Implementing a site waste management plan - A case study of a medium sized building contractor in Ireland.

Jan Göttsche

Supervisor: Dr. Mark Kelly

A Dissertation Submitted in Partial Fulfilment of the Masters in Environmental Systems.

Galway – Mayo Institute of Technology.

2011/2012

Plagiarism Declaration – September 2012

I, Jan Göttsche, declare that this thesis is an original work carried out by the author with due reference and acknowledgements given where necessary towards the work of others. No part of this thesis has previously been accepted for any degree and is not concurrently submitted for any other award. I declare that the work contained in this thesis is my original work unless otherwise stated. All information including tables and diagrams which is copied from or based on the work of others has its source clearly acknowledged in the text and its reference clearly outlined at the end of the document.

Signature: ______________________________ Date: _____________

This thesis has been printed on 100% recyclable paper.
The paper is FSC certified, carries the EU Ecolabel as
well as having ISO 9001 and ISO 14001 certification.

Abstract

Construction and demolition waste management is becoming increasingly important on construction sites as landfill space in Ireland is rapidly depleting and waste management costs are rising. Due to these factors waste management plans are seen as a good response to minimising waste on site and this thesis aims to investigate how to implement such a plan on a practical case study as well as investigating the legislation regarding construction and demolition waste along with market availability for the reuse of the waste. Main contractor surveys were also carried out in order to gain a better understanding of current attitudes within the industry and these surveys are analysed in chapter five. A survey was also carried out among sub-contractors but this survey has not been used for this thesis as the study is on-going.

The primary aim of this thesis is to examine the waste hierarchy opportunities that are available for construction and demolition waste in Ireland and to examine the effects of management strategies on construction and demolition waste reduction at the project level. A partnership was developed with Carey Developments Ltd in Co. Galway and an analysis of their waste management practices was undertaken. The primary case study will be the 'Taylors Hill' project in Co. Galway where work commenced in March, 2012. The secondary aim of the thesis is to develop specific waste minimisation strategies for the company and to develop a training tool kit for use on site.

This thesis concentrates on the possible waste management strategies which a company can use to successfully implement good practice waste management. The initial research found that the construction and demolition waste topic is a worldwide issue with research being compiled constantly in order to help contractors implement successful waste management strategies. The initial stage of research involved a review of the legislation, theories and studies related to construction and demolition waste management. This research revealed that while good practice waste management is challenging, it is an achievable goal.

Both primary and secondary research was carried out during this study. The research strategy comprises the collection of secondary and primary information on the issues and solutions to waste management in Ireland and a practical application through the case

study. In order to further develop arguments some of the findings from the questionnaire are woven into each chapter and discussed where relevant. The secondary research forms part of the literature review and the primary research focuses on the Carey Developments case study and the questionnaire. With the aid of both methods of research the thesis hypothesis will be investigated. The thesis will be considered successful if the author can help to implement waste management practices and develop a learning toolkit for Carey Developments. The literature review in the first chapter describes the secondary research that was carried out for this thesis. Secondary data was collected for the literature review in order to obtain an understanding of the current legislation and practices of waste management in Ireland. Following this the author could identify where the problems are occurring and work towards providing answers to these problems.

Questionnaires, a case study and a literature review were carried out and from this it was possible to gain an awareness of the attitudes and opinions in relation to construction and demolition waste management in Ireland. Results stemming from the research were analysed to give a snapshot insight into the waste management practices on site and also how the implementation of a waste management plan should be approached.

The use of a questionnaire provided a good insight into the current attitudes of main contractors towards waste management in Ireland. It was found that there is a lack of training and knowledge within the industry as the majority of the respondents had received no training in relation to waste management. The majority of respondents also believed that a lack of training and knowledge of waste management is a problem within the industry. The barriers to waste management were found to be; poorly defined responsibilities, waste management is not a goal of the main stakeholders and the lack of waste management policy was preventing companies from implementing waste reduction measures. The majority of respondents believe that waste prevention and minimisation will be a major issue for the construction industry in the future and that there are currently financial rewards to be gained from minimising, preventing and recycling waste. Through the use of the questionnaire and the case study an insight into the current practices and attitudes within the industry has been gained.

The case study for this thesis was seen as a good opportunity to develop an insight into the realities of the treatment of construction waste on construction sites in Ireland. From the observations made on the case study and the research carried out as part of the thesis it is clear that waste minimisation can be carried out quite easily once waste minimisation is considered at an early stage and is linked into the contract documents.

Typically the implementation of waste minimisation techniques requires three basic components; waste minimisation during the design stage, source reduction and recycling. Waste minimisation during the design stage has huge potential to impact positively on waste minimisation as it is during this stage that some of the major decisions are made such as the form of the building. Source reduction helps avoid waste generation while recycling helps to conserve natural resources and prevents wasted materials from entering the waste stream. There is huge potential for the minimisation of construction waste which arises through both design and the construction process. In order to reduce wastage rates it is important to focus on both issues. The most important factor for on-site waste management is the on-site segregation of the waste. If this process fails then it becomes difficult for the waste to be recycled. At the outset this will take some extra time and training of the construction staff but once the segregation habits are established the waste segregation on site can be done at a small or no additional cost.

It is also important that a waste management plan should be formulated at the earliest possible stage of the project; the formal production of the waste management plan can be at a later stage but a waste management philosophy ought to be adopted by the designer at the earliest possible stage. The aim of the plan is for it to become common practice on-site and eventually merge into day to day activities. A waste management plan should not be seen as a complicated document or seen as a burden by the person nominated for its implementation. It is clear that a change in the current waste management practices is needed in order to eliminate waste on site. This will require a shift from thinking of construction waste as something that is unwanted and destined to be discarded to thinking of these materials as a resource that can be reused, recycled or recovered.

There are a number of recommendations which have been drawn from the research carried out as part of this thesis. These recommendations are;

- Waste management plans should be made mandatory for all but minor developments such as one off houses.

- The benefits of waste management, waste minimisation and the use of recycled materials should be promoted by professional bodies such as the construction industry federation.

- The setting up of recycling plants to process construction waste and other wastes should be encouraged.

- Standards for recycled products need to be published so that the perception of the industry can be changed towards these products.

- All parties within the construction process have a role to play in relation to waste management. Main contractors need to engage with suppliers and manufactures so that take back schemes for materials and packaging waste can be set up in Ireland.

- It is important that main contractors choose sub-contractors, suppliers and waste management contractors who will comply with their waste management objectives.

Acknowledgements

Thanks and acknowledgements are due to many people who have given their time, support, encouragement, advice and expertise over the past year.

Firstly I would like to thank my thesis supervisor Dr Mark Kelly for his help and guidance in the preparation and compilation of this thesis. Marks commitment to helping with this thesis is an inspiration and despite having a packed work schedule he always made time for me as a master's student. It is safe to say that without his help and assistance this thesis would not have been possible.

I would also like to thank my family for all their help and support through my thesis and also through my previous third level education. Without my families help it would not be possible to be where I am today. Thank you to my mother, Margaret and my brothers Klaus, Killian and Mark. A special acknowledgement for my late father, Jürgen, who supported me through everything I have ever done and was always there to help me along when I needed him. This thesis is dedicated to my father. A mention also for Elva who provided the necessary moral support and was always there when I needed her help.

I also acknowledge the opportunity Carey Developments provided in working with the company and developing a case study based on my experience with them. I would also like to extend a thank you to the people, companies and organisations who contributed to this thesis by answering questionnaires, supplying literature, answering queries and their valuable time to help me with my research.

I would like to thank my classmates and friends who often referred me to websites, reports, journals and books relevant to my subject matter. I wish them all good fortune in their own theses and in the future.

I would finally like to thank all of the lecturing and learning information staff at Galway Mayo Institute of Technology for their help and guidance during my time in third level and post graduate education. The library facilities in the college are of the highest standard and supplied a substantial amount of literature and information to the thesis.

Chapter structure and layout

This thesis contains eight chapters that cover different aspects with relation to site waste management plans and their implementation on site. There are also a number of appendices included to support the information contained in the thesis and also to outline some practical applications.

Chapter one – Introduction and research methodology

Chapter one introduces the thesis topic and outlines the authors' aims and objectives. The research methodology and the hypothesis of the thesis are also stated along with a definition of waste and a statement of the problem.

Chapter two – Waste legislation in Ireland

Chapter two contains information regarding the current waste legislation in Ireland and how it is enforced. The chapter also outlines the construction waste arisings in Ireland and explains the waste hierarchy concept. Landfill capacity and the implications of construction and demolition waste are also discussed.

Chapter three – Waste minimisation and management

This chapter contains information on waste minimisation and also the management of waste. Outlined in this chapter are also details of practical information on how to minimise and manage waste within a construction company and also on site. The information contained in this chapter can help contractors reduce resource waste and its cost.

Chapter four – Site waste management plans

Chapter four discusses the use of site waste management plans and outlines the information that should be contained in such a plan. The waste recording tools are analysed and the true cost of waste is explained. The chapter also outlines the role of designers, contractors and sub-contractors in relation to waste management.

Chapter five – Main contractors' attitudes towards waste management

Chapter five analyses the results of a national survey of main contractors on the issue of construction waste and aims to investigate the current attitudes within the industry in relation to construction waste.

Chapter six – Study of a main contractor in Ireland

Chapter six contains information regarding the practical application of a site waste management plan on a case study in Co. Galway. The chapter contains details of the seventeen site visits carried out and the lessons learnt from these visits.

Chapter seven – Recycling markets for construction waste in Ireland

Chapter seven investigates the current markets for waste in Ireland and also contains details of an audit carried out with Barna Waste in Galway to identify the final destination of waste and the markets available to them.

Chapter eight – Conclusions and recommendations

The final chapter outlines the conclusions and recommendations of the thesis and also identifies areas where further study may be required.

Table of contents

Plagiarism declaration…………………………………………………………………..i

Abstract……………………………………………………………………………………iii

Acknowledgements………………………………………………………………………vii

Chapter structure and layout………………………………………………………...viii

Table of contents……………………………………………………………………...x

List of figures……………………………………………………………………….xix

List of tables…………………………………………………………………………...xxi

List of pictures……………………………………………………………………..xxii

Table of appendices……………………………………………………………….xxvii

List of acronyms and definitions………………………………………………….xxviii

1.0 CHAPTER ONE – INTRODUCTION AND RESEARCH METHODOLOGY…..1

1.1 Aims and Objectives...1

1.2 Introduction……………………………………………………………………..1

1.3 Thesis Statement…………………………………………………………………...4

1.4 Background to the study……………………………………………………………...5

1.5 Statement of the problem……………………………………………………………….6

1.6 Target audience…………………………………………………………………………6

1.7 Identification of the knowledge gap……………………………………………………7

1.8 Research problem………………………………………………………………………7

1.9 Research question………………………………………………………….............7

1.10 Aims and objectives of the thesis……………………………………………………...7

1.11 Thesis hypothesis……………………………………………………………………...8

1.12 Research methodology………………………………………………………………...9

1.13 Research limitations………………………………………………………………….11

1.14 Questionnaire………………………………………………………………………....11

1.15 Case study…………………………………………………………………………….12

1.16 Definition of waste…………………………………………………………………...12

1.17 Summary……………………………………………………………………………..16

2.0 CHAPTER TWO – WASTE LEGISLATION IN IRELAND……………………17

2.1 Aims and objectives……………………………………………………………...17
2.2 Introduction………………………………………………………………………17
2.3 Waste management framework in Europe……………………………………….18
2.3.1 European community strategy for waste management 1989………………...18
2.3.2 Council Directive 91/156/EEC amending Directive 75/442/EEC on waste...20
2.3.3 Council Directive 2006/12/EC……………………………………………21
2.3.4 Developments prior to the Waste Framework Directive……………………21
2.3.5 Waste framework directive 2008 98/2008 EC………………………………24
2.3.6 Guidelines on the interpretation of Directive 2008/98/EC on waste………...26
2.3.7 International review of Waste Management policy 2009…………………...27
2.3.8 A resource-efficient Europe – Flagship initiative of Europe 2020 Strategy...28
2.3.9 Sustainable competitiveness of the construction sector 2011……………….29
2.3.10 EU Material resources and waste - 2012 update…………………………...29
2.3.11 European Union – Roadmap to a resource efficient Europe……………….29
2.4 Waste management framework in Ireland………………………………………..32
2.4.1 National Recycling - Recycling for Ireland……………………………....32
2.4.2 Waste Management Act 1996 S.I. 10/1996…………………………………33
2.4.3 Changing Our Ways (1998)…………………………………………………33
2.4.4 Waste Management (Collection Permit) Regulations, 2007 S.I. 820/2007…34
2.4.5 Planning and Development Act 2000 S.I. 30/2000…………………………34
2.4.6 Waste Management (Collection Permit) Regulations 2001 S.I. 402/2000….35
2.4.7 Waste Management (Amendment) Act 2001 S.I. 36/2001………………….35
2.4.8 Delivering Change – Preventing and Recycling Waste 2002……………….35
2.4.9 Protection of the Environment Act 2003 S.I. 27/2003………………………35
2.4.10 Waste Management (Licensing) Regulations 2004 S.I. 395/2004…………36
2.4.11 Waste Management – Taking Stock and Moving Forward 2004…………..36
2.4.12 The Environment (Miscellaneous Provisions) Act 2011 S.I. 20/2011……..36
2.4.13 European Communities (Waste Directive) Regulations S.I. 126/2011…….37
2.4.14 Waste Management (Landfill Levy) Regulations 2011 S.I. 434/2011..........38
2.4.15 End of waste criteria – final report 2008…………………………………...39
2.4.16 Towards a new National waste policy discussion document 2011……......39
2.4.17 A Resource Opportunity - Waste management policy in Ireland 2012……41

2.5 Enforcement of waste legislation………………………………………………………...41
2.6 Quantities of construction and demolition waste in Ireland…………………………..42
2.7 Landfill capacity……………………………………………………………………….45
2.8 Construction waste arisings…………………………………………………………....46
2.9 Implications of construction and demolition waste……………………………………47
2.10 Sustainable waste management……………………………………………………….49
2.11 What can be done?..49
2.12 Summary……………………………………………………………………………..49

