne

These costs are subject to constant review depending on level of processing used to recover/recycle the waste and the nature of the material being delivered. The type of construction activity will largely determine the costs involved.



Photograph 8.8 Permitted adjacent site being filled with inert material

The recovered clean timber fraction has a current resale value of €18.00 per tonne and is accepted by Scariff Ltd. in Clare where it is used for chipboard manufacture. The recovered metal content is accepted by the Galway Metal Company for recycling charge of €10.00 per tonne.

It can be seen that construction and demolition waste represents a substantial percentage (48 per cent) of the total waste accepted at the facility. Table 8.4 outlines the final destination points for the different waste streams. The quantity of construction and demolition waste being immediately recovered for use as fill on the permitted site amounts to 17 767.54 tonnes, which represents a recovery/reuse percentage of 71 per cent.

Table 8.4 Waste outgoing – 12th February 2001 to 14th May 2002

(adapted from Barna Waste Ltd. on-site waste records)

Description	Quantity in tonnes	Destination
Cardboard	1615.13	Fibre Recycling
Commercial/Domestic	30508.30	Ballinasloe Landfill Site
Construction and Demolition Waste	17767.54	Barna Waste permitted site
Mixed Plastics	713.54	Fibre Fuels
Newspapers	88.10	Fibre Recycling
Metal	717.18	Galway Metal
Timber	400.00	Scariff Engineering
Total	51809.79	

To calculate the total construction and demolition waste outgoing, you need to add the metals and the timber recovered to the recovered construction and demolition waste, i.e.

$$17\,767.54 \text{ tonnes (to permitted site)} + 717.18 \text{ tonnes (metals recovered)} + 400.00 \text{ (recovered timber)} = 18\,884.72 \text{ tonnes}$$

which represents a 74 per cent recovery/recycling rate for the quantity of construction and demolition waste accepted and accounts for 36 per cent of the total waste stream accepted.

8.8 Conclusions

The aim of this chapter was to provide a descriptive overview of the development of the Barna Waste Ltd. Waste Transfer and Recycling Facility. The main conclusions are:

- The Barna Waste Ltd. site has seen significant development since 1993, cumulating in the granting of a waste licence by the EPA in December 2000.
- The facility is in an ideal location, beside a disused landfill (Carrowbrownne Landfill) and in close proximity to the city centre.
- The facility is licensed to accept and handle: household waste (55 500 tonnes p.a.); Commercial and industrial waste (40 500 tonnes p.a.); and construction and demolition waste (30 000 tonnes p.a.).
- The current processing system for construction and demolition waste is operating at 'Level 1-2'. This is in response to the composition and quantity of construction and demolition waste being accepted, i.e. mainly source separated soil and stones. The system has the potential to operate at 'Level 2-3' if so required.
- The environmental impacts are under strict regulation by the EPA through the waste licence. All aspects are addressed, e.g. air, ecology, surface water and foul water, landscape, human beings and odour.

- Barna Waste Ltd. has a fully permitted site adjacent to the recycling facility. This provides a low-level end market, using secondary materials as fill.
- Barna Waste Ltd. is currently recycling/recovering approximately 74 per cent of the delivered construction and demolition waste. This figure is variable depending on the composition and quantity of construction and demolition waste being accepted at any given time.

The development of the Barna Waste Ltd. Waste Transfer and Recycling Facility is comparable to the best practice facilities outlined in Chapter 6. In order to determine if the Barna Waste Facility is operating effectively, a comparison will be made of the four case studies using the best practice indicator checklist. This will also establish if the Barna Waste Facility could be used as a model for the development of the other construction and demolition waste recycling facilities as recommended in the recent Policy Statement, *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002).

Chapter 9 : Assessing the Operational Effectiveness of the Barna Waste Construction and Demolition Waste Recycling Facility

9.1 Introduction

The aim of this chapter is to examine the operational effectiveness of the Barna Waste Ltd. Construction and Demolition Waste Recycling Facility. This will be achieved by:

- Comparing the Barna Waste Ltd. Facility with the three other best practice case studies using the best practice indicator checklist.
- Examining the company's waste management strategy and how it incorporates the recommendations outlined in the *Connaught Waste Management Plan 1999-2004*.

9.2 Comparison with Best Practice Case Studies

Each facility is graded using the best practice indicator checklist. The Copenhagen Recycling Centre will be assessed first followed by the Sysav Facility, the DemCon 20/20 Project and then the Barna Waste Ltd. Facility.

Each facility will be given a total mark and the results will be compared to establish if the Barna Waste Ltd. Facility is comparable to the identified areas of best practice.

9.2.1 Checklist 9.1 Assessment of the Copenhagen Recycling Centre

Condition	Grading	Detail
1. Site Location	3	<ul style="list-style-type: none"> • Appropriate area and access • No residential/commercial areas in immediate surroundings. • Excellent proximity to construction/demolition activities
2. Ownership	2	<ul style="list-style-type: none"> • Public/private partnership between local authorities and private contractors. • No expansion needed as it is a fully licensed 100 ha site which is to be transformed into an amenity area
3. Regulation and enforcement	2	<ul style="list-style-type: none"> • Fully licensed and regulated by EPA. • All of the C&D W produced is processed at the centre.
4. Scope of licensed activities	2	<ul style="list-style-type: none"> • Capable of processing up to 1 million tonnes per annum • Alternative disposal options include landfill and incineration/energy recovery.
5. Accepted materials	3	<ul style="list-style-type: none"> • Processing 600 000 to 800 000 tonnes per annum. • Majority of materials delivered are source separated. • Majority of materials delivered are inert, i.e. concrete, bricks etc.
6. Processing technology	3	<ul style="list-style-type: none"> • System is capable of applying different levels of technology depending on materials. • A quality control system is in operation. • Good experience and training.
7. End markets	3	<ul style="list-style-type: none"> • Good existing markets available. • Research continuing into potential markets. • Published guidance for the reuse of secondary materials.
8. Construction industry	2	<ul style="list-style-type: none"> • Construction industry committed to the recycling/recovery effort. • Regulation of illegal dumping is strict.
9. Charges and fees	3	<ul style="list-style-type: none"> • Appropriate fees encourage recycling/recovery • High landfill charges • Good resale value
Total	23	<ul style="list-style-type: none"> • Indicates that the Copenhagen Recycling Centre is a best practice example of a construction and demolition waste recycling operation