3.0 CHAPTER THREE – WASTE MINIMISATION AND MANAGEMENT……51

3.1 Aims and objectives………………………………………………………………...51
3.2 Introduction………………………………………………………………………...51
3.3 Improving materials resource efficiency…………………………………………….53
3.4 Good practice waste management and minimisation……………………………......54
3.5 Why not aim for best practice?...56
3.6 Benefits of waste minimisation……………………………………………………..57
3.7 Training and communication………………………………………………………..58
3.8 Forecasting waste arisings…………………………………………………………..60
3.9 Waste minimisation strategy………………………………………………………..61
3.10 Setting targets and KPIs……………………………………………………………...62
3.11 Waste recovery quick wins…………………………………………………………...64
3.12 Prevention, reuse and recycling……………………………………………………....66
3.13 Good practice examples and guidelines……………………………………………...67
3.13.1 Initial commitment, targets and company policy…………………………..67
3.13.2 Pre design stage……………………………………………………………70
3.13.3 Procurement………………………………………………………………...70
3.13.4 Design………………………………………………………………………72
3.13.5 Pre-construction stage……………………………………………………...74
3.13.6 Construction stage…………………………………………………………74
3.13.7 Logistics……………………………………………………………………78
3.13.8 Materials procurement……………………………………………………...79
3.13.9 Post construction stage……………………………………………………..79
3.13.10 Measuring and reporting…………………………………………………80

3.14 The segregation of common waste streams……………………………………………..80
3.15 Modern methods of construction (MMC)……………………………………........82
3.15.1 Volumetric modular…………………………………………………………..84
3.15.2 Panellised modular building systems…………………………………………85
3.15.3 Pods…………………………………………………………………………...86
3.15.4 Building envelope components………………………………………………87
3.15.5 Structural pre-cast concrete building components……………………………87
3.16 Practical applications of MMC on the 'Taylors Hill Site'…………………………...88
3.17 Alternative details……………………………………………………………………89
3.17.1 Aerated concrete blocks with thin joint mortar……………………………….89
3.17.2 Voided biaxial slab……………………………………………………………90
3.17.3 Door Jambs……………………………………………………………………92
3.17.4 Post tensioned floor slab………………………………………………………93
3.17.5 Flexible plumbing system…………………………………………………….94
3.17.6 Tile detailing…………………………………………………………………..96
3.18 Trade specific opportunities for waste minimisation………………………………...97
3.18.1 Contractor……………………………………………………………………..97
3.18.2 Dry-liners and plasterers……………………………………………………...99
3.18.3 Fit out contractors……………………………………………………………100
3.18.4 Carpenters and wood workers………………………………………………..102
3.18.5 Electricians…………………………………………………………………..103
3.18.6 Plumbers……………………………………………………………………..105
3.18.7 Painters and decorators……………………………………………………..108
3.18.8 Labourers on site……………………………………………………………109
3.19 Good practice checklist……………………………………………………………..110
3.20 Waste management action plan (Table 3.26)………………………………………112
3.21 Skip management plan……………………………………………………………...113
3.21.1 Skip management - current practice compared to future (good) practice...115
3.21.2 Mini skips……………………………………………………………………115
3.22 Barriers to achieving good practice…………………………………………………116
3.23 Overcoming the barriers to achieve good waste management practice…………….117
3.24 Summary……………………………………………………………………………119

4.0 CHAPTER FOUR - SITE WASTE MANAGEMENT PLANS………………......120

4.1 Aims and objectives……………………………………………………………120
4.2 Introduction……………………………………………………….……………120
4.3 Best Practice Guidelines – Ireland……………………………………………...121
4.4 Best practice guidelines – UK…………………………………………………..122
4.5 Waste management plans for planning…………………………………………123
4.6 Site waste management plans…………………………………………………...124
4.6.1 Benefits of a waste management plan……………………………………...126
4.6.2 Difficulties in implementing a waste management plan…………………...127
4.6.3 Summary of benefits and difficulties in implementing a WMP……………129
4.7 Roles and responsibilities for waste management…………………………….....129
4.7.1 Role of designers…………………………………………………………...129
4.7.2 Role of clients………………………………………………………………130
4.7.3 Role of main contractor…………………………………………………….131
4.7.4 Role of sub-contractors……………………………………………………..132
4.7.5 Role of waste management contractor……………………………………..133
4.7.6 Role of a waste champion…………………………………………………..134
4.8 Implementing a waste management plan………………………………………..134
4.8.1 Step one – Prepare and plan………………………………………………..136
4.8.2 Step two – Allocate responsibility for the waste management plan………..137
4.8.3 Step three – Identify the waste that will be produced……………………...137
4.8.4 Step four – Identify how to manage the waste……………………………..138
4.8.5 Step five – Identify how and where the waste will be disposed……………138
4.8.6 Step six – Plan the effective organisation of materials and waste…………139
4.8.7 Step seven – Communication and training…………………………………139
4.8.8 Step eight – Measure the quantity of waste and update WMP……………..140
4.8.9 Step nine – Review the success of the plan and any lessons learnt………...140
4.9 Content…………………………………………………………………………141
4.10 Cost of waste management……………………………………………………142
4.11 Responsibilities when dealing with waste……………………………………..142
4.11.1 Duty of care……………………………………………………………….142
4.11.2 Waste transfer note………………………………………………………..143
4.12 Demolition plan………………………………………………………………..143

4.13 Training and responsibilities……………………………………………………..144
4.13.1 Construction and demolition waste manager……………………………..144
4.14 Record keeping procedures……………………………………………………145
4.15 Waste auditing…………………………………………………………………146
4.15.1 The Net Waste Tool – WRAP UK……………………………………..146
4.15.2 Site waste management plan template – WRAP UK……………………..148
4.15.3 Waste management plan tracker – WRAP UK…………………………...149
4.15.4 Site specific waste analysis tool (SSWAT) – WRAP UK………………...149
4.15.5 The designing out waste tool for buildings (DoWT-B) – WRAP UK……149
4.15.6 SMARTWaste – BRE Group……………………………………………..150
4.15.7 SMARTWaste tools and add-ons…………………………………………150
4.16 Procurement strategies………………………………………………………...151
4.16.1 Pre tender/ qualification stage……………………………………………151
4.16.2 Tender requirements……………………………………………………....152
4.16.3 Forms of contract……………………………………………………….....152
4.17 Cost benefits…………………………………………………………………...152
4.18 Summary……………………………………………………………………....154

5.0 CHAPTER FIVE – MAIN CONTRACTORS' ATTITUDES TOWARDS WASTE MANAGEMENT……………………………………………………………………...…156

5.1 Aims and objectives……………………………………………………………….156
5.2 Introduction………………………………………………………………………..156
5.3 Target audience……………………………………………………………………157
5.4 Research knowledge gap…………………………………………………………..157
5.5 Questionnaire development………………………………………………………..158
5.6 Research limitations……………………………………………………………….159
5.7 Bias………………………………………………………………………………...160
5.8 Response rate…………………………………………………………………...….160
5.9 Designation of respondents………………………………………………………..161
5.10 Results and analysis of questionnaire…………………………………………….161
5.11 Conclusions……………………………………………………………………….205
5.12 Summary………………………………………………………………………….206

6.0 CHAPTER SIX – STUDY OF A MAIN BUILDING CONTRACTOR IN IRELAND……………………………………………………………………………..207

6.1 Aims and objectives……………………………………………………………….207

6.2 Introduction………………………………………………………………………..207

6.3 Scope of the project……………………………………………………………….208

6.4 Methodology…………………………………………………………………........208

6.5 The contractor……………………………………………………………………...209

6.6 The project…………………………………………………………………………209

6.7 Review of site visits……………………………………………………………..…209

6.8 Current waste streams……………………………………………………………..210

6.8.1 Timber……………………………………………………………………...210

6.8.2 Packaging waste (Cardboard and plastic)…………………………………211

6.8.3 Metal………………………………………………………………………..211

6.8.4 Insulation…………………………………………………………………...211

6.8.5 Concrete, blocks, rubble etc………………………………………………..212

6.9 Future waste streams………………………………………………………………212

6.9.1 Plasterboard………………………………………………………………...212

6.10 Waste recovery quick wins……………………………………………………….213

6.11 Site visit observations and solutions……………………………………………..…214

6.11.1 Practices that require improvement……………………………………..…218

6.12 Waste auditing…………………………………………………………………...…264

6.13 Comments…………………………………………………………………………...285

6.14 Current recommendations for improvement……………………………………..285

6.15 Future recommendations for further improvement………………………………291

6.16 Desktop study of the design drawings…………………………………………....293

6.17 Desktop study of the project specifications………………………………………317

6.18 Lessons learned……………………………………………………………………..329

6.19 Site waste audit sheet……………………………………………………………….331

6.20 Conclusions…………………………………………………………………………342

6.21 Summary……………………………………………………………………………346

7.0 CHAPTER SEVEN – RECYCLING MARKETS FOR CONSTRUCTION WASTE IN IRELAND……………………………………………………………….347

7.1 Aims and objectives……………………………………………………………….347
7.2 Introduction……………………………………………………………………..347
7.3 Environmental benefits of reuse and recycling………………………………………349
7.4 Market development initiatives…………………………………………………....350
7.4.1 DEMCON 20/20…………………………………………………………350
7.4.2 Rx3 – Rethink, Recycle, Remake………………………………………..351
7.4.3 Market development programme for waste resources 2007 – 2011……….352
7.4.4 FÁS and CIF………………………………………………………………..352
7.4.5 Market development outside Ireland……………………………………….353
7.5 Practical examples…………………………………………………………………....354
7.5.1 Plasterboard……………………………………………………………...354
7.5.2 Timber…………………………………………………………………...…354
7.5.3 Plastic……………………………………………………………………....354
7.6 The impact of legislation on recycling markets…………………………………...355
7.7 Standards in Ireland……………………………………………………………….356
7.8 Market possibilities in Ireland……………………………………………………..356
7.9 Why reclaim materials?...357
7.10 Embodied energy and carbon footprint…………………………………………..357
7.11 Sourcing reclaimed materials…………………………………………………….359
7.12 Decision of where to dispose of construction waste……………………………..359
7.13 Potential market availability……………………………………………………...360
7.13.1 Timber……………………………………………………………………306
7.13.2 Blocks, rubble, waste concrete…………………………………………360
7.13.3 Metal……………………………………………………………………....361
7.13.4 Gypsum/ Plasterboard…………………………………………………….361
7.13.5 Insulation………………………………………………………………….361
7.13.6 Packaging waste and paper/ plastic waste………………………………...362
7.14 Take back schemes………………………………………………………………….362
7.15 Site visit to Barna Waste, Co. Galway……………………………………………...364
7.15.1 Methodology…………………………………………………………...364
7.15.2 Introduction……………………………………………………………….364

7.15.3 EPA Licence……………………………………………………………364
7.15.4 Waste collection permit…………………………………………………...365
7.15.5 Waste acceptance………………………………………………………365
7.15.6 Skip sizes available……………………………………………………….366
7.15.7 Waste cycle from site to recovery…………………………….……….366
7.15.8 Timber…………………………………………………………………….368
7.15.9 Plastic……………………………………………………………………..369
7.15.10 Cardboard and paper…………………………………………………….371
7.15.11 Plasterboard/ Gypsum…………………………………………………...373
7.15.12 Metal……………………………………………………………………..373
7.15.13 Insulation………………………………………………………………...374
7.15.14 Concrete/ rubble etc……………………………………………………...375
7.15.15 Hazardous waste…………………………………………………………376
7.15.16 Organic waste……………………………………………………………376
7.15.17 Canteen waste……………………………………………………………378
7.15.18 Office waste……………………………………………………………...378
7.15.19 Final Destination………………………………………………………...379
7.15.20 RDF – Refuse Derived Fuel……………………………………………..380
7.15.21 Waste costs per tonne…………………………………………………....380
7.15.22 Record keeping…………………………………………………………..381
7.15.23 Recommendations……………………………………………………….381
7.16 Incentives and disincentives of reusing or recycling construction waste…………...382
7.17 Barriers to reuse and recovery………………………………………………………383
7.18 Barriers to market development…………………………………………………….384
7.19 Summary……………………………………………………………………………385

8.0 CHAPTER EIGHT - CONCLUSIONS AND RECOMMENDATIONS………..387

8.1 Aims and objectives…………………………………………………………………387
8.2 Conclusions…………………………………………………………………………..387
8.3 Recommendations…………………………………………………………………394
8.4 Areas for further study……………………………………………………………….395
8.5 Summary……………………………………………………………………………..395

9.0 REFERENCES…………………………………………………………………...396

List of figures

Figure 2.1 Waste hierarchy (Source: European commission, 1989)……………………...19
Figure 2.2 Waste Hierarchy WFD (Source: Defra.gov.uk)………………………………25
Figure 2.3 Waste legislation enforcement network………………………………………42

Figure 3.1 Typical waste recovery rates for construction waste (WRAP, 2012)…………64
Figure 3.2 Low waste door jamb (Source: WRAP UK)………………………………..92

Figure 4.1 Steps in producing a waste management plan. (Source: DTI, 2004)………...136
Figure 4.2 Net Waste method (Source: WRAP, 2011)…………………………………147
Figure 4.3 Net Waste Tool screenshot…………………………………………………..148
Figure 4.4 WRAP waste management plan template screenshot………………………..149

Figure 5.1 Question twenty four results…………………………………………………162
Figure 5.2 Question twenty five results…………………………………………………163
Figure 5.3 Question twenty six results…………………………………………………..164
Figure 5.4 Question twenty seven results………………………………………………..165
Figure 5.5 Question two results…………………………………………………………167
Figure 5.6 Question three results………………………………………………………...168
Figure 5.7 Question four results…………………………………………………………169
Figure 5.8 Question five results…………………………………………………………170
Figure 5.9 Question six results…………………………………………………………..171
Figure 5.10 Question seven results………………………………………………………172
Figure 5.11 Question eight results………………………………………………………173
Figure 5.12 Question nine results………………………………………………………..174
Figure 5.13 Question ten results…………………………………………………………175
Figure 5.14 Question eleven results……………………………………………………..176
Figure 5.15 Question twelve results……………………………………………………..177
Figure 5.16 Question thirteen results…………………………………………………….178
Figure 5.17 Question fourteen results…………………………………………………...179
Figure 5.18 Question fifteen results……………………………………………………..180