9.2.2 Checklist 9.2 Assessment of the Sysav Waste Management Facility

Condition	Grading	Detail
1. Site Location	3	<ul style="list-style-type: none"> • Appropriate area and access • No residential/commercial areas in immediate surroundings. • Excellent proximity to construction/demolition activities
2. Ownership	2	<ul style="list-style-type: none"> • Public/private partnership between local authorities and private contractors. • No expansion needed as it is a fully site which is to be transformed into an amenity area
3. Regulation and enforcement	2	<ul style="list-style-type: none"> • Fully licensed and regulated by EPA. • High percentage of C& D W is transferred to the Sysav Facility
4. Scope of licensed activities	2	<ul style="list-style-type: none"> • Capable of processing up to 300 000 tonnes per annum. • Alternative disposal options include landfill and incineration/energy recovery.
5. Accepted materials	3	<ul style="list-style-type: none"> • Processing 250 000 tonnes per annum. • Majority of materials delivered are source separated. • Majority of materials delivered are inert, i.e. concrete, bricks etc.
6. Processing technology	3	<ul style="list-style-type: none"> • System is capable of applying different levels of technology depending on materials. • A quality control system is in operation. • Good experience and training.
7. End markets	3	<ul style="list-style-type: none"> • Good existing markets available. • Research continuing into potential markets. • Published guidance for the reuse of secondary materials.
8. Construction industry	2	<ul style="list-style-type: none"> • Construction industry committed to the recycling/recovery effort. • Regulation of illegal dumping is strict.
9. Charges and fees	3	<ul style="list-style-type: none"> • Appropriate fees encourage recycling/recovery • High landfill charges • Good resale value
Total	23	<ul style="list-style-type: none"> • Indicates that the Sysav Facility is a best practice example of a construction and demolition waste recycling operation

9.2.3 Checklist 9.3 Assessment of the DemCon 20/20 Project

Condition	Grading	Detail
1. Site Location	2	<ul style="list-style-type: none"> • Appropriate area and access • Excellent proximity to construction/demolition activities • Some residential/commercial areas in immediate surroundings.
2. Ownership	1	<ul style="list-style-type: none"> • Public/private partnership between local authorities and private contractors. • Public opposition to expansion plans.
3. Regulation and enforcement	2	<ul style="list-style-type: none"> • Fully licensed and regulated by EPA. • All of the C&D W produced is processed at the centre.
4. Scope of licensed activities	1	<ul style="list-style-type: none"> • Capable of processing up to 800 000 tonnes over a 5-year period. • The only alternative disposal option is landfill.
5. Accepted materials	3	<ul style="list-style-type: none"> • Processing 600 000 to 800 000 tonnes over a 5-year period. • Majority of materials delivered are source separated. • Majority of materials delivered are inert, i.e. concrete, bricks etc.
6. Processing technology	3	<ul style="list-style-type: none"> • System is capable of applying different levels of technology depending on materials. • A quality control system is in operation. • Good experience and training.
7. End markets	1	<ul style="list-style-type: none"> • Markets are for low-grade applications, i.e. landfill engineering works and capping layers. • Lack of research into potential markets. • No published guidance for the reuse of secondary materials.
8. Construction industry	0	<ul style="list-style-type: none"> • Lack of commitment from the construction industry. • No effective regulation of illegal dumping
9. Charges and fees	3	<ul style="list-style-type: none"> • Appropriate fees encourage recycling/recovery • High landfill charges • Minimal resale value
Total	16	<ul style="list-style-type: none"> • The main constraints are the lack of markets to divert the secondary materials away from landfill and the lack of regulation of illegal dumping.

9.2.4 Checklist 9.4 Assessment of the Barna Waste Ltd. Recycling Facility

Condition	Grading	Detail
1. Site Location	2	<ul style="list-style-type: none"> • Appropriate area and access • Excellent proximity to construction/demolition activities • Some residential/commercial areas in immediate surroundings.
2. Ownership	1	<ul style="list-style-type: none"> • Private ownership. Lack of co-operation from local authorities. • Public opposition to expansion plans.
3. Regulation and enforcement	2	<ul style="list-style-type: none"> • Fully licensed and regulated by EPA. • Lack of regulation on illegal dumping practices throughout the region.
4. Scope of licensed activities	1	<ul style="list-style-type: none"> • Capable of processing up to 30 000 tonnes. • The only alternative disposal option is landfill.
5. Accepted materials	3	<ul style="list-style-type: none"> • Processing approx. 25 000 to 30 000 tonnes per annum. • Majority of materials delivered are source separated. • The main fractions accepted are the inert fraction, i.e. soil, stones, concrete etc. and the wood fraction.
6. Processing technology	2	<ul style="list-style-type: none"> • System is capable of applying different levels of technology depending on materials. • Good experience and training. • No quality control system in operation.
7. End markets	1	<ul style="list-style-type: none"> • Markets are for low-grade applications, i.e. as fill in permitted sites or in landfill engineering works. • Lack of research into potential markets. • No published guidance for the reuse of secondary materials.
8. Construction industry	0	<ul style="list-style-type: none"> • Lack of commitment from the construction industry. • No effective regulation of illegal dumping
9. Charges and fees	3	<ul style="list-style-type: none"> • Appropriate fees encourage recycling/recovery • High landfill charges • No resale value
Total	15	<ul style="list-style-type: none"> • Lack of regulation of illegal dumping. • No established markets. • Lack of specifications and standards. • Construction industry involvement improving.

9.3 Assessment Results

A summary of the comparisons provides the following results:

- The Copenhagen Recycling Centre with a mark of 23 out of a possible 24 is confirmed as a best practice facility.
- The Sysav Facility with a mark of 23 out of a possible 24 is confirmed as a best practice example.
- The DemCon 20/20 project achieved a mark of 16 out of a possible 24. This is a credible result and confirms it as an excellent model in an Irish context.
- The Barna Waste Facility scored a credible 15 out of a possible 24 to confirm that it is currently operating effectively.

This comparison using the best practice indicator checklist has identified two main areas that the Barna Waste Facility needs to focus on to improve its operational effectiveness:

1. Investigate the implementation of a higher level processing system in co-operation with a quality control system to identify the economic viability of processing construction and demolition waste when there are limited end-markets available.

2. Establish improved working relationships with the construction industry to encourage source separation and the use of secondary materials.

There are a number of constraints, which are outside of the company's control:

1. Public opposition to development plans, which delay the planning process.
2. Lack of regulation of illegal dumping. Higher landfill fees may increase the amount of illegal dumping rather than encourage producers to bring their waste to the recycling facility.
3. There is a lack of alternative disposal options. The Ballinasloe Landfill site is located approximately 60 kms outside of the city centre and provides the only alternative disposal option in the region. Landfill space is at a premium and the authorities are reluctant to accept construction and demolition waste materials.
4. There is a lack of end-uses and/or end-markets. Most of the secondary materials are reused for low-grade applications such as for fill and landfill engineering works.
5. No published guidance on the reuse of secondary materials to encourage engineers/quantity surveyors to specify its use.

These factors need to be tackled by the Government and the local authorities to encourage the development of construction and demolition waste recycling facilities. Another key factor in assessing the operational effectiveness is to examine how the company implements the recommendations outlined in the various policy documents (both European and Irish) and more especially the *Connaught Waste Management Plan 1999-2004*.

9.4 Barna Waste Ltd. Waste Management Strategy

For ease of reference the examination of the Barna Waste Ltd. Waste Management Strategy is illustrated in Table 9.1.

Table 9.1 Examination of the Barna Waste Ltd. Waste Management Strategy

Recommending Body	Recommendation	Barna Waste Ltd. Action
European Commission	Apply the principles of the waste hierarchy	Provides a facility for reuse and recycling.
European Commission	Apply the EU Proximity Principle	The facility is located just 6 km north of Galway City beside a disused landfill site.
European Commission (EU Framework Directives)	Recycling and reuse without endangering human health and harming any part of the environment.	The Barna Waste facility is strictly regulated by the EPA to prevent any adverse environmental impacts to the surrounding areas.
Department of the Environment and Local Government (<i>Changing Our Ways</i> , 1998)	Recycling of at least 50 % of construction and demolition waste by 2003; with a progressive increase to 85% by 2013.	The Barna Waste facility is currently achieving these targets.
<i>Connaught Regional Waste Management Plan 1999-2004</i>	Promotes an integrated approach requiring adequate sorting and access to reprocessing facilities	The Barna Waste facility provides such an integrated approach.
<i>Connaught Regional Waste Management Plan 1999-2004</i>	Recommends the need for a construction and demolition waste recycling facility	The Barna Waste facility meets this need.
<i>Galway Regional Waste Management Strategy Study 1998</i>	Recommends that a construction and demolition waste recycling be constructed immediately in the east or north environs of Galway City	The Barna Waste development was carried out on the basis of this recommendation.

9.5 Conclusions

The aim of this chapter was to assess the operational effectiveness of the Barna Waste Ltd. Construction and Demolition Waste Recycling Facility. This was achieved by:

1. Comparing the Barna Waste Facility with the Copenhagen Recycling Centre, Sysav Waste Management Facility and the DemCon 20/20 Project using the best practice indicator checklist.
2. Examining the company's waste management strategy.

The main conclusions are:

- The operational effectiveness of the Barna Waste Facility is comparable with the identified areas of best practice throughout Ireland and Europe.
- This would imply that the Barna Waste Facility is worthy of being promoted as a model for any future developments of this sort.
- Many of the constraints identified in the assessment fall outside of the control of any individual company. The role of the government and the local authorities is vital to provide the necessary measures to enable a construction and demolition waste recycling facility to operate in a viable manner. The widespread use of

public/private partnerships in Europe may be the key to the integration of these resources to provide this viable framework.

- The assessment demonstrates that the checklist method is appropriate for a range of construction and demolition waste recycling facilities, i.e. large-scale (>100 000 tonnes p.a.) or small-scale (<50 000 tonnes p.a.).

- The company's waste management strategy plays a vital role in establishing good operational procedures for the facility and encourages co-operation from the local authorities.

- The assessment of the Barna Waste Facility identified two areas that were in need of improvement:
 - Establish improved working relationships with the construction industry to encourage on site source separation and the use of secondary materials in low-grade construction applications.

 - Investigate the implementation of alternative processing systems incorporating quality control to identify the economic viability of processing construction and demolition waste when there are limited end-markets available.

The next chapter will examine the implementation of alternative processing systems by identifying which processing system and what level of technology is the most economically viable for the Barna Waste Facility.

Chapter 10 : Examination of the Economic Viability of the Barna Waste Construction and Demolition Waste Recycling Operations

10.1 Introduction

This chapter aims to determine the economic viability of the alternative processing systems available to the Barna Waste Ltd. Recycling Facility. The three levels of processing technology as defined by Symonds *et al.* (1999) are assessed. The aim is to determine which processing system and level of technology is most suitable to the Barna Waste Construction and Demolition Waste Recycling Facility.

10.2 Processing Systems

The different scenarios examined are:

1. Level 1 (low) processing technology, where the use of crushing and sieving plant is used to process inert construction and demolition waste.
2. Level 2 (intermediate) processing technology, where additional metal removal equipment is utilised in addition to more complex sorting and sieving. This is used to process mixed (mainly inert) construction and demolition waste.
3. Level 3 (high) processing technology, where the addition of hand sorting, washing plant and other facilities for different construction and demolition waste streams, e.g. wood are used to process all types of construction and demolition waste.

In each case, a comparison will be made between the processing costs (including capital costs) against the gate charges and/or resale value of any recycled/recovered materials. The following categories will be examined:

- Capital costs
- Operating and maintenance costs
- Charges applied

10.3 Calculation Considerations

A number of parameters are assumed in order to ensure each scenario accurately reflects the current operations at the Barna Waste Ltd. Facility:

- For all the scenarios, the calculations are based on a 5-year payback period on the investment at 240 days a year (48 weeks x 5-day week) for 8 hours per day.
- The cost of the purchase of the land, both of the existing facility and the adjacent site is not included in the capital costs.
- It is taken that all the construction and demolition waste is delivered to the facility, thus excluding transport costs associated with collection services.

- It is assumed that the inert and timber fractions are delivered source separated. The remaining tonnages are delivered in a mixed fraction and it is from this that the metals are recovered.

- The potential output of the facility is set at the maximum possible level, i.e. 30 000 tonnes per annum, which is equal to 150 000 tonnes over the 5-year period.

- The estimated costs for the equipment specific to the processing of construction and demolition waste reflect the actual cost of the plant on site (the majority of the plant and equipment was purchased 'second-hand' and this is reflected in the estimated costs):
 - Extec Stone Crusher: €100 000
 - Erin Fingerscreener FS165: €100 000
 - Manual Picking Station: €150 000
 - Volvo BM L160 Loading Shovel: €60 000
 - Komatsu WA 200-1 Loading Shovel: €35 000
 - Liebherr 932 Track Machine with 5-Type Grab: €90 000
 - Case Porclain 688 €50 000
 - Washing plant €75 000
 - Air Classifier €75 000
 - Timber shredder €50 000

- The estimated capital cost of the construction of the existing facility is taken as €1 500 000⁸. This total is divided by 3 to distinguish between the main operations of the facility, which are:
 - The collection of domestic and commercial waste at the Transfer/Recycling Facility by Barna Waste Ltd. and private refuse collection vehicles, the loading of this waste into ejector trailers to provide for the bulk haul of the waste to the final disposal site (currently the Ballinasloe Landfill site).
 - The deposition and sorting of recyclable waste and household hazardous waste for collection and re-use or safe disposal elsewhere.
 - The treatment of construction and demolition waste and the recovery of soil, crushed stone, ferrous metal and timber.

This results in an estimated capital cost for the development of the construction and demolition waste recycling section of €500 000.

- The current composition of construction and demolition waste entering the facility is based on-site waste records and adapted from Table 8.2. Table 10.1 outlines the assumed composition for the facility operating at full capacity:

⁸ Based on estimated costings prepared by Patrick J. Tobin Consulting Engineers and Co. Ltd.

Table 10.1 Projected quantities estimated over a 5-year period operating at full capacity (based on current percentages being received at the facility)

Waste Type	Current quantities accepted at the facility (tonnes)	Expressed as percentage	Extrapolated over 5 years at 150 000 tonnes capacity (tonnes)
Inert C&D W	17 767.54	70 %	105 000
Timber fraction	400.00	1 %	1 500
Mixed fraction*	7331.08	29 %	43 500
Total	25 498.62	100 %	150 000

* Of this total, 717.18 tonnes was recovered as metals. This is taken to represent approximately 10 per cent of the mixed waste stream.