Figure 5.19 Question sixteen results……………………………………………………181
Figure 5.20 Question seventeen results…………………………………………………182
Figure 5.21 Question eighteen (A) results………………………………………………183
Figure 5.22 Question eighteen (B) results………………………………………………184
Figure 5.23 Question eighteen (C) results………………………………………………184
Figure 5.24 Question eighteen (D) results………………………………………………185
Figure 5.25 Question nineteen (A) results………………………………………………187
Figure 5.26 Question nineteen (B) results………………………………………………188
Figure 5.27 Question nineteen (C) results………………………………………………188
Figure 5.28 Question nineteen (D) results………………………………………………189
Figure 5.29 Question nineteen (E) results………………………………………………189
Figure 5.30 Question twenty (A) results…………………………………………………...191
Figure 5.31 Question twenty (B) results…………………………………………………....192
Figure 5.32 Question twenty (C) results…………………………………………………192
Figure 5.33 Question twenty (D) results…………………………………………………...193
Figure 5.34 Question twenty (E) results…………………………………………………193
Figure 5.35 Question twenty one (A) results……………………………………………194
Figure 5.36 Question twenty one (B) results……………………………………………195
Figure 5.37 Question twenty one (C) results……………………………………………195
Figure 5.38 Question twenty one (D) results……………………………………………196
Figure 5.39 Question twenty one (E) results……………………………………………196
Figure 5.40 Question twenty two (A) results……………………………………………197
Figure 5.41 Question twenty two (B) results……………………………………………198
Figure 5.42 Question twenty two (C) results……………………………………………198
Figure 5.43 Question twenty two (D) results……………………………………………199
Figure 5.44 Question twenty two (E) results……………………………………………199
Figure 5.45 Question twenty three (A) results…………………………………………..201
Figure 5.46 Question twenty three (B) results…………………………………………...202
Figure 5.47 Question twenty three (C) results…………………………………………...202
Figure 5.48 Question twenty three (D) results…………………………………………..203
Figure 5.49 Question twenty three (E) results…………………………………………...203

Figure 7.1 Construction sector opportunities for recycling (Source: DoEHLG, 2011)…352

Figure 7.2 Material usage compared to embodied energy (Source: Lazarus, 2005)…….358

List of tables

Table 2.1 Landfill levy rates (Source: EPA, 2010) ……………………………………….39
Table 2.2 Quantities of C&D Waste in Ireland……………………………………………...43
Table 2.3 Collection and management of soil and stones 2010 (Source: EPA, 2012)…....44
Table 2.4 Collection and management of non-soil and stone C&D Waste 2010…………44

Table 3.1 Waste minimisation targets…………………………………………………….68
Table 3.2 Potential benefits of aerated concrete blocks with thin joint mortar…………...90
Table 3.3 Potential benefits of voided biaxial slab………………………………………..91
Table 3.4 Potential benefits of low waste door jamb……………………………………...92
Table 3.5 Potential benefits of post tensioned floor slab…………………………………94
Table 3.6 Potential benefits of flexible plastic piping……………………………………95
Table 3.7 Potential benefits of tile detailing……………………………………………....97
Table 3.8 Contractor waste reduction opportunities……………………………………....97
Table 3.9 Contractor waste reuse opportunities…………………………………………..98
Table 3.10 Contractor waste recycling opportunities……………………………………..98
Table 3.11 Dry-liners and plasterers waste reduction opportunities……………………...99
Table 3.12 Dry-liners and plasterers waste reuse opportunities…………………………100
Table 3.13 Dry-liners and plasterers waste recycling opportunities……………………..100
Table 3.14 Fit out contractors waste reduction opportunities……………………………100
Table 3.15 Fit out contractors waste reuse opportunities………………………………..101
Table 3.16 Fit out contractors waste recycling opportunities…………………………....101
Table 3.17 Carpenters and wood workers waste reduction opportunities……………….102
Table 3.18 Carpenters and wood workers waste reuse opportunities…………………....102
Table 3.19 Carpenters and wood workers waste recycling opportunities……………….103
Table 3.20 Electricians waste reduction opportunities…………………………………..104
Table 3.21 Electricians waste reuse opportunities……………………………………….104
Table 3.22 Electricians waste recycling opportunities…………………………………..105
Table 3.23 Plumbers waste reduction opportunities……………………………………..106
Table 3.24 Plumbers waste reuse opportunities………………………………………....107
Table 3.25 Plumbers waste recycling opportunities……………………………………..107

Table 3.26 Labourers good practice waste management opportunities…………………109
Table 3.27 Good practice checklist ……………………………………………………..110
Table 3.28 Waste management action plan ……………………………………………..112
Table 3.29 Waste management options…………………………………………………114
Table 3.30 Current practice compared to future (good) practice………………………...115

Table 4.1 Summary of benefits and difficulties…………………………………………129

Table 5.1 Responses from main contractors' survey……………………………………160
Table 5.2 Designation of respondents…………………………………………………...161

Table 6.1 Waste in skip one summary…………………………………………………...266
Table 6.2 Waste in skip two summary…………………………………………………...278
Table 6.3 Waste in skip three summary…………………………………………………282
Table 6.4 Waste in skip four summary…………………………………………………..284
Table 6.5 Initial commitment, targets and company policy……………………………..286
Table 6.6 Construction stage good practice……………………………………………...287
Table 6.7 Logistics good practice………………………………………………………..291

Table 7.1 Maximum distances before benefits of reclaimed material is lost……………359
Table 7.2 Availability of take back schemes in Ireland…………………………………362
Table 7.3 Barna waste, waste acceptance………………………………………………..365
Table 7.4 Availability of skip sizes……………………………………………………...366
Table 7.5 Final destination of waste……………………………………………………..380
Table 7.6 Waste types and cost per tonne………………………………………………..380
Table 7.7 Incentives and disincentives of recycling or reusing C&D waste…………….382

List of pictures

Picture 3.1 Volumetric modular construction……………………………………………85
Picture 3.2 Timber frame construction using SIPs……………………………………….86
Picture 3.3 Bathroom Pod………………………………………………………………...86
Picture 3.4 Composite panel cladding…………………………………………………….87
Picture 3.5 Hollowcore flooring…………………………………………………………..88

Picture 3.6 AAC blocks with thin joint mortar……………………………………………...90
Picture 3.7 Voided Biaxial Slab……………………………………………………….91
Picture 3.8 Post tensioned floor slab…………………………………………………...94
Picture 3.9 Flexible plastic piping……………………………………………………...95
Picture 3.10 Mosaic tiles………………………………………………………………96

Picture 6.1 Overview of case study site………………………………………………209
Picture 6.2 On-site crusher……………………………………………………………214
Picture 6.3 Delivery of blocks………………………………………………………...215
Picture 6.4 Mortar mixing silos………………………………………………………215
Picture 6.5 Importing fill material……………………………………………………216
Picture 6.6 Window and door delivery………………………………………………..216
Picture 6.7 Timber roof trusses………………………………………………………217
Picture 6.8 Precast concrete stairs……………………………………………………217
Picture 6.9 Hollowcore installation…………………………………………………...218
Picture 6.10 Bitumen packaging……………………………………………………...219
Picture 6.11 Leftover pallets 1………………………………………………………..220
Picture 6.12 Leftover pallets 2………………………………………………………..220
Picture 6.13 Roofing battens overruns………………………………………………..221
Picture 6.14 Slate crates and slate waste……………………………………………...221
Picture 6.15 Inadequate storage of sand………………………………………………222
Picture 6.16 Inadequate storage of stone……………………………………………...223
Picture 6.17 Poor storage of protection barrier………………………………………223
Picture 6.18 Incorrect storage of topsoil……………………………………………...224
Picture 6.19 Poor storage of materials 1……………………………………………...225
Picture 6.20 Poor storage of materials 2……………………………………………...225
Picture 6.21 Protection barrier damage 1……………………………………………..226
Picture 6.22 Protection barrier damage 2……………………………………………..226
Picture 6.23 DPC waste 1……………………………………………………………..227
Picture 6.24 DPC waste 2……………………………………………………………..227
Picture 6.25 Poor storage of concrete bags…………………………………………...228
Picture 6.26 Poor storage of concrete bags…………………………………………...228
Picture 6.27 Insulation materials damaged…………………………………………...229
Picture 6.28 Equipment damage……………………………………………………230

Picture 6.29 Poor storage of protection barrier……………………………………………230
Picture 6.30 Poor storage of windows and doors…………………………………………..231
Picture 6.31 Incorrect use of materials 1…………………………………………………...232
Picture 6.32 Incorrect use of materials 2…………………………………………………...232
Picture 6.33 Material wastage 1……………………………………………………………233
Picture 6.34 Material wastage 2……………………………………………………………233
Picture 6.35 Material wastage 3……………………………………………………………234
Picture 6.36 Concrete block waste…………………………………………………………235
Picture 6.37 Overfilling mortar bins 1……………………………………………………..235
Picture 6.38 Overfilling mortar bins 2……………………………………………………..236
Picture 6.39 Wastage of concrete 1………………………………………………………...236
Picture 6.40 Wastage of concrete 2………………………………………………………...237
Picture 6.41 Wastage of concrete during delivery 1……………………………………….237
Picture 6.42 Wastage of concrete during delivery 2 ……………………………………….238
Picture 6.43 Concrete waste after delivery 1……………………………………………….238
Picture 6.44 Concrete waste after delivery 2……………………………………………….239
Picture 6.45 Concrete waste after delivery 3……………………………………………….239
Picture 6.46 Hollowcore waste 1…………………………………………………………...240
Picture 6.47 Hollowcore waste 2…………………………………………………………...240
Picture 6.48 Cut window sill. ……………………………………………………………...241
Picture 6.49 Metal waste 1…………………………………………………………………241
Picture 6.50 Metal waste 2…………………………………………………………………242
Picture 6.51 Canteen bin 1…………………………………………………………………243
Picture 6.52 Canteen bin 2…………………………………………………………………243
Picture 6.53 Fly tipping of waste on site…………………………………………………...244
Picture 6.54 Fly tipping of waste 2………………………………………………………...245
Picture 6.55 Fly tipping of waste 3………………………………………………………...245
Picture 6.56 Fly tipping of waste 4………………………………………………………...246
Picture 6.57 Walls built incorrectly………………………………………………………...247
Picture 6.58 Breaking out to accommodate future work…………………………………...248
Picture 6.59 Breaking out for services……………………………………………………..249
Picture 6.60 Breaking out for services……………………………………………………..249
Picture 6.61 Electrical wire tails…………………………………………………………...250
Picture 6.62 Electrical wire tails…………………………………………………………...250

Picture 6.63 Mobile generator……………………………………………………………...251
Picture 6.64 Volvo dump truck……………………………………………………………252
Picture 6.65 Mobile water butt……………………………………………………………..253
Picture 6.66 Leaking water pipe……………………………………………………………253
Picture 6.67 Early stages of waste production……………………………………………..254
Picture 6.68 Inappropriate use of materials………………………………………………...255
Picture 6.69 Illegal dumping by sub-contractor……………………………………………255
Picture 4.70 Untidy site entrance…………………………………………………………..256
Picture 6.71 Cleaning out waste 1…………………………………………………………257
Picture 6.72 Cleaning out waste 2…………………………………………………………257
Picture 6.73 Poor installation of materials 1………………………………………………258
Picture 6.74 Poor installation of materials 2………………………………………………258
Picture 6.75 Drying room…………………………………………………………………..259
Picture 6.76 Overflowing skips……………………………………………………………259
Picture 6.77 Material wastage……………………………………………………………...260
Picture 6.78 Insulation damage……………………………………………………………261
Picture 6.79 Efflorescence on block work…………………………………………………261
Picture 6.80 Plastic piping waste…………………………………………………………...262
Picture 6.81 Holes in the roofing membrane………………………………………………263
Picture 6.82 Mini skip 4th of April………………………………………………………...264
Picture 6.83 General waste skip 22nd of May……………………………………………..265
Picture 6.84 Mini skip 22nd of May………………………………………………………266
Picture 6.85 Mini skip with timber waste 22nd of May…………………………………266
Picture 6.86 Mini skip 29th of May………………………………………………………..267
Picture 6.87 General waste skip 1st of June……………………………………………..268
Picture 6.88 Mini skip 1st of June…………………………………………………………269
Picture 6.89 General waste skip 5th of June………………………………………………270
Picture 6.90 Mini skip with timber waste 5th of June…………………………………...271
Picture 6.91 General waste skip 13th of June……………………………………………...272
Picture 6.92 Mini skip 13th of June………………………………………………………..273
Picture 6.93 General waste skip 19th of June……………………………………………...274
Picture 6.94 Mini skip 19th of June………………………………………………………..275
Picture 6.95 General waste skip 26th of June……………………………………………...276
Picture 6.96 General waste skip 4th of July………………………………………………..277

Picture 6.97 Mini skip with timber waste 4th of July……………………………………...277
Picture 6.98 Mini skip 4th of July……………………………………………………………278
Picture 6.99 General waste skip 12th of July…………………………………………………279
Picture 6.100 General waste skip 18th of July………………………………………………..280
Picture 6.101 General waste skip 26th of July………………………………………………..281
Picture 6.102 Mini skip 26th of July…………………………………………………………282
Picture 6.103 General waste skip 14th of August……………………………………………283
Picture 6.104 General waste skip 22nd of August……………………………………………284

Picture 7.1 Mixed waste skip on site…………………………………………………………366
Picture 7.2 Centralised sorting area…………………………………………………………...367
Picture 7.3 Timber holding area………………………………………………………………368
Picture 7.4 Shredded timber…………………………………………………………………..369
Picture 7.5 Plastic temporary holding area……………………………………………………369
Picture 7.6 Baled hard plastic………………………………………………………………...370
Picture 7.7 Baled soft plastic…………………………………………………………………370
Picture 7.8 Cardboard temporary holding area………………………………………………371
Picture 7.9 Baled cardboard…………………………………………………………………..372
Picture 7.10 Baled paper and cardboard………………………………………………………372
Picture 7.11 Metal segregation stage…………………………………………………………373
Picture 7.12 Metal waste holding bay………………………………………………………...374
Picture 7.13 Baled metal waste………………………………………………………………374
Picture 7.14 Concrete/ rubble waste holding area……………………………………………375
Picture 7.15 Concrete/ rubble used as fill……………………………………………………375
Picture 7.16 Organic waste holding bay………………………………………………………376
Picture 7.17 Conveyors and trommel screens………………………………………………...377
Picture 7.18 Compost…………………………………………………………………………377
Picture 7.19 Baled canteen waste……………………………………………………………..378
Picture 7.20 Baled office waste………………………………………………………………379
Picture 7.21 Shipping containers……………………………………………………………...379
Picture 7.22 True cost of waste………………………………………………………………382

Table of appendices

Appendix A - Waste management plan checklist

Appendix B - Template waste management plan

Appendix C – Useful tables

Appendix D - Site Visits Diary

Appendix E - Waste signage on site

Appendix F - Chapter 17 – European waste catalogue

Appendix G - EIREBLOC product information

Appendix H - Skip audit dockets

Appendix I - Copy of questionnaire

Appendix J - Copy of questionnaire results

Appendix K - Copy of phone call results

Appended documents

Carey Developments waste management plan and strategy

Carey Developments training package

Carey Developments carbon strategy

List of acronyms and definitions

6EAP - The Sixth Environment Action Programme.

AAC - Aerated Autoclaved Concrete.

Aggregates - A granular product obtained by processing natural materials. It may be sand or gravel produced by natural disintegration of rock, or it may be manufactured as a graded material by passing rock through a series of crushers.

BIM - Building Information Modelling.

C&D - Construction and Demolition.

C&DW - Construction and Demolition Waste.

C&DWMP - Construction and Demolition Waste Management Plan.

CAD - Computer Aided Design.

CEN - European Committee for standardization.

CIF - Construction Industry Federation.

Co2 - Carbon Dioxide.

DECLG - Department of the Environment, Community and Local Government.

DEFRA - Department for Environment, Food and Rural Affairs, UK.

Development Plan - A Plan within the meaning of Section 9(1) of the Planning and Development Act 2000 which sets out an overall strategy for the proper planning and sustainable development of the area of the development plan indicating the development objectives of the area.

DoEHLG - Department of the Environment Heritage and Local Government.

EC - European Comission.

EEA - European Environment Agency.

EPA - Environmental Protection Agency, Ireland.

EPA - Environmental Protection Agency.

EPS - Extruded Polystyrene.

EU - European Union.

EWC - European Waste Catalogue. The European Waste Catalogue and Hazardous Waste List are used for the classification of all wastes and are designed to form a consistent waste classification system across the EU.

FCI - Forum for the Construction Industry.

GMIT - Galway Mayo Institute of Technology.

Hazardous Waste - Waste listed as hazardous in the European Waste Catalogue.

ICE - Institute of Civil Engineers.

Inert waste - Waste materials that will not harm or cause adverse effects to the environment when disposed of, or do not decompose when buried.

JIT - Just In Time.

KPIs - Key Performance Indicators.

Landfill - Waste disposal facilities where waste is deposited onto or into land.

LCA - Life Cycle Analysis.

MDF - Medium Density Fibreboard.

MDPIT - Market Development Programme Implementation Team.

MMC - Modern Methods of Construction.

NCDWC - National Construction and Demolition Waste Council.

NHWMP - National Hazardous Waste Management Plan.

Non-hazardous waste - Waste materials that will break down/decompose when buried, resulting in the production of landfill gases such as methane and carbon dioxide.

NRA - National Roads Authority.

OECD - The Organisation for Economic Co-Operation and Development.

OEE - Office of Environmental Enforcement.

RDF - Refuse Derived Fuel.

SIPS - Structurally Insulated Panels.

SWMP - Site Waste Management Plan.

TJM - Thin Joint Masonry.

UK - United Kingdom.

VBS - Voided Biaxial Slab.

Waste Audit - A check of waste to determine amount generated, type, sources and potential means to avoid or reduce waste production.

Waste Segregation - Waste segregation is the practice whereby waste is segregated at source into different types of materials.

WFD - Waste Framework Directive.

WMP - Waste Management Plan.

1.0 Chapter One – Introduction and research methodology

1.1 Aims and Objectives

This chapter provides a background to the study and outlines the author's aims and objectives. The research methodology and the hypothesis of the thesis are stated along with a definition of waste and a statement of the problem.

This chapter will give an insight into the following:

- An introduction to construction and demolition waste.
- Thesis statement.
- Background to the study.
- Statement of the problem.
- Aims and objectives of the thesis.
- Thesis hypothesis.
- Research methodology.
- Research limitations.
- Definition of construction waste.

1.2 Introduction

Construction activities consume large amounts of natural resources, energy and materials but it also generates a large amount of waste. Kulatunga et al. (2006) states that the construction industry consumes 25 per cent of virgin wood and 40 per cent of raw stone and sand used each year globally. The production and manufacturing process required for the construction industry involves the extraction of billions of tonnes of materials annually. Faced with this large amount of waste the industry has carried out continuous research to investigate how to minimise the generation of waste so that the adverse impacts of construction and demolition waste can be reduced. Waste legislation goes back as far as 1975 in the EU and previous studies such as Symonds et al. (1994) and Teo and Loosemore (2001) have covered a wide range of topics ranging from waste production, recycling and reuse to waste minimisation and attitudes towards construction waste. The existing studies can by categorised into four groups, namely;

- Barriers to implementing waste management.
- Strategies for reducing waste.
- Stakeholders/ companies attitude to waste management.
- Benchmarking of waste management performance.

Yuan and Shen, (2011) found through the use of a trend analysis that the previous areas of study into construction waste were the following; outlined below with the most studied topics listed first;

- Construction and demolition waste management in general.
- Construction and demolition waste recycling.
- Construction and demolition waste reduction.
- Construction and demolition waste generation.
- Construction and demolition waste recycling.
- Construction and demolition waste management in general.
- Human factors in construction and demolition waste management.

This thesis will aim to address all of these four groups. Chini (2007) found that reducing waste and increasing the use of recycled materials on a project will be driven by higher costs of landfilling waste, greater acceptance of recycled products and the development of guidelines and specifications for these products. This is also applicable to the situation in Ireland where the costs of landfilling is rising continuously (Forfás et al., 2010). The price has risen from €15 per tonne in June 2002 to €65 per tonne in July 2012. There is a further increase planned for July 2013 when the rate will rise to €75 per tonne. The cost of skip hire is also quite high, a 12 cubic yard skip for use on a construction site costs in the region of €320 (Walsh Waste, 2012).

Construction and demolition waste is a large component of the waste stream in Ireland particularly with the high levels of construction that have taken place in the past. The construction and demolition industry traditionally was one of Ireland’s largest waste producers; however the amount of waste produced has decreased in previous years due to the economic downturn (EPA, 2012). The EPA estimate that 3.5 million tonnes of construction and demolition waste was collected in 2010 compared to 17.8 million tonnes in 2007 (EPA, 2012). The EU commission estimates that 500 million tonnes of construction and demolition waste is produced annually in Europe (European Commission, 2010) and this figure rises to 900 million tonnes when soil and stone waste is included (European Union, 2010). While Irelands rate of recovery of 87 per cent is very high, this figure is mainly due to the amount of soil and stones that are recycled. The rates for core construction and demolition waste are actually quite low at 44 per cent (EPA, 2012). Core construction and demolition waste is defined as;

"*Those types of materials which are obtained when an empty building or civil engineering infrastructure is demolished (but not necessarily obtained as a direct result of demolition). It excludes road planings, excavated soil, external utility and service connections (drainage pipes, water, gas and electricity connections) and surface vegetation, because the techniques for recovering and recycling these are quite distinct from other demolition wastes"*

(Symonds et al., 1999).

During the past few decades, construction and demolition waste has received increasing attention from construction practitioners and researchers worldwide. There is now a growing consensus worldwide that there is an urgent need to address climate change and the increase in greenhouse gases as well as developing a more sustainable relationship with the planet through our construction practices (Beg et al., 2002; Najam et al., 2003). Given the high embodied energy of the materials used in construction and the significant environmental impact as a result of extracting the minerals from the Earth, huge positive environmental impacts can be achieved by increasing the levels of material reuse in the industry (Cole, 2010). In Ireland the construction industry is one of the largest consumers of resources and consequently one of the largest producers of waste annually. Ireland produced almost 3.5 million tonnes of construction waste in 2010 despite being in an economic recession (EPA, 2012). The Irish government has put in place an ambitious target to achieve a recovery rate for construction and demolition waste of 85 per cent by 2013 (DoEHLG, 1998) and the Draft Statement of Policy 2011 sets a target of 90 per cent by 2016 (EHLG, 2011). The Waste Framework Directive and the Waste Management Act are two major pieces of legislation in place in Ireland that set out the policies in place in order to achieve these targets. The focus must now be on the actual waste management and minimisation if these legislative improvements are to be maintained and national targets for construction and demolition waste recovery are to be achieved.

Teo and Loosemore (2001) examined the attitudes of construction operatives towards construction and demolition waste reduction. In this thesis the attitudes of the main contractors will be assessed to develop an understanding of their opinions and policies towards waste management. On site observations of the waste in the skip will be used to assess the quantity of waste being sent to the waste recovery facility. There are various methods used to measure construction waste and in this thesis direct observation will be used similar to Formoso et al., (2002). Formoso et al (2002) directly observed the waste production on a site in a period of four to five months and gathered data. This observation involved site visits to determine the causes and quantities of waste being produced on the site aswell as the methods of delivery.

Research into waste management measures to reduce waste at project level has also been carried out. Previous studies have shown that there are a number of variables that affect waste production including design changes, investment in waste management, government regulations, space constraints on site, construction technology and the waste management culture in the organisation. Changing the design during the construction phase is seen as a large producer of waste. Up to 33 per cent of construction waste could be related to the project design (Osmani et al., 2008). Studies carried out by Jaillon et al., (2009) and Esin and Cosgun (2007) have shown that the use of low waste construction techniques such as off-site fabrication and modularisation can significantly reduce on site waste production.

This dissertation will examine a number of different aspects in relation to construction and demolition waste and then discuss the possible solutions to the problem.

1.3 Thesis Statement

This thesis is entitled, *"Implementing a site waste management plan – a case study of a medium sized building contractor in Ireland."*

Materials and resources are vital in terms of supporting the construction industry (Knoeri et al., 2011). However, a number of materials used in the industry are non-renewable and it is now important that the industry starts a shift towards the sustainable reuse of waste and the use of recycled materials on construction and demolition projects (Rao et al. 2006). The Irish government has set a target of the recovery of 85 per cent of construction and demolition waste by 2013, as outlined in the *'Changing Our Ways'* document in 1998 (DoEHLG, 1998). Targets set out in the EU Waste Framework Directive (2008/98/EC) state that member states must by 2020 recycle 70 per cent by weight for construction and demolition waste (European Parliament, 2008).

In order to achieve these targets a radical change in attitudes, design considerations and on site waste management is needed. Developing and setting up markets for construction and demolition waste is also vital to achieve the targets outlined above (Duran et al., 2005). This can help Ireland's construction industry to become more sustainable and also help to meet the ever increasing appetite for materials and resources on construction projects (Just et al., 2004).

1.4 Background to the study

The construction industry is now becoming aware that it has an important role to play in the minimising of waste production (Osmani, 2012). The level of waste produced needs to be reduced for environmental and economic reasons (Coelho and de Brito, 2011). The positive impacts of construction are well publicised but the negative environmental consequences receive a lot less attention. It is now realised that waste produced has a value and that the contractor can either save money from producing less waste or recycle the waste to generate an income (Dhir et al., 2004).

The motivation for this thesis is due to the emphasis on environmental issues in the last number of years and the need for the construction industry to realise that it also has negative impacts on the environment and that these impacts need to be avoided where possible. The key players need to understand and implement waste management and minimisation strategies in order to reduce waste generation. If a company can reduce its waste and thus benefit from lower construction costs and higher productivity, it can then become more competitive (Cheol et al., 2010; Damnjanovic et al., 2008).

1.5 Statement of the problem

A lot of construction waste ends up in landfills (44,621 tonnes was disposed at EPA licensed landfills in 2010) and there is an increasing concern for landfill capacity in Ireland (EPA, 2010). At the current rate 15 of the 28 active landfills in Ireland will close in the next three years. The remaining national capacity is 12 years (EPA, 2012). Waste from construction may contain solvents and chemicals that result in soil and water pollution (Fehrs, 1996). There is a solution to this problem as many of the materials discarded can be recycled into the same product or into other usable products. Unfortunately reprocessing materials for recycling is not always economically viable unless the facility that is recycling the materials is located close to the waste production source (Tam and Tam, 2006). This is difficult in Ireland because of the dispersed layout of the towns and villages around the country. The present context in relation to waste management demonstrates an urgent need to reduce construction waste in Ireland (EPA, 2011). According to the waste hierarchy reuse is imperative and it is also one of the most effective means to achieve waste reduction and carbon savings (second only to the prevention of waste through design and the minimisation of waste). If the waste cannot be reused or recycled then we must focus on waste minimisation and the tools required in achieving this. This will stop materials ending up in landfill and minimise environmental impacts.

1.6 Target audience

This thesis is targeted at medium sized companies who may not have any waste management procedures in place and are interested in doing so. When this thesis is read it will give the reader the knowledge required to successfully implement good practice waste management on site. In addition the thesis aims to achieve national relevance and add to the quantity of literature available on the topic of construction and demolition waste management. Using this approach it is hoped that the results will provide a waste management tool to both Carey Developments Ltd and other medium sized construction companies in Ireland.