- It is also assumed that all the waste delivered will be processed using the system under examination, i.e. even if the construction and demolition waste is inert, it will still be processed before being used as fill.
- The transportation costs are estimated in co-operation with Barn Waste management who provided actual transporting costs for disposing of waste to the Ballinasloe Landfill Site. The transportation costs estimated incorporate capital costs of vehicles, salaries of personnel and fuel requirements.
- The financing costs include general administration and maintenance costs. Again these are estimates calculated in co-operation with the Barna Waste Ltd. management staff in order to provide an accurate reflection of actual costs.

10.4 Calculation of Operating Costs

10.4.1 Scenario 1 – ‘Level 1’ technology

This is the use of low-level technology to process inert construction and demolition waste materials. The total operating cost is calculated as follows:

1. Calculate the capital costs

- Capital costs are estimated at €500 000 for the construction of the facility and €250 000 for the plant and equipment (Extec crusher, Volvo BM L160 Loading Shovel and Liebherr 932 Track Machine with 5-Type Grab). This gives a total of €750 000 for capital costs.

2. Determine the potential output

- The facility is licensed is licensed to process 30 000 tonnes of construction and demolition waste per annum. Over a 5-year period, this is equal to 150 000 tonnes or 125 tonnes per day.

3. Calculate the financing costs:

- The financing costs are estimated at €10 000 for general administration and €10 000 for maintenance costs, which is equal to €100 000 over the 5-year period.

4. Calculate the processing costs:
 - The operating cost of processing construction and demolition waste using 'Level 1' technology is equal to €250 000 (capital cost of plant and equipment) x 1/10 000⁹. This is equal to €25.00/hour x 8 hours/day x 240 days/year x 5 years (payback period) = €240 000.

5. Calculate the total operating cost:
 - This implies that the total processing costs (including capital costs) is equal to €1 090 000 over 5 years. This implies that to process 150 000 tonnes of construction and demolition waste using 'Level 1' technology, it would cost **€7.27 per tonne.**

⁹ Symonds *et al.* (1999) reported that over a range of processing equipment, the hourly operating cost amounts to approximately 1/10 000 of the capital costs.

10.4.2 Scenario 2 – ‘Level 2’ technology

This is the use of intermediate technology to process primarily inert construction and demolition waste. More plant and equipment is required, resulting in an increase in the capital costs. The total operating cost is calculated as follows:

1. Calculate the capital costs:

- The capital cost is estimated at €500 000 for the construction of the facility and €435 000 for the plant and equipment (Extec crusher, Komatsu WA 200-1 Loading Shovel , Volvo BM L160 Loading Shovel, Liebherr 932 Track Machine with 5-Type Grab, Timber shredder and Erin Fingerscreener FS165). This gives a total of €935 000 for the capital costs.

2. Determine the potential output

- The output is the same for scenario 1, i.e. 125 tonnes/day giving a total of 150 000 tonnes for the 5-year period.

3. Calculate the financing costs:

- The financing costs will increase due to the higher maintenance for the processing plant and equipment, i.e. €10 000 for administration and €15 000 for maintenance, giving a total of €25 000 per annum or €125 000 for the 5 years.

4. Calculate the processing costs:

- The operating cost of processing construction and demolition waste using 'Level 2' technology is equal to €435 000 (capital cost of plant and equipment) x 1/10 000. This is equal to €43.50/hour x 8 hours/day x 240 days/year x 5 years (payback period) = €417 600.

5. Calculate the total operating costs

- This implies that the total processing costs (including capital costs) is equal to €1 477 600 over 5 years. This implies that to process 150 000 tonnes of construction and demolition waste using 'Level 2' technology, it would cost **€9.85 per tonne.**

10.4.3 Scenario 3 – ‘Level 3’ technology

This is the use of high-level technology to process mixed construction and demolition waste. An extension to the existing facility would be required in addition to supplementary plant and equipment. The total operating costs is calculated as follows:

1. Calculate the capital costs:

- The capital cost is estimated at €500 000 for the construction of the facility plus €100 000 for the required extension (roof cover) giving a total of €600 000. This is added to the capital cost of the plant and equipment which is equal to €785 000 and includes the Extec crusher, Volvo BM L160 Loading Shovel, Case Porclain 688 with grab attachment, Erin Fingerscreener FS165, Manual Picking Station, Timber Shredder, Komatsu WA 200-1 Loading Shovel, Washing plant, Air classifier and the Liebherr 932 Track Machine with 5-Type Grab. This gives a total of €1 385 000 for the capital costs.

2. Determine the potential output:

- The output is the same for scenario 1 and 2, i.e. 150 000 tonnes over 5 years.

3. Calculate the financing costs:

- The financing costs will increase due to the increased maintenance of the additional plant and machinery, i.e. €40 000 per annum over 5 years is equal to €200 000.

4. Calculate the processing costs:

- The operating cost of processing construction and demolition waste using 'Level 3' technology is equal to €785 000 (capital cost of plant and equipment) x 1/10 000. This is equal to €78.50/hour x 8 hours/day x 240 days/year x 5 years (payback period) = €753 600.

5. Calculate the total operating cost:

- This implies that the total processing costs (including capital costs) is equal to €2 338 600 over 5 years. This implies that to process 150 000 tonnes of construction and demolition waste using 'Level 3' technology, it would cost **€15.60 per tonne**.

From these calculations it can be concluded that the total operating cost for the following technologies are:

- 'Level 1' technology = €7.27 per tonne
- 'Level 2' technology = €9.85 per tonne
- 'Level 3' technology = €15.60 per tonne

The next objective is to compare these costs with the fees charged and any resale value from the processed materials.

10.5 Calculation of Potential Profit Margins

The following are the gate charges currently in operation for accepting construction and demolition waste delivered to the Barna Waste Facility:

- Inert construction and demolition waste materials: € 11.00 per tonne
- Source separated timber waste: € 35.00 per tonne
- Source separated metals: € 50.00 per tonne
- Mixed construction and demolition waste: €145.00 per tonne

Other charges relevant to the facility are:

- Ballinasloe Landfill charges €136.00 per tonne
- Recycling metals charges € 10.00 per tonne

The current resale value of the processing materials is:

- Processed clean timber resale value €18.00 per tonne

To illustrate the economic viability three scenarios will be investigated using the three levels of technology. In each case the following composition will apply:

- 70.0 per cent inert fraction = 105 000 tonnes
- 29.0 per cent mixed fraction = 43 500 tonnes*
- 1.0 per cent wood fraction = 1 500 tonnes

** 10 per cent of this total is recovered metals, i.e. 4 350 tonnes.*

10.5.1 Scenario 1 using 'Level 1' technology

The potential profit margin for scenario 1 is calculated by comparing the costs of processing and disposal with the fees charged and any resale value of processed materials.