1.7 Identification of the knowledge gap

Previous research carried out in GMIT has looked at construction and demolition waste management through designers and sub-contractors but not through main contractors and specifically the attitudes towards waste management by the main contractors. The main knowledge gap that is addressed in this thesis is the absence of suitable markets for construction and demolition waste. Based on the literature review it was found that a gap in knowledge includes a failure to examine to what extent main contractors are implementing waste management plans in accordance with Irish legislation on site, a failure to consider the ultimate destination of the waste by main contractors and a failure to encourage employees to minimise waste on site.

1.8 Research problem

Typically in Ireland the main contractor purchases the materials and then provides the materials to the sub-contractors to be used in the construction of the project. There is a problem however once these materials are passed on it is often the case that the materials are not used effectively by the sub-contractor on site (Teo and Loosemore, 2001). There is a need therefore to develop a waste minimisation plan for the case study contractor, Carey Developments, to work towards their aim of reducing waste production on site.

1.9 Research question

How can a medium sized construction company in Ireland implement and develop waste management both within the company and practically on site in order to deliver economic, social and environmental benefits?

1.10 Aims and objectives of the thesis

The primary aim of this thesis is to examine the waste hierarchy opportunities that are available for construction and demolition waste in Ireland and to examine the effects of management strategies on construction and demolition waste reduction at the project level. A partnership has been developed with Carey Developments Ltd in Co. Galway and an analysis of their waste management practices will be undertaken. The primary case study will be the ‘Taylors Hill’ project in Co. Galway where work commenced in March, 2012. The secondary aim of the thesis is to develop specific waste minimisation strategies for the company and to develop a training tool kit for use on site.

The objectives of the study are to:

- Carry out a literature review of current waste management legislation along with waste management practices focusing on prevention, minimisation, reuse, recycling and disposal/ treatment.

- Make an assessment of waste management practices on the selected case study. This will include on site audits to determine the amount of waste being produced and the associated causes.

- Carry out a national online questionnaire of main contractors in order to determine their attitudes and knowledge of waste management.

- Investigate the market availability for construction waste in Ireland.

- Enable Carey Developments Ltd to engage in a more resource efficient approach to waste management.

1.11 Thesis hypothesis

The hypothesis for the thesis is *‘Implementing a waste management plan – A case study of a medium sized building contractor in Ireland.’*

The scope of the thesis is limited to Construction Industry Federation (CIF) registered contractors under the heading of general building and civil engineering. This is because the quality of the data that will be obtained from these contractors in the survey is expected to be of a high quality since these companies are more likely to employ professionals with a good knowledge of the subject matter. However, it must be noted that the findings and results are not only restricted to this group in particular. The purpose of this thesis is to evaluate and investigate the different approaches and strategies that can be used for waste management in the construction industry. The methods must be laid out logically and be easy to understand as well as be cost efficient.

1.12 Research methodology

This thesis concentrates on the possible waste management strategies which a company can use to successfully implement good practice waste management. The initial research found that the construction and demolition waste topic is a worldwide issue with research being compiled constantly in order to help contractors implement successful waste management strategies. The initial stage of research involved a review of the legislation, theories and studies related to construction and demolition waste management. This research revealed that while good practice waste management is challenging, it is however an achievable goal.

Both primary and secondary research was carried out during this study. The research strategy comprises the collection of secondary and primary information on the issues and solutions to waste management in Ireland and a practical application through the case study. In order to further develop arguments some of the findings from the questionnaire are woven into each chapter and discussed where relevant. The secondary research forms part of the literature review and the primary research focuses on the Carey Developments case study and the questionnaire. With the aid of both methods of research the thesis hypothesis will be investigated. The thesis will be considered successful if the author can help to implement waste management practices and develop a learning toolkit for Carey Developments. The literature review in the following chapter describes the secondary research that was carried out for this thesis. Secondary data was collected for the literature review in order to obtain an understanding of the current legislation and practices of waste management in Ireland. Numerous journal papers, books and guidance documents have been written on the issue of waste management in construction as well as the environmental effects that construction causes. Following the completion of the secondary research the author gained a good knowledge in relation to waste management practices in Ireland. Following this the author could identify where the problems are occurring and work towards providing answers to these problems.

This thesis used both qualitative and action research methods. The qualitative research method is often used at the early stages of a research project when the researcher knows what they are looking for. The aim for this type of research is to develop a detailed description of the chosen topic and as the data is gathered a clear goal emerges. The qualitative method of research is subjective and the interpretation by an individual is important (Miles and Huberman, 1994). Qualitative information helps to develop an understanding of what people think about a specific topic. This research method is not standardised and it can use a variety of formats including interviews and questionnaires. The qualitative method identifies the information required to solve the problem and helps generate ideas on how to do so. As well as this, this method of research allows the author to see the topic from the perspective of the people that it involves and allows for information to be gathered about the opinions and behaviours of the authors target audience. The second method of research adopted in this study is 'Action Research'. Action research is used to solve an immediate problem by individuals working with others to improve the way issues are addressed and problems are solved. Action research involves actively participating in an organisation where change will take place whilst conducting research (O' Brien, 1998). Action research is used in real situations because its primary objective is to solve a real life problem. Action research is often applied when academics are invited into an organisation by the stakeholders who are aware that a problem exists but they lack the requisite knowledge to deal with it. This is the case in the instance of this thesis.

With the use of both methods of research and the literature review the author is then better placed to successfully complete the dissertation. The questionnaire allows the author to gain an insight into the industries attitudes and the case study allows the author to gain a practical knowledge of on-site practices. The literature review provided a significant amount of information relating to the subject matter and helped to identify the main drivers and barriers that affect construction and demolition waste management in Ireland. Based on the literature review and other research the author will make a proposal on how to implement waste management practices within a company.

1.13 Research limitations

The use of a questionnaire provided a good insight into the current attitudes of main contractors towards waste management in Ireland. There were however a number of limitations which were incurred during the use of the questionnaire. The main research limitation for this questionnaire was the number of respondents to the survey. Unfortunately the quantity obtained was not significant enough to enter the results into a statistical package as it was felt that the results would not be accurate. Instead it was decided to briefly analyse the answers and draw some conclusions. It is considered that this survey has provided a good snapshot of current industry practice in relation to attitudes towards waste management by main contractors. It is a common limitation for surveys not to be answered online and considering the amount sent out the response rate is considered good. However the research into main contractors attitudes will be on going after this thesis is finished so more responses will be gathered so that the results can be analysed statistically. Another limitation is that the majority of respondents were managerial staff within the company so the answers may be biased. Due to the number of respondents it is considered that the conclusions reached should not be considered definitive but could be used as a basis for further study within the area.

Another research limitation was the observations carried out on site were only specific to one site. If a larger number of sites were monitored then it would be possible to gain a better insight into current waste management practices being carried out by main contractors. Despite these limitations it is felt that this thesis has provided an accurate account of current attitudes and practices and has also outlined some possible solutions to the problems encountered.

1.14 Questionnaire

A questionnaire survey is adopted as a means to explore the problems within the industry and then apply this to the case study used for this thesis. The use of a questionnaire survey allowed for the fast and efficient gathering of information on waste management from within the industry. A questionnaire was formulated by Hands (2011) and it was used to collect primary data from main contractors in Ireland and was formulated in a way as to gain an insight into the attitudes that main contractors have towards waste management. Any information provided is confidential and the contractors are not singled out in the thesis. In relation to the thesis hypothesis it was decided that a questionnaire would provide a good insight into the industries attitudes and opinions towards waste management and is also seen as a critical part of this study. In an attempt to generate a high response rate possible contributors to the online survey were first contacted by phone. This method encourages respondents to fill out the thesis once it is sent to them as they have had a point of contact with the researcher. Often sending a questionnaire to the company's general email will fail to generate a response so this initial phone call was seen as an important tool in generating a good response rate. The questionnaire was hosted on an external website and the respondents were contacted by email and provided with the link. The questionnaire also came with a short description of the reasons for the questionnaire and contact details in the event that further information was required by the respondent. In a further attempt to generate a good response rate reminder emails were also sent out. The use of email improves the speed at which data can be collected and also cuts out the costs of postage and printing. The questionnaire was sent out during the development of the literature review so that the data could be collected early on in the research phase. This gives the author a better idea of the problems that need to be overcome in the industry in order to implement good practice waste management. In regards to the thesis hypothesis the questionnaire provided valuable information into the industry's viewpoint and is seen as a crucial part of this study.

1.15 Case study

A case study was also used in order to apply the educational side of the thesis to a practical example. The case study assisted in gaining a better insight into the waste generation behaviours on site by both the main contractor and the sub-contractors. The case study will provide a substantial quantity of information to this thesis. The case study allows the author real world practical experience on site monitoring the generation of waste and providing solutions to the contractor. The aim of the case study is to help Carey Developments develop their waste management strategies and help them achieve their goal of producing a waste management plan in line with industry good practice standards.

1.16 Definition of waste

The definitions used when discussing waste are sometimes confused and used interchangeably. For the purpose of this thesis the definitions stated in the ICE Demolition Protocol will be used (ICE, 2008). The definitions are outlined below;

Recover*; "A generic term which means that a material, product/component is managed by a defined process so that it either does not become waste, or is taken out of the waste stream."*

Reuse; *"Buildings/ infrastructure, products, components etc. recovered for use without reprocessing activities or alterations to their characteristics. In situ reuse could refer to the refurbishment of a building, involving the reuse of the steel frame, without any disassembly. Ex situ reuse is synonymous with reclamation, and involves the disassembly or removal of products/components prior to their reuse."*

Reclaim; *"Refers to the removal of products/components from a building or structure, with the aim of subsequently reusing them."*

Recycle; *"To take a product/component (e.g. concrete block) and, because of the nature and characteristics of its constituent material, put it through a reprocessing activity. The output will be a material which can then be used in a range of products and applications, including its previous use."*

Deconstruct; *"Synonymous with 'reclaim' and typically referring to the action of disassembling products/components as part of an overall approach to managing entire elements of a building (e.g. the roof, walls etc.). 'Design for deconstruction' is the commonly used term to describe how the end of life of a building/structure is considered at the outset - to ensure the future ease of disassembly for components/elements."*

There are a number of definitions used to define waste and these are outlined below;

According to the Basel Convention waste can be defined as;

"Wastes are materials that are not prime products (that is products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded"

(OECD/Eurostat, 2005).

"Wastes are substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law"

(Basel Convention, 1992).

The waste framework directive 1991 defines waste as;

"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"

(European Union, 2006).

The European Waste Catalogue 2002 defines waste as;

"Any substance or object which the holder disposes or is required to dispose, which arise from construction, renovation or demolition activities"

(EPA, 2002).

The Waste Management Act 1996 defines waste as;

"In this Act, waste means any substance or object belonging to a category of waste specified in the First Schedule or for the time being included in the European Waste Catalogue which the holder discards or intends or is required to discard, and anything which is discarded or otherwise dealt with as if it were waste shall be presumed to be waste until the contrary is proved"

(Waste management act, 1996).

According to the European court of justice,

"It is immaterial to the legal definition of waste whether a substance or object may have a commercial value or is capable of economic re-utilisation"

(Defra, 2009).

The Organisation for Economic co-operation and Development (OECD) state 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 self-sufficient beneficial use"

(OECD, 1998).

The EPA in Ireland use the definition outlined in the *'European Waste Catalogue.'* Almost all of the definitions, except the OECD statement, classify waste as exactly what it is – a waste product destined to be discarded. However a lot of waste produced in the construction industry has a value (CSCE, 2011) and the definitions need to state that this may be the case.

A report by Symonds et al in 1999 provides a different interpretation. It states that the destination of the material is the decisive factor not the fact that it is to be discarded;

"Products and materials destined for reuse and recycling are not identified as waste"

(Symonds et al, 1999).

For the purpose of this thesis the Symonds et al. (1999) definition of waste will be used. This is a more pragmatic view, moving away from the tradition of sending valuable waste to landfill. If products and materials that were destined for landfill are now sent for recycling and reuse, what do these materials become? The answer is that they are no longer a waste but a product or material that has a monetary value to the client or contractor. However (Standbury and Thompson, 1995) warned that if waste is eliminated it is also costly, therefore it may be more beneficial not to achieve a concept such as zero waste but to focus on reducing and minimising construction waste.

Waste management is the collection, transport, processing and disposal of waste materials (OECD, 2005). The term refers to materials produced by human activity and it is undertaken to reduce the effect on the environment. Waste management is a separate practice to resource recovery, but the two should go hand in hand in the construction industry. Resource recovery focuses on delaying the rate of consumption of the planets natural resources. Resource recovery uses a life cycle analysis in an attempt to offer an alternative to waste management.

The most important factor for on-site waste management is the on-site segregation of the waste. If this process fails then it becomes difficult for the waste to be recycled. At the outset this will take some extra time and training of the construction staff but once the segregation habits are established the waste segregation on site can be done at a small or no additional cost (Begum et al., 2006). For construction waste numerous studies have been carried out in relation to waste management both on and off site. An important method of waste management is the prevention of waste being created also known as waste minimisation. There are numerous methods of avoidance and these will be explored in the thesis.

1.17 Summary

The construction industry has a potential adverse effect on sustainable development and the large amount of waste produced is a big problem, and because of this there is a need to minimise waste. This chapter introduced the thesis and after a background to the thesis, waste was defined and the problems were identified. The aims and objectives along with the research methodology were also outlined. The next chapter will look at current and future waste legislation as well as current waste arisings in Ireland. The waste hierarchy and the barriers to waste management will also be discussed.

2.0 Chapter two – Waste legislation in Ireland

2.1 Aims and objectives

The previous chapter provided a background to the study and outlined the authors' main aims and objectives. This chapter contains information on the relevant waste legislation in both Europe and Ireland and including the waste hierarchy. Waste legislation dictates the way waste should be managed and disposed of by some form of waste management and the legislation applicable to construction and demolition waste is discussed in this chapter. The quantities and arisings of construction and demolition waste in Ireland are outlined along with the remaining capacity of landfills in Ireland and the applicable levies to landfill waste. Finally the implications of construction and demolition waste are stated along with the barriers to implementing good waste management practices and minimisation.