This is calculated as follows:

1. Calculate the processing cost:

$$150\,000 \text{ tonnes} \times \text{€}7.27(\text{operating cost}) = \text{€}1\,090\,500$$

2. Calculate the cost of disposal including transportation costs:

- 'Level 1' technology is unable to process the delivered source separated timber fraction or recover any of the metal content from the mixed fraction, which implies:

$$43\,500 \text{ tonnes (mixed fraction)} + 1\,500 \text{ (timber fraction)} = 45\,000 \text{ tonnes}$$

$$\text{€}136 \text{ per tonne (landfill fee)} = \text{€}6\,120\,000.$$

- The transportation cost¹⁰ is calculated as follows:

$$45\,000/22 = 2045.5 \text{ loads} \times \text{€}132 \text{ per load} = \text{€}270\,006.$$

- The total cost of disposal including transportation costs is equal to:

$$\text{€}6\,120\,000 + \text{€}270\,006 = \text{€}6\,390\,006.$$

- The total cost of processing and disposal is equal to:

$$\text{€}6\,390\,006 + \text{€}1\,090\,500 = \text{€}7\,480\,506.$$

¹⁰ The transportation costs were estimated at 22 tonnes per load for a 120km round-trip. For 45 000 tonnes, this is equal to 2045.5 deliveries to the landfill at a cost (including capital costs, fuel, labour) of €132 per load.

3. The fees charged would amount to:

- *105 000 tonnes (inert fraction) x €11 = €1 155 000*
- *43 500 tonnes (mixed fraction) x €145 = €6 307 500*
- *1 500 tonnes (timber fraction) x €35 = € 52 000*

This gives a total of €7 515 000

6. The profit margin is calculated by;

€7 515 000 (fees) - €7 480 506 (cost of processing and disposal) = €34 494 which represents a profit margin of €0.23 per tonne (€34 494/150 000 tonnes).

10.5.2 Scenario 2 using 'Level 2' technology

The potential profit margin for scenario 2 is calculated by comparing the costs of processing and disposal with the fees charged and resale value of processed materials. This is calculated as follows:

1. Calculate the processing cost:

$$150\,000 \text{ tonnes} \times \text{€}9.85(\text{operating cost}) = \text{€}1\,477\,500$$

2. Calculate the cost of disposal including transportation costs:

- 'Level 2' technology will process the delivered source separated timber fraction and will recover approximately 10 per cent (4 350 tonnes) of the metal content from the mixed fraction, which implies:

$$43\,500 \text{ tonnes (mixed fraction)} - 4\,350 \text{ (recovered metal fraction)} = 39\,150 \text{ tonnes} \times \text{€}136 \text{ per tonne (landfill fee)} = \text{€}5\,324\,400.$$

- The transportation costs¹¹ is calculated as follows:

$$39\,150/22 = 1780 \text{ loads} \times \text{€}132 \text{ per load} = \text{€}234\,900.$$

- The recovery of the 4 350 tonnes of metal would incur a recycling charge when sent to the metal recycling facility:

$$4\,350 \text{ tonnes} \times \text{€}10 \text{ (recycling charge)} = \text{€}43\,500$$

¹¹ The transportation costs were estimated at 22 tonnes per load for a 120km round-trip. For 39 150 tonnes, this is equal to 1780 deliveries to the landfill at a cost (including capital costs, fuel, labour) of €132 per load.

- The total cost of disposal including transportation costs and recycling charges is equal to:

$$€5\,324\,400 + €234\,900 + €43\,500 = €5\,602\,800.$$

- The total cost of processing and disposal is equal to:

$$€5\,602\,800 + €1\,477\,500 = €7\,080\,300.$$

3. The fees charged would amount to:

- 105 000 tonnes (inert fraction) x €11 = €1 155 000
- 43 500 tonnes (mixed fraction) x €145 = €6 307 500
- 1 500 tonnes (timber fraction) x €35 = €52 500

This gives a total of €7 515 000

4. The resale value of the processed clean timber is as follows:

$$1\,500\text{ tonnes} \times €18\text{ per tonne} = €27\,000\text{ giving an overall total of }€7\,542\,000.$$

5. The profit margin is calculated by:

$$€7\,542\,000\text{ (fees + resale value)} - €7\,080\,300\text{ (cost of processing and disposal)} = €461\,700\text{ which represents a profit margin of }€3.08\text{ per tonne (€461 700/150 000 tonnes).}$$

10.5.3 'Level 3' technology

The potential profit margin for scenario 3 is calculated by comparing the costs of processing and disposal with the fees charged and resale value of processed materials. This is calculated as follows:

1. Calculate the processing cost:

$$150\,000 \text{ tonnes} \times \text{€}15.60 \text{ (operating cost)} = \text{€}2\,340\,000.$$

2. Calculate the cost of disposal including transportation costs:

- 'Level 3' technology will process the delivered source separated timber fraction and will recover approximately 20 per cent¹² (8 700 tonnes) of the metal content from the mixed fraction, which implies:

$$43\,500 \text{ tonnes (mixed fraction)} - 8\,700 \text{ (recovered metal fraction)} = 34\,800 \text{ tonnes} \times \text{€}136 \text{ per tonne (landfill fee)} = \text{€}4\,732\,800.$$

- The transportation costs¹³ are calculated as follows:

$$34\,800/22 = 1582 \text{ loads} \times \text{€}132 \text{ per load} = \text{€}208\,800.$$

- The recovery of the 8 700 tonnes of metal would incur a recycling fee when sent to the metal recycling facility:

$$8\,700 \text{ tonnes} \times \text{€}10 \text{ (recycling charge)} = \text{€}87\,000$$

¹² The addition of the extra plant and equipment will increase the capacity of the system to recover more materials from the mixed fraction, especially metals.

¹³ The transportation costs were estimated at 22 tonnes per load for a 120km round-trip. For 34 800 tonnes, this is equal to 1582 deliveries to the landfill at a cost (including capital costs, fuel, labour) of €132 per load.

- The total cost of disposal including transportation costs and recycling charges is equal to:

$$€4\,732\,800 + €208\,800 + €87\,000 = €5\,028\,600$$

- The total cost of processing and disposal is equal to:

$$€2\,340\,000 + €5\,028\,600 = €7\,368\,600.$$

3. The fees charged would amount to:

- *105 000 tonnes (inert fraction) x €11 = €1 155 000*
- *43 500 tonnes (mixed fraction) x €145 = €6 307 500*
- *1 500 tonnes (timber fraction) x €35 = € 52 500*

This gives a total of €7 515 000

4. The resale value of the processed clean timber is as follows:

$$1\,500\text{ tonnes} \times €18\text{ per tonne} = €27\,000\text{ giving an overall total of }€7\,542\,000.$$

5. The profit margin is calculated by;

$$€7\,542\,000\text{ (fees + resale value)} - €7\,368\,600\text{ (cost of processing and disposal)} =$$
$$€173\,400\text{ which represents a profit margin of }€1.16\text{ per tonne (€173 400/150 000}$$

tonnes).