This chapter will give an insight into the:

- Waste management framework in Europe and Ireland.
- Waste hierarchy.
- Enforcement of waste legislation.
- Quantities of construction and demolition waste in Ireland.
- Landfill capacity.
- Landfill levy.
- Construction waste arisings.
- Implications of construction and demolition waste.

2.2 Introduction

'Ireland's Environment 2012 – An Assessment' carried out by the EPA every four years provides an outline of the state of the environment in Ireland and the pressures currently being placed on it. Since the previous report in 2008 there have been a number of legislative and policy changes in relation to waste and also sustainable development. The report states that the effects of the recession and property market collapse have meant a dramatic reduction in the quantity of construction and demolition waste being produced.

The volumes in line with the economic downturn have seen construction waste volumes decrease by 81 per cent since 2007. The assessment also states that current raw material consumption in the EU is 16 tonnes per person per annum with 6 tonnes of these materials ending up as waste and consequently 3 tonnes of this waste is being sent to landfill. The overall findings of the assessment are that Ireland's environment is in good condition but that there are a number of areas for concern, namely; the lack or underdevelopment of waste infrastructure in a number of regions across the country. The reports final statement is that the current recession has meant that some waste quantities have been reduced and this should not be confused with environmental management progression. What is needed now is for Ireland to further develop its waste infrastructure so that when Ireland's construction industry sector begins to develop and recover that waste is managed in a sustainable way (EPA 2012).

2.3 Waste management framework in Europe

2.3.1 European community strategy for waste management 1989

The European Commission initially set out its waste policy in the European Community Strategy for Waste Management of 1989 (SEC (89) 934 Final 1989). This document forms the cornerstone of European waste policy. As well as many detailed measures, the strategy contains the following points:

- Confirmation of the 'Proximity Principle'. This requires that waste is dealt with as near as possible to its source.

- The establishment of a waste management hierarchy. The waste hierarchy sets out the most favored options of waste management in a pyramid shape showing the most favored option (prevention) at the top and the least favored option (disposal) at the bottom.

The European Union Waste Framework Directive in 1975 first introduced the concept of the waste hierarchy and in the European Commission's Community Strategy for Waste Management in 1989 it was formed into a hierarchy of waste management options. Further to this the hierarchy was endorsed in the Commissions review of this strategy in 1996. This traditional waste hierarchy prioritises the prevention and reduction of waste, and then followed by reuse and recycling and the final option being disposal.

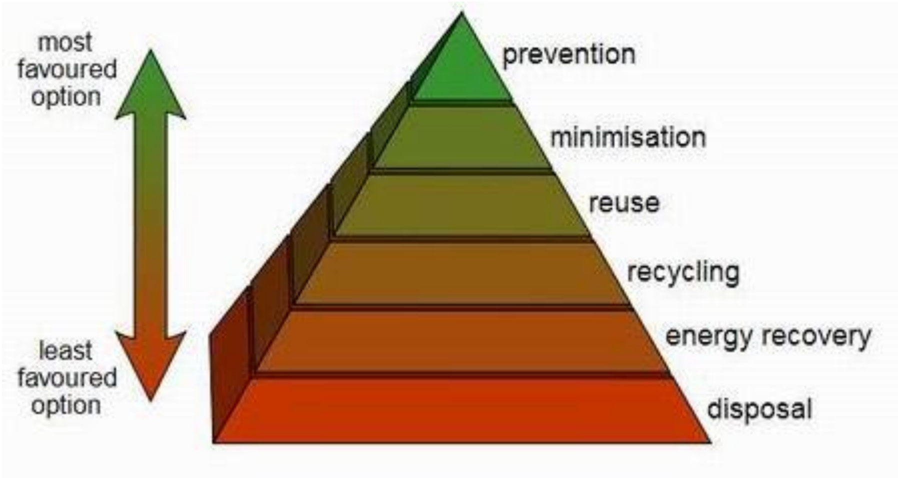


Figure 2.1 Waste hierarchy (Source: European commission, 1989)

If the waste hierarchy is followed then waste should be reduced at source and where waste cannot be prevented the waste materials should be reused or recycled. If this is not possible the next option is to recover the energy content from the materials. Only if none of these options are available should waste be sent for disposal and this disposal should be done in a controlled and authorised way. Applying the waste hierarchy to construction waste means that waste materials should be managed in a way that protects both people and the environment. Human health, safety and security should be considered along with any environmental decision making. When undertaking waste management it is important that the contamination of waste streams with hazardous waste is prevented.

During the past the waste hierarchy has taken different forms but the most basic concept is still the basis for most waste minimisation strategies. The main aim of the hierarchy is to extract the maximum benefits from products and to generate the minimum amount of waste possible. Price and Joseph (2000) state that the reality of the waste hierarchy is that it is a prescriptive approach and that the hierarchy does very little to alleviate the over reliance on end of the line solutions. They believe that if more regard was given to the development of efficient processes and demand management that it would reduce resource and energy usage and impact directly on waste generated. The waste hierarchy was initially developed to focus on high population areas such as the core of the EU. Barrett and Lawlor (2010) found that the application of the waste hierarchy in areas of low population density may place an unnecessary economic burden on that region. The study found that landfill is significantly cheaper in these low population industries and consequently cheaper than the alternative methods. In conclusion they found that landfill should not be excluded as a disposal option in areas of low population density. This scenario is applicable to certain areas of rural Ireland where the waste recovery facilities are a considerable distance from the waste source.

Subsequent to the establishment of the European Union in 1993, a revised version of the strategy was adopted by the commission in July 1996. This strategy included the following amended points:

- Energy recovery may in some cases be environmentally superior to recycling within the hierarchy.
- 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 will be incorporated in all future measures.
- The Commission will come forward with proposals to control landfill.

(European Commission, 1989)

2.3.2 Council Directive 91/156/EEC amending Directive 75/442/EEC on waste

The aim of this directive is to encourage the recycling and reuse of waste as raw materials. The directive includes the following objectives to be attained:

- The prevention or reduction of waste production and its harmfulness.

- The recovery of waste by means of recycling, reuse or reclamation or any other process with a view to extracting secondary raw materials, or the use of waste as a source of energy.

- The use of clean technologies to achieve its aims.

- Waste management plans to be drawn up.

Further provisions were added to Directive 75/442/EEC:

"In accordance with the polluter pays principle, the cost of disposing of waste must be borne by the holder who has waste handled by a waste collector or by an undertaking as referred to in article 9, or the previous holders or the producer of the product from which the waste came (art. 15)."

"In accordance with article 4, waste must be disposed of without endangering human health and without the use of processes or methods likely to harm the environment."

(European Union, 1991)

2.3.3 Council Directive 2006/12/EC

This directive replaces the Directive 75/442/EEC as subsequently amended. The directive clarified and consolidated the legislation but did not change the content of the applicable rules. This directive was repealed by Directive 2008/98/EC on 12th of December 2010 (European Union, 2006).

2.3.4 Developments prior to the Waste Framework Directive

In 1991 the European Commission initiated the priority waste streams programme for six waste streams. One of these was construction and demolition waste. In 1992 the Commission invited some 80 specialists from a wide range of organisations and groups to join the construction and demolition waste project group. The key principles adopted by the project group for guiding the strategy were:

- To conserve natural resources.

- To reduce the quantities of waste for final disposal.

- To reduce the environmental harm caused by waste.

(European Union, 1991)

In 1995, the Symonds project group published a series of reports, making 55 recommendations for action to improve the management of construction and demolition waste.

Following the issue of the project group report, the European Commission funded a study by the Symonds consultancy group which was published in 1999. The Symonds report of 1999 describes the best practices of construction and demolition waste management in the EU member states, as well as the economics associated with the re-use and recycling of this type of material. Chapter 8 of the Symonds report details the range of measures used within the member state countries to promote the re-use and recycling of C&DW and also provides an indication of their effectiveness (Symonds et al, 1999).

In 2001, Task Group 3 as part of the sustainable construction working group published a number of recommendations in relation to C&DW management. These included:

- Designers and producers should develop policies with regard to prevention.

- Where specifications permit, the designer and contractor should be encouraged to favour the use of reused/recycled materials.

- The industry should agree to adopt acceptable Key Performance Indicators (KPIs).

- Governments are recommended to draw up national Waste Management Plans (WMP).

- All member states should report annually on targets, waste data and standards.

- All member states should implement the landfill directive.
- The European commission should use the classifications from the European waste catalogue.
- C&DW derived materials produced for use must be considered as products, not waste.

(Working Group for Sustainable Construction, 2001)

In December 2005 the commission published a communication on the *'Thematic strategy on the prevention and recycling of waste.'*

The main objectives from this report are:

- Modernise by bringing new environmental thinking into waste policy.
- Improve the regulatory environment, i.e. clarify and simplify.
- Reinforce the waste recycling market.
- Put prevention policies into action.
- Harmonisation of waste statistics and LCA.

Progress towards the objectives set out in the strategy have been reviewed in a report on the thematic strategy on waste prevention and recycling adopted on the 19th January 2011 by the commission. It includes the main actions taken by the commission, the main available statistics on waste generation and management, a summary of the main forthcoming challenges and recommendations for future actions (European Commission, 2011).

2.3.5 Waste framework directive 2008 98/2008 EC

The waste framework directive repeals the previous 2006 directive on waste as well as Directives 75/439/EEC and 91/689/EEC regarding waste oils and hazardous waste respectively. The revised waste framework directive sets out provisions to boost waste prevention and clarifies the key concepts and definitions.

The waste framework directive 2008 was entered into Irish law in March 2011. The directive sets out the concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It also explains when waste ceases to be waste and becomes a secondary raw material (so called end-of-waste criteria), and how to distinguish between waste and by-products.

The Directive lays down some basic waste management principles, these include:

- It requires that waste be managed without endangering human health and harming the environment.

- Waste legislation and policy of the EU member states shall apply the waste management hierarchy.

- The directive introduces the polluter pays principle and the extended producer responsibility. Extended producer responsibility might include an acceptance of returned products and of the waste that remains after those products have been used, as well as the management of the waste and financial burden for such activities.

- It includes a new target for re-use, recycling and other recovery of 70 per cent of construction and demolition waste by 2020.

- The directive requires that member states adopt waste management plans and waste prevention programs.

A new waste hierarchy was set out in Article four of the Waste Framework Directive and is, as before, the priority order for waste management. The hierarchy lists five ways of dealing with waste (although prevention is technically not a waste management method because it concerns objects before they become waste). The following figure illustrates the new waste hierarchy;

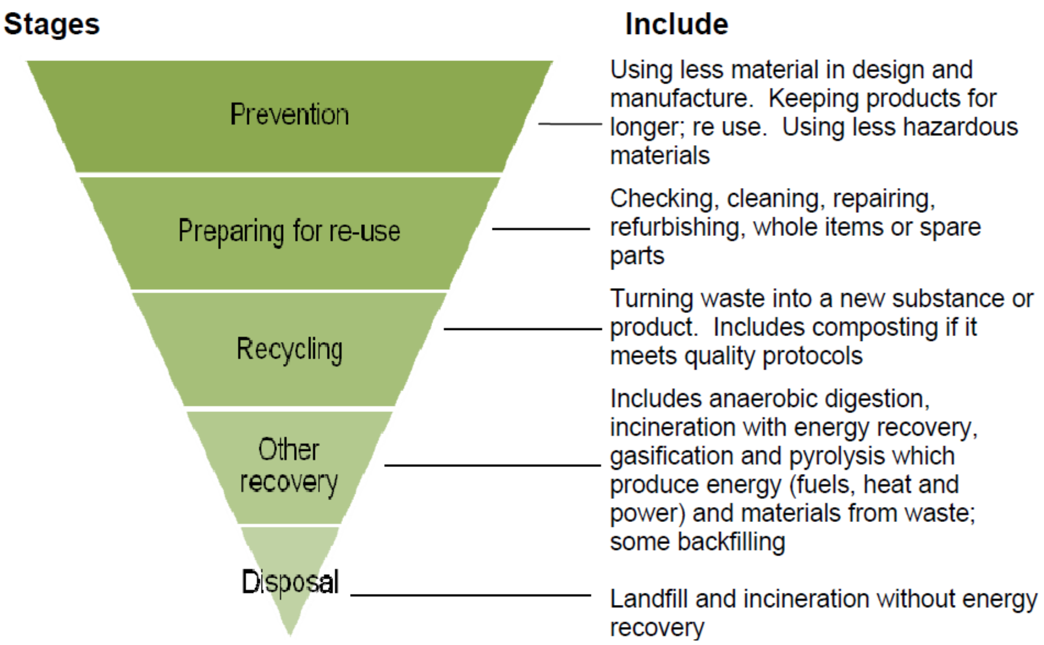


Figure 2.2 Waste Hierarchy WFD (Source: Defra.gov.uk)

There are a number of changes in comparison to the previous waste hierarchy as laid out in the 2006/12/EC Directive. The former waste hierarchy was expanded to five steps and 'preparing for reuse' was added as a new concept. The previous legislation ranked preparation for reuse, recycling and recovery as equal but this new hierarchy distinguishes between these and now ranks preparing for reuse above recycling and recovery. It is now mandatory for Member States to apply the waste hierarchy and the options that deliver the best environmental outcome must be considered. In the third paragraph of Article 4(2) of the WFD it states that;

"*Member States shall take into account the general environmental protection principles of precaution and sustainability, technical feasibility and economic viability, protection of resources as well as the overall environmental, human health, economic and social impacts when applying the waste hierarchy.*"

(European Parliament, 2008).

As well as this Articles 28(1) and 29(1) of the WFD emphasise that waste management plans and waste prevention should be established in accordance with the waste hierarchy. (European Parliament, 2008) Although the concept of the waste hierarchy is nothing new, in the past there was no obligation on Member States to encourage it, now under the Waste Framework Directive 2008 it has become mandatory.