10.6 Calculation Results

A comparison of the estimated profit margins gives the following results:

- Scenario 1 using 'Level 1' technology = a profit of €0.23 per tonne
- Scenario 2 using 'Level 2' technology = a profit of €3.08 per tonne
- Scenario 3 using 'Level 3' technology = a profit of €1.16 per tonne

The calculations show that 'Level 2' technology is currently the most appropriate and economically viable processing technology for the Barna Waste Ltd. Facility considering its projected quantities and composition.

The following points should be noted in respect of the above results:

- The estimates involved in calculating the transportation costs and financing costs are not based on any previous research findings. They were estimated in consultation with the management staff at the Barna Waste Ltd. Facility, so can be only taken as 'best guess' figures.
- The calculations are based on four components of the construction and demolition waste stream, i.e. inert fraction, wood fraction, mixed fraction and the metal fraction. No account is taken of other materials such as plastics, cardboard, glass etc. that could be possibly recovered using 'Level 3' technology. This is because the current estimates of the composition of construction and demolition waste being accepted at the facility only addresses the four fractions examined.

- The appropriate processing system is dependent on the composition and quantity of the construction and demolition waste stream being delivered to the facility, i.e. if the percentage of mixed construction and demolition waste were to rise, this would decrease (or eliminate) the profit margins for 'Level 1' technology because it would not be able to process this material, thus increasing disposal fees and encouraging the use of a higher level of technology.

10.7 Conclusions

The main aim of this chapter was to examine the economic viability of three alternative processing systems suitable for the processing of construction and demolition waste. This was achieved by:

- Calculating the total operating costs for each of the processing systems.
- Calculating the potential profit margins for each processing system by comparing the costs with the revenue.

The main conclusions are:

- The more intensive the processing system the higher the cost.
- It is essential to have the appropriate processing system for quantity and composition of waste to be accepted.
- The economic viability is dependent of two main factors:
 - The facility and processing system must be operating at full capacity.
 - The percentage of source separated construction and demolition waste materials need to be high.
- The Barna Waste Ltd. Construction and Demolition Waste Facility is currently economically viable due to the composition and quantity of materials being accepted.

- The modular nature of the processing system in operation at the Barna Waste Ltd. Facility provides an advantage over competitors as it can adapt the system to process the different fractions of construction and demolition waste as required.
- A more in-depth investigation of the economic viability of processing operations throughout Europe could lead to the establishment of best practice performance criteria.

The next chapter will outline the main conclusions and recommendations arising out of this study.

Chapter 11 : Conclusions and Recommendations

11.1 Introduction

To clearly set out the conclusions and recommendations for this thesis each objective will be addressed individually outlining the relevant conclusions. Some limitations and recommendations are also outlined.

The main aim of this project was to examine the development of a construction and demolition waste recycling facility in the Galway region with a view to establishing:

1. A list of best practice criteria for the development of construction and demolition waste recycling facilities.
2. The economic viability of a construction and demolition waste recycling operation.

11.2 Objectives

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

1. Identify the various definitions, legislation and policy actions specifically related to construction and demolition waste management.
2. Determine the characteristics of the construction and demolition waste stream.
3. Examine previous research carried out in assessing the potential of construction and demolition waste materials for recycling and/or reuse.

4. Examine the design criteria and equipment choices available for the development of construction and demolition waste recycling facilities.
5. Identify areas of best practice and evaluate them to establish best practice criteria.
6. Examine the development of the Barna Waste Facility and compare it with best practice facilities.
7. Examine the economic viability of the existing and potential operations being carried out at the Barna Waste Facility.

11.3 Conclusions

Objective No. 1

- Identify the various definitions, legislation and policy actions specifically related to construction and demolition waste management.

This was achieved by examining the development of construction and demolition waste definitions, regulations, legislation and policy actions from an international, European, national and regional perspective.

Conclusions

- There has been a considerable influx of environmental documentation into Ireland over the past decade, which has provided the necessary regulatory framework for the management of the construction and demolition waste stream.
- The targets set out in the policy statement '*Changing Our Ways*' (DoELG, 1998) provide an ambitious goal for the construction industry.
- The Irish construction industry is beginning to realise its responsibilities and is aiming to implement a voluntary industry programme to meet the Government's objectives for the recovery/recycling of construction and demolition waste as set out in the Policy Statement, '*Changing Our Ways*' (DoELG, 1998).

Objective No. 2

- Determine the characteristics of the construction and demolition waste stream.

This was achieved by investigated the nature, source, composition and the quantities of construction and demolition waste being produced each year.

Conclusions

- The nature and composition of the construction and demolition waste is variable and is almost entirely dependent on the type of construction/demolition activity.
- The estimated quantities illustrate the extent of the problem facing the construction industry throughout Europe, i.e. approximately 180 million tonnes of 'core' construction and demolition waste produced each year.

Objective No. 3

- Examination of previous research carried out in assessing the potential of construction and demolition waste materials for recycling and/or reuse.

This was achieved by investigating research carried out during the post-war period (1945-1960) through the 1970s, 1980s, 1990s, up to the present day. The investigation concentrated on research from the USA, Japan, Australia and Europe.

Conclusions

- The recycling and/or reuse of construction and demolition waste materials is not a new concept, as there is evidence of extensive reuse/recycling of secondary material in post-war Germany and the U.K.
- The most frequently used applications are for low-grade applications, i.e. general fill, drainage material, lightly trafficked concrete pavement etc.
- The inert fraction of the construction and demolition waste stream has in theory the potential to be fully recovered and reused. This would imply that an estimated 90 per cent of the current construction and demolition waste stream in Ireland is potentially fully recoverable.

Objective No. 4

- Examine the design criteria and equipment choices available for the development of construction and demolition waste recycling facilities.

Conclusions

- The main design factors to be considered at inception stage are: site location; proper equipment; experience in construction and demolition waste operations; trained staff; knowledge of end-markets; business/financial capacity; and knowledge of environmental and safety regulations.
- The processing system is largely determined by the composition and the quantities of materials being accepted at the facility.
- There are primarily three distinct levels of processing technology available. The application of the different levels of technology is dependent on the economic viability of their use and the potential end uses.

Objective No. 5

- Evaluate best practice facilities to establish a set of best practice indicators

Conclusions

- The examination of the case studies identified a number of conditions that are common to each of the best practice facilities, namely:
 - Site Location
 - Scope of licensed activities
 - Processing systems
 - Environmental impacts
 - End-markets
- Each case study demonstrated that construction and demolition waste recycling facilities are an essential component in the successful implementation of regional waste management strategies.
- The establishment of best practice indicators provide a useful tool for developers to examine the development and/or operational effectiveness of a proposed or existing facility.
- The simplicity of the grading system in a checklist format provides a user-friendly and practical design for the assessment of a proposed development or the evaluation of operational effectiveness of an existing facility.

Objective No. 6

- Examine the development of the Barna Waste Ltd. Facility and evaluate its operational effectiveness.