2.3.6 Guidelines on the interpretation of Directive 2008/98/EC on waste

This guidance document has been published to explain the key provisions set out in the waste framework directive and while it is not legally binding it is important as it provides information on the interpretation of the directive. Since the application of the directive many questions have been raised regarding its application and interpretation. This document was intended to assist authorities and stakeholders with the previously mentioned Waste Framework Directive.

The revised Waste Framework Directive has been a source of contention for many in the recycling industry as many were worried about the stance regarding the separation of waste prior to collection. In section 4.3.3 it states that;

"Co-mingling is permissible only when either member states or local authorities have demonstrated that separate collection of waste is not technically, economically and environmentally practicable."

(EC, 2012)

Separate collection is defined under Article 3 (11) as;

"A collection where a waste stream is kept separate from waste of a different type or nature, so as to facilitate a specific treatment."

(EC,2012)

While this separate collection is not directly targeted at construction waste it may be paving the way for future legislation that will require source segregation of construction waste. The rationale behind separate collection is stated as being;

"In line with the objective of helping move the EU closer to a recycling society, and as a means to facilitating or improving its recovery potential, waste should be separately collected before undergoing recovery operations that deliver the best overall environmental outcome."

(EC,2012)

As well as this it states that if hazardous waste is removed from waste streams then it may contribute to achieving environmentally sound waste management. Therefore it can be found that separate collection (or source segregation) can facilitate better recovery and recycling opportunities and improve the quality of the recovered products. Recital 28 of the Waste Framework Directive calls for the separation of waste when it is generated for the first time rather than trying to separate mixed waste. In practice on construction sites this would involve source segregation followed by separate storage and transport as well as enforcing a ban on mixing waste on site. In Article 10 (2) of the directive member states are encouraged to separate waste to improve recovery possibilities. It states that this provision applies to all waste streams and that the precondition for this is that separating the waste is;

"Technically, environmentally and economically practicable."

(EC, 2012)

As previously stated the legislation discussed here is currently not specifically aimed at the construction industry but the points outlined above show that source segregation where feasible has numerous benefits.

2.3.7 International review of Waste Management policy 2009

According to this report the recovery of C&DW is reported by the EPA at 72 per cent, though the rate is very different for soil and stones (81 per cent) to that for other materials (44 per cent). Recommendation 6 of the report outlines the target rates for C&DW. These targets are:

- 75% in 2010
- 80% in 2012

- 85% in 2014
- 90% in 2016

These targets are the levels to which Ireland should aspire to and it should be recognized that these targets can be achieved. Section 6.3 of the report concerns refunded compliance bonds for construction and demolition projects. A compliance bond would require a contractor to pay a monetary sum to the local authority; this sum would be related to the size of the project in addition to an administrative fee. The financial sum would be retained by the local authority as a bond to ensure that the project exceeds a specified recycling rate. All of the bond excluding the administrative fee would be returned on demonstrating that the desired recycling rate had been met. In the event of partial compliance, a proportion of the bond would be refunded.

Recommendation 7 of the report states that a site waste management plan would be mandatory within the parameters set out in the Planning and Development Act 2000, and that the plans should demonstrate that the following recycling targets will met:

- 80% in 2011
- 85% in 2012
- 90% in 2014
- 92% in 2016.

(DoEHLG, 2009)

2.3.8 A resource-efficient Europe – Flagship initiative of Europe 2020 Strategy

This strategy supports the Europe 2020 strategies aim to shift to a resource efficient, low carbon, sustainable construction economy. The report states that continuing with our current use of resources is not an option and that increasing resource efficiency is the key to securing jobs and economic growth. Improving resource efficiency will improve competitiveness, lower costs and improve productivity.

2.3.9 Sustainable competitiveness of the construction sector 2011

This report was initiated in 2010 by the European Commission to analyse the needs of the construction sector and investigate the feasibility of launching a renewed agenda for the construction sector under the Smart Growth Agenda 2020. The Europe 2020 strategy sets out the future framework for construction under three priorities;

Smart growth: This means developing an economy based on innovation and knowledge.

Sustainable growth: Promoting a greener, more competitive and more efficient economy.

Inclusive growth: Foster a high employment economy that delivers social and territorial cohesion.

In the medium to long term the construction industry will need to adapt to future climate risks and future competitiveness strategies will need to address the environmental and social challenges both in the EU and globally.

2.3.10 EU Material resources and waste - 2012 update

This document states that 32 per cent of Europe's total waste is construction and demolition waste and that this figure is closely related to economic activity within the sector. It is also stated that this waste contains mainly inert materials and to a lower extent other materials such as wood, metals and plastics resulting in a generally low impact on the environment per tonne of waste. The data presented shows that in 16 out of 20 EU countries, construction waste quantities increased between 1995 and 2006. However the economic downturn is now likely to have reduced these quantities but reliable data is not yet available (EEA, 2012).

2.3.11 European Union – Roadmap to a resource efficient Europe

In recent years the sustainable use of resources and the management of waste with an emphasis being placed on prevention and recycling has moved up the ladder of the EUs environmental policy agenda under the heading of resource efficiency. Currently the economy in Europe is dependent on a large amount of natural resources in order to function. It is estimated by the European Environment Agency that 20-30 per cent of the resources that we use in Europe are imported from other countries. It is also predicted that as countries recover from the economic recession there will be an increase in material usage. At current usage rates the natural resources of the world are in danger of being over exploited and may lead to an eventual collapse of the availability of these resources (EEA, 2012).

The EU is currently aiming to become a recycling society and become better at managing its resources efficiently. Europe 2020 is the EU's growth strategy for the coming decade and the aim of the strategy is to make the EU's economy a smart, sustainable and inclusive economy. In the recent past the sustainable use of resources has moved up the European Union's policy agenda under the title of resource efficiency. According to the *'Roadmap to a Resource Efficient Europe'* the term resource efficiency means;

"Allowing the economy to create more with less, delivering greater value with less input, using resources in a sustainable way and minimising their impacts on the environment."

(EC, 2011)

If we consider resource efficiency in economic terms it is about creating more outputs with fewer inputs, in ecological terms it can be considered as using resources sustainably while maintaining ecosystems and its functions. In social terms resource efficiency can be viewed as minimising the impacts of resource use on people's health and sharing the benefits of resource use for welfare, wealth and quality of life.

The *'Thematic Strategy on the sustainable use of natural resources'* (EC, 2005) and the *'Thematic Strategy on the prevention and recycling of waste' (*EC, 2005) set out measures that are designed to achieve resource efficiency. The Waste Framework Directive of 2008 then implements these measures by placing them into European Law. The EU Sustainable Strategy 2006 stated that improving resource efficiency would:

"…reduce the overall use of non-renewable natural resources and the related environmental impacts of raw materials use, thereby using renewable natural resources at a rate that does not exceed their regeneration capacity."

(EU, 2006)

The strategy acknowledged the challenges in achieving better resource efficiency and stated one of its key objectives as being to;

"Safeguard the Earth's capacity to support life in all its diversity, respect the limits of the planet's natural resources and ensure a high level of protection and improvement of the quality of the environment. Prevent and reduce environmental pollution and promote sustainable consumption and production to break the link between economic growth and environmental degradation."

(EU, 2006)

The Sixth Environment Action Programme (6EAP) state that the adoption of the Europe 2020 strategy which contains resource efficiency as one of its top priorities;

"Provides new stimulus to develop an economy which is competitive, inclusive and provides a high standard of living with much lower environmental impacts."

(6EAP, 2011)

The Sixth EAP also stated that;

"Europe is a densely populated and an economically advanced continent which means that we use more environmental resources than we produce. This needs to be addressed if the EU is to reduce its contribution to global pollution and resource depletion. At the same time, we are dependent on using the environmental resources of third countries and have a strong interest that these resources be used in a sustainable manner."

(6EAP, 2011)

The *'Roadmap to a Resource Efficient Europe'* was adopted in 2011 and this roadmap aims to address the challenges of resource efficiency through economic innovation, a change in consumption habits, ecological resilience and social cohesion (EC, 2011). The

EUs *'Material Resources and Waste - 2012 Update'* published in June 2012 states that waste management in the EU is improving as less waste is being landfilled and more waste is being recycled or incinerated with energy recovery. This development has been driven by national and EU legislation, for example, by setting targets for waste recovery, imposing landfill taxes and placing restrictions on the waste allowed in landfills. As well as this the rising prices for raw materials and fuels has caused a shift towards recycling and the use of recycled materials.

The report states that globally it is expected that waste generation is expected to grow and along with this waste generation will rise. It is estimated that between 2003 and 2035 that waste generation in the EU will increase by 60 – 84 per cent (EEA, 2012). This is a clear indication that efficient resource use and recycling now need to be two clear goals for the construction industry in Ireland and also globally. It is clear from the documents and legislation being produced by Europe that resource efficiency is an important target for the future. The challenge for the construction industry now is to try and implement resource efficiency on a day to day basis on site. Achieving resource efficiency can be done by; using less resource intensive products, decreasing the energy use in installing these products and using more renewable resources. Some of these changes can be made in the short term while others may require technological improvements in order to achieve long term sustainability.

2.4 Waste management framework in Ireland

2.4.1 National Recycling - Recycling for Ireland

This strategy was published in 1994.The strategy focused on packaging waste, newsprint and organic (compostable) waste. The principle of producer responsibility was adopted, whereby producers take responsibility for the waste produced by their products. However there was no mention of C&DW.

2.4.2 Waste Management Act 1996 S.I. 10/1996

The Waste Management Act, 1996 was enacted in May, 1996. The main objectives of the Act are:

- To organize the functions of public authorities more effectively in relation to waste management.
- Improve performance of prevention and recovery of waste.
- Set out a regulatory framework in response to EU and national requirements.

The 1996 the Waste Management Act was subsequently amended by the Waste Management (Amendment) Act 2001 and the Protection of the Environment Act 2003. These Acts are the legislative basis for all waste management issues (Waste management act, 1996).

2.4.3 Changing Our Ways (1998)

In 1998 the Irish government published *'Changing Our Ways'* – a policy document on waste management. The document focused on the need for a significant reduction in our reliance on landfill, in favor of integrated waste management services and infrastructure that will deliver ambitious landfill diversion and recovery targets.

The document set out a number of targets, these include:

- Development of waste recovery facilities.
- Reduce the number of landfills to a network of 20 state of the art facilities incorporating energy recovery.
- Recycle/ Recovery a minimum of 50 per cent of C&DW by 2003.

- Recycle/ Recovery a minimum of 85 per cent of C&DW by 2013.

The report also stated that;

"A very large quantity of construction waste is being landfilled, despite its potential resource value."

(DoELG, 1998).

2.4.4 Waste Management (Collection Permit) Regulations, 2007 S.I. 820/2007

These regulations provide for the granting of waste permits by local authorities in respect of specified waste recovery and disposal activities. Under these regulations a multi-region waste collection permit has been introduced which removes the requirement for permit holders to hold separate waste collection permits in each region in which they operate and applications can be made to one nominated authority with one application form.

2.4.5 Planning and Development Act 2000 S.I. 30/2000

The planning and development act of 2000 set out specific details of when a construction and demolition waste management plan should be used:

- New residential units if the project is greater than 10 units.
- New developments with an aggregate floor area of greater than 1250m^3.
- Projects generating greater than 100m^3 by volume of C&DW.
- Civil engineering projects producing greater than 500m^3 of waste (1000 tonnes).

(DoEHLG, 2006)

2.4.6 Waste Management (Collection Permit) Regulations 2001 S.I. 402/2000

These regulations are complementary to the Waste Management (Licensing) regulations, 2000. The regulations set out procedures for permit applications, public consultation, consideration by local authorities of public submissions to permit applications, and the grant, refusal and review of permits by authorities.

2.4.7 Waste Management (Amendment) Act 2001 S.I. 36/2001

The Waste Management (Amendment) Act, 2001 was enacted on 17 July, 2001 and its primary purpose was to provide a legal basis on which regional waste management plans could be based. The Act also set a levy on the landfill of waste, at an initial rate of not more than £15 (19 euro) per tonne.

2.4.8 Delivering Change – Preventing and Recycling Waste 2002

This document provides for a range of actions to be taken which will affect the way in which we deal with goods and materials at all stages from production to disposal. This document built on *‘Changing Our Ways’* moving to give authorities more power to tackle the problem of waste. The document also announced the establishment of a national waste prevention programme in the environmental protection agency. The document also outlined details in relation to the landfill levy and producer responsibility.

2.4.9 Protection of the Environment Act 2003 S.I. 27/2003

The protection of the environment act is the second amendment to the Waste Management Act of 1996. This Act made a number of amendments to the 1996 Waste Management Act; this act stated that the review, variation or replacement of a waste management plan should be an executive function. An executive function means that these tasks should be carried out by management or by order of the management.

2.4.10 Waste Management (Licensing) Regulations 2004 S.I. 395/2004

These regulations provide for the continued operation of the licensing by the EPA of waste recovery and disposal activities under Part V of the Waste Management Act, 1996. The regulations set out procedures for waste license applications, reviews of licenses and consideration of objections, including the holding of oral hearings.

2.4.11 Waste Management – Taking Stock and Moving Forward 2004

This document is a review of progress on waste management since 1998 and a program of key points to underpin future progress. The document reviews progress and the continuing challenges in dealing with waste. It envisages the near-term introduction of thermal waste treatment as an alternative to landfill. The National overview of waste management document was published in association with *'Taking Stock and Moving Forward'* and gives details for each of the ten waste management planning regions about the following:

- The waste management plan's projections for future waste arisings.
- The waste management plan's objectives in terms of recycling, thermal treatment and landfill.
- The potential implications of changes for the implementation of the waste management plan.

(DoEHLG, 2004)

2.4.12 The Environment (Miscellaneous Provisions) Act 2011 S.I. 20/2011

The Environment (Miscellaneous Provisions) Act 2011 stated revisions to the Waste Management Act 1996 and in particular, provided greater flexibility in the setting of the landfill levy. The change is driven by the targets set for Ireland in the EU Landfill Directive (1999/31/EC) with regard to the diversion of biodegradable municipal waste from landfill.