Conclusions

- The development of the Barna Waste Ltd. Facility is comparable to the three case studies identified in Chapter 6.
- The Barna Waste Ltd. Facility scored a 15 out of a possible 24 using the 'Best Practice Indicator Checklist'. This would indicate that the facility is operating efficiently.
- Many of the constraints identified in the assessment fall outside the control of any individual company, i.e. illegal dumping regulation.
- Two areas were identified where the facility could improve its operations:
 - Improve working relationships with the construction industry to encourage source separation on site and promote the use of secondary material for use as low-level applications in construction works.
 - Investigate the implementation of alternative processing systems incorporating quality control to identify the economic viability of processing construction and demolition waste for limited end markets.

Objective No. 7

- Examine the viability of alternative processing systems proposed for the Barna Waste Ltd. Facility.

Conclusions

- The higher the level of processing the higher the cost to the facility.
- It is essential to have a processing system appropriate to the throughput of materials, i.e. there is no point in having a 'Level 3' system if the facility is only processing inert construction and demolition waste materials.
- The economic viability is dependent on two main factors:
 - The processing system must be operating at or near full capacity.
 - The percentage of source separated construction and demolition waste material need to be high.
- The Barna Waste Ltd. Construction and Demolition Waste Recycling Facility is currently operating efficiently and is economically viable due to the fact that the two factors mentioned above are prevalent.

11.4 Limitations

Each of the conclusions must be evaluated considering the limitations of the research. The following limitations apply:

1. The lack of statistical data available on the production of construction and demolition waste does not provide an accurate reflection of the extent of the problem in Ireland.
2. The list of conditions that form the best practice indicator checklist is not a definitive one. There are a number of variables involved including the geographical location of the facility, e.g. Denmark and Sweden have a successful waste management framework in place for the past ten years whereas Ireland is just beginning to implement its strategy.
3. The calculation of the total operating costs and potential profit margins is based on a number of assumptions, i.e. estimation of transportation cost and processing costs. These assumed estimates are likely to fluctuate in a 'real' situation, affecting the results.
4. The methodology would have benefited from the use of structured interviews in the evaluation of the best practice case studies.

11.5 Recommendations

1. The establishment of a practical waste audit methodology to accurately report on the annual production of construction and demolition waste materials. This was identified early in the study and subsequently formed the basis of a successful application to the Environmental Protection Agency under the Environmental RTDI Programme 2000-2006 by the Department of Building and Civil Engineering at the Galway-Mayo Institute of Technology.
2. Further research is required to establish a definitive list of best practice indicators to produce a two separate sets of criteria:
 - a. For the initial development of a construction and demolition waste recycling facility; and
 - b. For the operation of a construction and demolition waste recycling facility.
3. The use of best practice indicators could be developed into the establishment of best practice performance indicators. These would be based on the study of existing construction and demolition waste recycling facilities over a specified time-frame, i.e. 2-3 years.

11.6 Summary

This study has examined the development of the Barna Waste Ltd. Construction and Demolition Waste Recycling Facility and concludes that it is currently operating efficiently but there is room for improvement. It is recommended that this facility could be used as a model for the proposed eighteen construction and demolition waste recycling facilities to be constructed across the country as outlined in the recent policy statement *Preventing and Recycling Waste – Delivering Change* (DoELG, 2002).

The two significant contributions to knowledge in this area are:

1. The establishment of a list of best practice indicators for interested parties.
2. The economic and operational assessment of a newly constructed facility to demonstrate the feasibility of such operations.

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APPENDICES

APPENDIX A

European Waste Catalogue and Hazardous Waste List 2002

Section 17 - Construction and Demolition Waste

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

- 17 01 concrete, brick, 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 01 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 in 17 05 05
- 17 05 07* track ballast containing dangerous substances
- 17 05 08 track ballast other than those mentioned in 17 05 07
- 17 06** **insulation materials and asbestos-containing construction materials**
- 17 06 01* insulation materials containing asbestos
- 17 06 03* other insulation materials consisting of or containing dangerous substances
- 17 06 04 insulation materials other than those mentioned in 17 06 01 and 17 06 03
- 17 06 05* construction materials containing asbestos
- 17 08** **gypsum-based construction material**
- 17 08 01* gypsum-based construction materials contaminated with dangerous substances
- 17 08 02 gypsum-based construction materials other than those mentioned in 17 08 01
- 17 09** **other construction and demolition waste**
- 17 09 01* construction and demolition wastes containing mercury
- 17 09 02* construction and demolition wastes containing pcb (for example pcb-containing sealants, pcb-containing resin-based flooring, pcb-containing sealed glazing units, pcb-containing capacitors)
- 17 09 03* other construction and demolition wastes (including mixed wastes) containing dangerous substances
- 17 09 04 mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03

** indicates hazardous materials*

APPENDIX B

Waste Catalogue and Hazardous Waste List 1996

Section 17 – Construction and Demolition Waste

17 00 00 Construction and demolition waste (including road construction)

17 01 00 Concrete, bricks, tiles, ceramics and gypsum-based materials

- 17 01 01 Concrete
- 17 01 02 Bricks
- 17 01 03 Tiles and ceramics
- 17 01 04 Gypsum-based construction materials
- 17 01 05 Asbestos-based construction materials

17 02 00 Wood, glass and plastic

- 17 02 01 Wood
- 17 02 02 Glass
- 17 02 03 Plastic

17 03 00 Asphalt, tar and tarred products

- 17 03 01 Asphalt containing tar
- 17 03 02 Asphalt (not containing tar)
- 17 03 03 Tar and tar products

17 04 00 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 08 Cables

17 05 00 Soil and dredging spoil

- 17 05 01 Soil and stones
- 17 05 02 Dredging spoil

<u>17 06 00</u>	<u>Insulation materials</u>
17 06 01*	Insulation materials containing asbestos
17 06 02	Other insulation materials
<u>17 07 00</u>	<u>Mixed construction and demolition waste</u>
17 07 01	Mixed construction and demolition waste

*Indicates hazardous materials.

APPENDIX C

Box C.1 – Key European Enactments

Box C.1 Relevant European and Domestic Waste Legislation

European Legislation

- 1975 Council Directive on the Disposal of Waste Oils (75/439/EEC);
- 1975 Council Directive on Waste (75/442/EEC);
- 1976 Council Directive on the Disposal of Polychlorinated Biphenyls and Polychlorinated Terphenyls (PCB/PCT) (76/403/EC);
- 1985 Council Directive on Containers of Liquids for Human Consumption (85/339/EEC);
- 1986 Council Directive on the Protection of the Environment when Sewage Sludge is Used in Agriculture (86/278/EEC);
- 1987 Council Directive on the Prevention and Reduction of Environmental Pollution by Asbestos (87/217/EEC);
- 1991 Council Directive on Waste (91/156/EEC)
- 1991 Council Directive on Hazardous Waste (91/689/EEC);
- 1993 Commission Directive on Batteries and Accumulators Containing Certain Dangerous Substances (93/86/EEC);
- 1993 Council Regulation (EC) No. 259/93 of 1 February 1993 on the shipment of waste within, into and out of the European Community;
- 1993 Commission Decision on a list of Wastes (94/3/EC);
- 1994 Commission Decision on Questionnaires on Reports on Directive in the Waste Sector (94/741/EC);
- 1994 Commission Decision on the Standard Consignment Note Referred to in Council Regulation (EEC) No. 259/93 on Shipment of Waste (94/774/EC);
- 1994 European Parliament and Council Directive on Packaging and Packaging Waste (94/62/EC);
- 1994 Council Directive on the Incineration of Hazardous Waste (94/67/EC);
- 1994 Council Directive on a List of Hazardous Waste (94/904/EC);
- 1996 Council Directive on the Disposal of Polychlorinated Biphenyls and Polychlorinated Terphenyls (PCB/PCT) (96/59/EC);
- 1996 Council Directive Concerning Integrated Pollution Prevention and Control (96/61/EC);
- 1996 Commission Decision Establishing a Format for Information under Article 8(3), Council Directive 91/689/EEC on Hazardous Waste (96/302/EC).

- 1997 Commission Decision Establishing the Identification System for Packaging Materials (97/138/EC);
- 1997 Commission Decision Establishing Formats Relating to the Database System pursuant to European Parliament and Council Directive 94/62/EC on Packaging and Packaging Waste (97/138/EC);
- 1997 Commission Decision on Harmonised Measurement Methods in Determining the Mass Concentration of Dioxins and Furans in Atmosphere Emissions (97/283/EC);
- 1998 Commission Decision on a Questionnaire for Council Directive 94/67/EC on the Incineration of Hazardous Waste (98/184/EC);
- 1999 Council Directive on the Landfill of Waste (93/31/EC);
- 1999 Commission Decision on Derogations for Plastic Crates and Pallets from Directive 94/31/EC).

Domestic Legislation

Acts

Air Pollution Act, 1987;
Environmental Protection Agency Act, 1992;
Dumping at Sea Act, 1996;
Waste Management Act, 1996;
Litter Act, 1997.

Regulations

Air Pollution Act, 1987 (Municipal Waste Incineration) Regulations, 1992 SI 347 of 1992;
The Waste Management (Licensing) Regulations, 1997 SI No 133 of 1997;
The Waste Management (Planning) Regulations, 1997 SI No 137 of 1997;
The Waste Management (Register) Regulations, 1997 SI No 183 of 1997;
The Waste Management (Packaging) Regulations, 1997 SI No 242 of 1997;
The Waste Management (Farm Plastics) Regulations, 1997 SI No 315 of 1997;
The Waste Management (Amendment of the Waste Management Act, 1996) Regulations, 1998 SI No 146 of 1998;
The Waste Management (Movement of Hazardous Waste) Regulations, 1998 SI No 147 of 1998;
The Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 SI No 148 of 1998;
The Waste Management (Transfrontier Shipment of Waste) Regulations, 1998 SI No 149 of 1998;
The Waste Management (Licensing) (Amendment) Regulations, 1998 SI No 162 of 1998;
The Waste Management (Hazardous Waste) Regulations, 1998 SI No 163 of 1998;
The Waste Management (Miscellaneous Provisions) Regulations, 1998 SI No 164 of 1998;
The Waste Management (Permit) Regulations, 1998 SI No 165 of 1998;
The European Communities (Amendment of Waste Management Act, 1996) Regulations, 1998 SI No 166 of 1998;
The European Communities (Licensing of Incinerators of Hazardous Waste) Regulations, 1998 SI No 64 of 1998;
The Waste Management (Water Pollution) (Nutrient Management Planning Consultation) Regulations, 1998 SI No 257 of 1998;
The Waste Management (Packaging) (Amendment) Regulations, 1998 SI No 382 of 1998.

APPENDIX D

Table D.1 - Summary of Waste Flow Information and Landfilling Information Reported by Local Authorities for Construction and Demolition Waste (tonnes) in their functional area (FA).

**Table D.1 Summary of Waste Flow Information and Landfilling Information
Reported by Local Authorities for Construction and Demolition Waste (tonnes) in
their functional area (FA).**

Local Authority	Arising in FA	Imported into FA	Exported from FA	Managed within FA	Reported Landfilled in FA
Carlow County Council	30 000	0	0	30 000	0
Cavan County Council	30 178	0	0	472	472
Clare County Council	200	0	0	200	0
Cork Corporation	218 880	21 425	83 838	302 718	240 000
Cork County Council	312 667	43 666	11 159	345 174	183 854
Donegal County Council	0	0	0	0	1 900
Dublin Corporation	614 745	0	0	0	0
Dun Laoghaire-Rathdown County Council	201 677	200 000	80 000	401 677	245 673
Fingal County Council	195 566	962 881	0	1 158 437	1 091 119
Galway Corporation	0	0	0	0	0
Galway County Council	0	0	0	0	1 050
Kerry County Council	40 000	0	0	40 000	25 000
Kildare County Council	0	0	0	0	250 100
Kilkenny County Council & Corporation	32 400	0	0	32 400	647
Leitrim County Council	0	0	0	0	0
Limerick Corporation	50 000	0	50 000	0	0
Limerick County Council	0	0	0	0	0
Longford County Council	260	0	0	0	0
Louth County Council	52 534	7 411	0	59 945	67 049
Mayo County Council	0	0	0	0	2 500
Meath County Council	10 270	0	0	10 270	4 500
Monaghan County Council	54 649	0	0	179	172
Offaly County Council	1 000	0	0	1 000	622
Roscommon County Council	13 300	0	0	13 300	0
Sligo County Council	60 000	0	0	60 000	0
South Dublin County Council	0	0	0	0	0
Tipperary County Council (NR)	0	0	0	0	0
Tipperary County Council (SR)	32 470	0	0	32 470	900
Waterford Corporation	27 200	0	0	27 200	0
Waterford County Council	0	0	0	0	32 832
Westmeath County Council	4 800	0	0	4 800	4 800
Wexford County Council	7 000	0	0	7 000	4 800
Wicklow County Council	72 000	0	0	0	541 000
TOTAL	2 092 564	1 235 383	224 997	2 558 010	2 704 958

Source: National Waste Database Report 1998 (EPA, 2000)

APPENDIX E

Barna Waste Ltd. Waste Permit

COMHARILE CHONTAE NA GAILLIMHE

WASTE MANAGEMENT ACT 1996

WASTE PERMIT

Barna Waste Ltd.,
Derryloughane,
Spiddal,
Co. Galway

Ref No: **WR/22**

Galway County Council in exercise of the powers conferred on it by the Waste Management Act, 1996 as amended by the European Communities (Amendment of Waste Management Act, 1996) Regulations 1998, **hereby grants a Waste Permit under the Waste Management (Permit) Regulations 1998.**

Nature of activity: **reclamation of land using soil, sub soil, rock, stone and concrete.**

Location of the facility: Carrowbrowne,
Headford Road,
Co. Galway.

The Waste Permit is issued subject to the conditions set out in the attached Schedule.

Signed this 28 day of August, 2001 on behalf of Galway County Council.

DIRECTOR OF SERVICES