2.4.13 European Communities (Waste Directive) Regulations, 2011 S.I. 126/2011

These regulations amended the previous Waste Management Act and transpose Directive 2008/98/EC on waste into Irish Law. These regulations outline some of the duties required from waste producers which are outlined below;

Section 2A (a) states that;

"It shall be the duty of waste producers and holders to ensure that waste undergoes recovery operations in accordance with sections 21A." (Section 21A relates to the waste hierarchy.)

Section 5A (a) states that;

"It shall be the duty of waste producers and holders to ensure that, where recovery in accordance with section 29 (2A) (a) is not undertaken, waste undergoes safe disposal operations which meet the requirements of section 32(1) on the protection of human health and the environment."

Section 33 (1) states that;

"It shall be the duty of waste producers and waste holders to ensure that the production, collection and transportation of hazardous waste, as well as its storage and treatment, are carried out in conditions providing protection for the environment and human health."

Section 34 (1) (a) states that;

"It shall be the duty of waste producers and waste holders to ensure that hazardous waste is not mixed, either with other categories of hazardous waste or with other waste, substances or materials."

2.4.14 Waste Management (Landfill Levy) Regulations 2011 S.I. 434/2011

These regulations increased the landfill levy to €50 per tonne for each tonne of waste disposed of at landfill facilities. The previous rate was €20 per tonne. This change in the landfill levy was first outline in The Environment (Miscellaneous Provisions) Act 2011 which stated revisions to the Waste Management Act 1996 and in particular, provided greater flexibility in the setting of the landfill levy.

There are a number of exemptions to the landfill levy, these are;

- Non-hazardous waste from construction and demolition activity, comprising concrete, bricks, tiles, road planings or other such similar materials, with a maximum particle size of 150mm (used for landfill site engineering purposes).

- Quarrying and mining wastes, chemically unaltered.

- Excavation spoils.

- Dredge spoils.

(Oireachtas, 2011)

On the 1st of July 2012 the Minister for the Environment, Community and Local Government increased the landfill levy from €50 to €65 per tonne under the Waste Management (Landfill Levy) (Amendment) Regulations 2012 S.I. No. 221 of 2012. This charge is applicable to each tonne of waste disposed of at authorised and unauthorised landfill facilities. The Environment (Miscellaneous Provisions) Act 2011 S.I. 20 of 2011 allows the Minister to raise the levy once a year by no more than €50 at any one time up to a maximum of €120. It is anticipated that the levy will further increase from 1st of July 2013 to €75 per tonne (DECLG, 2012). Such increase in the landfill levy will significantly influence the market behaviour for waste to be disposed at landfill and may encourage the further development of waste recovery infrastructure. The landfill levy rates from 2002 to 2013 are shown in the table below;

Effective Date.	€ Per tonne.
1st June 2002	15
1st July 2008	20
31st December 2009	25
1st February 2010	30
1st September 2011	50
1st July 2012	65
1st July 2013	75

Table 2.1 Landfill levy rates (Source: EPA, 2010)

2.4.15 End of waste criteria – final report 2008

This report was commissioned to clarify under which conditions, at EU level, waste could cease to be waste and could be regarded as a non-waste material to be freely traded as such on the open market. The report establishes certain conditions that have to be complied by the end of waste requirements. A certain waste may only cease to be a waste if:

- The substance or object is commonly used for specific purposes.
- A market or demand exists for such a substance or object.
- The substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products.
- The use of the substance or object will not lead to overall adverse environmental or human health impacts.

(European commission, 2008)

2.4.16 Towards a new National waste policy discussion document 2011

This document was prepared because of the transposition of the Waste Framework Directive into Irish law in March 2011 and the programme for government, *"Government for National Recovery 2011-2016",* and commitments in relation to the development of a sustainable waste policy. The documents aim was to promote discussion and debate and to provide an opportunity for all parties to input into the development of a new national waste policy framework.

Following on from this the *'Draft Statement of Waste Policy'* was published in 2011. The draft policy statement on Irish Waste policy outlines the actions that will form Irish waste policy for the coming decade and beyond. The statements aim is to place sustainability at the centre of Irelands waste management policy. The aim is to move away from landfill and incineration and move towards higher levels of recycling. The statement indicates the following targets for the recycling of construction and demolition waste;

- 75% in 2010
- 80% in 2012
- 85% in 2014
- 90% in 2016

As well as this it is being considered to abolish the existing exemption for the 'de minimis' contributors to packaging waste. This will ensure that all producers of packaging waste will now have to contribute to its management, similar to the thresholds for waste management plans larger projects will incur greater producer responsibilities. It is also proposed to introduce compliance bonds for the developers of the projects set out above in order to guarantee a certain level of environmental performance, once these requirements are met the bond can be redeemed by the developer. It will also then be mandatory for such projects to implement waste management plans and that the plans must meet the following recycling targets;

- 80% in 2011
- 85% in 2012
- 90% in 2014
- 92% in 2016

(EHLG, 2011)

2.4.17 A Resource Opportunity - Waste management policy in Ireland 2012

This policy document outlines a roadmap on how Ireland will move away from a dependence on landfill by reducing waste and maximising the resources that can be recovered from waste. The policy is based on the waste hierarchy and sets out a range of measures across all tiers of the hierarchy. The policy recognises that waste is an important energy resource when used in terms of recovery and that there is a need to develop methods to use this resource. The document also reviews the producer responsibility initiative and examines the implementation of financial mechanisms in order to ensure compliance within sectors that produce large amounts of waste and which do not have voluntary initiatives in place. While the document is not directly related to construction and demolition waste it does state that producer responsibility requirements for construction and demolition projects over a certain threshold are also being considered.

In the document there a three core guidelines that apply to achieving better resource efficiency;

- Prevention and minimisation must be placed at the forefront of waste policies. This can be achieved through better design, the use of green purchasing and the use of locally sourced materials.

- When waste is generated, maximum value must be extracted from it. This can be done by reusing, recycling and recovering the waste.

- Disposal of waste to landfill should be a last resort. This will be carried out in line with the EUs roadmap to a resource efficient Europe. (EEA, 2012)

2.5 Enforcement of waste legislation

The rapid growth of Ireland's economy in the 1990's along with the improved regulations introduced by the Waste Management Act in 1996 greatly increased many of the previous waste management issues in Ireland (Connaughton, 2005). The establishment of the Environmental Protection Agency and the Office of Environmental Enforcement was an attempt to alleviate our waste management problems such as illegal dumping and the issue of legacy landfills. The OEE developed an enforcement network through the establishment of the National Enforcement Network. The Network was established in June 2004 and its work is conducted through a number of inter-agency groups and networks. There are six regional enforcement groups within the National Network and the overall objective is to ensure co-operation between the agencies involved in enforcement throughout the country. The enforcement of waste legislation is now being co-ordinated by the EPA through the National Enforcement Network. Enforcement is implemented at National, Regional and Local Authority level. Enforcing waste legislation is the responsibility of the EPA, Local Authorities and An Garda Siochana.

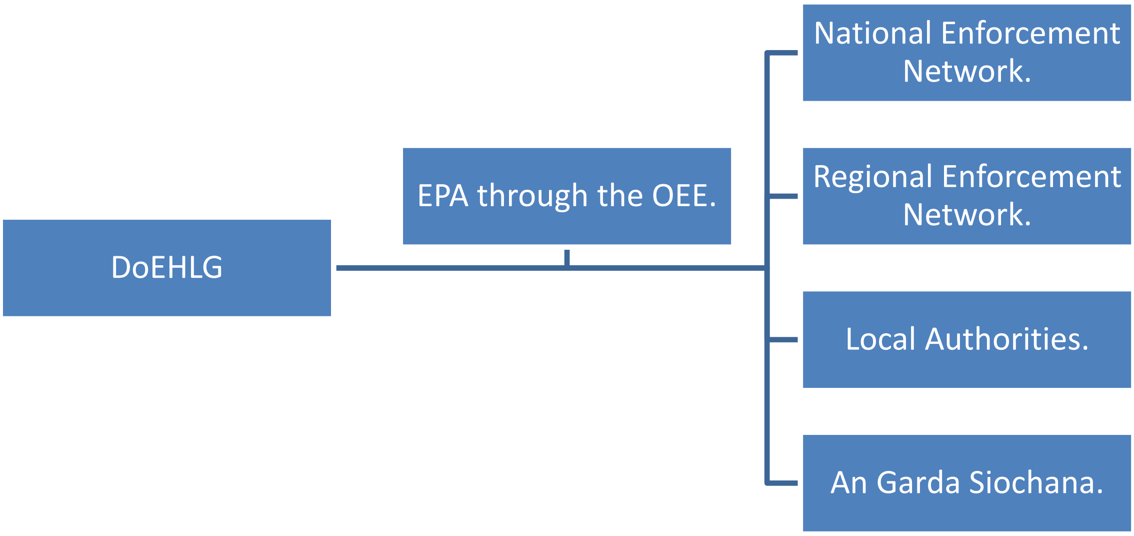


Figure 2.3 Waste legislation enforcement network

There is now an increasing pressure to enforce waste and environmental legislation particularly because of the rise in the landfill levy and the economic downturn. Companies may be tempted to illegally dispose of their waste in order to save costs and operators with no waste permits may profit from collecting and disposing of waste illegally.

2.6 Quantities of construction and demolition waste in Ireland

The economic down turn is having a noticeable impact on the amount of construction and demolition waste being generated in Ireland (see below). Since its peak in 2007 the quantity of construction waste has decreased by 86 per cent. This figure is decreasing in line with decreasing construction activity and despite a population increase.

The quantities reported by the EPA are outlined below;

Year	Quantity
1980	0.2 million tonnes*
1990	2.5 million tonnes**
1995	1.52 million tonnes (EPA, 1996).
1998	2.7 million tonnes (EPA, 2000).
2001	3.65 million tonnes (EPA, 2003).
2004	11.2 million tonnes (EPA, 2005).
2005	14.9 million tonnes (EPA, 2006).
2006	16.8 million tonnes (EPA, 2007).
2007	17.8 million tonnes (EPA, 2009).
2008	13.5 million tonnes (EPA, 2009).
2009	5.1 million tonnes (EPA, 2011).
2010	2.5 million tonnes (EPA, 2012).

Table 2.2 Quantities of C&D Waste in Ireland

* As estimated by Environmental Research Limited (EPA, 1996).

** As estimated by the European Demolition Association (EPA, 1996).

In 2010 it is estimated that 3,464,683 tonnes of construction and demolition waste was collected, this is a decrease of 32 per cent on the 2009 quantities. The majority of this waste is made up of soil and stones (2,517,194 tonnes) and the remaining waste (947,489 tonnes) is made up of other waste such as metal, timber, glass etc. The quantity of construction and demolition waste managed in 2010 was 2,578,076 tonnes which was a 50 per cent decrease on the 2009 quantity. 2,533,454 tonnes of this waste was estimated as recovered and 44,621 tonnes of this waste (2 per cent) was disposed of to landfill. The quantity of soil and stones collected was 2,517,194 tonnes and 1,720,469 tonnes of this waste was recovered (98 per cent). The quantity of non-soil and stone construction and demolition waste was 89,822 tonnes which was 10 per cent above the quantity reported as managed. This gave a recovery rate of 99 per cent (EPA, 2012). The recovery rate is based on the reported tonnages that were managed by recovery or disposed of. This means that Ireland is well on the way to meeting its target of 85 per cent recovery by 2013.

Total soil and stones collected: 2,517,194 tonnes.

Management	**Recovery (t)**	**Disposal (t)**
EPA licensed landfills	205,079	34,811
Local authority sites	1,390,419	0
EPA licensed facilities	90,160	0
Total	1,685,658	34,811
Grand total (t)	1,720,469	

Table 2.3 Collection and management of soil and stones 2010 (Source: EPA, 2012)

Table three outlines the management of the non-soil and stones waste fraction of construction and demolition waste. The quantity of this fraction of waste collected was 947,489 tonnes. The quantity of waste collected in this instance exceeded the quantity reported by 89,882 tonnes (10 per cent).

Management	**Recovery (t)**	**Disposal (t)**
Metal	314,348	
Wood	45,222	85
Glass		67
Plastic	50	30
Gypsum based waste	606	
Rubble	180,375	138
Other C&D waste	307,195	9,491
Total	847,796	9,811
Grand total (t)	857,607	

Table 2.4 Collection and management of non-soil and stone C&D Waste 2010 (Source: EPA, 2012)

There is a large gap between the reported waste collected and the reported waste recovered. There is a 0.8 million tonne gap in the soil and stones waste fraction (32 per cent) and a 0.1 million tonnes gap in the other waste fraction (10 per cent), this results in an overall gap of 0.9 million tonnes. The gaps in the data may be attributed to the lack of good records and poor record keeping within the sector. The recovery rates estimated need to be treated with extreme caution as it is likely that they are incorrect (EPA, 2012). The record keeping by waste operators needs to greatly improve and additional enforcement and data verification should be carried out by local authorities.

Given the significant gap between the figures there is a perception that illegal disposal of waste may be occurring (EPA, 2012). In recent years Ireland has been questioned about illegal backfilling of construction and demolition waste by the European Commission and there have been rulings and court cases brought by the European Court of Justice (European Commission, 2010). In 2011 the EPA set up a project to investigate the discrepancies between the reported collection and the reported managed quantities of construction and demolition waste. This EPA project will seek to carry out a construction and demolition waste flow analysis from collection to disposal and guidance documents will be produced based on the findings. The aim of this project was to ensure that local authorities were gathering and providing the correct waste data to the EPA. In April 2012 the EPA published the report entitled; *'Best Practice Guidance for Waste Data Management.'* This report outlines how a local authority should gather waste data and then present it to the EPA (EPA, 2012).

In the next few years Ireland will begin to make a move towards an economic recovery and during this regrowth it is important that the necessary actions and policies are put in place to break the link between economic growth and waste growth. The prevention of waste in the first place should be the target not just the diversion from landfill.

2.7 Landfill capacity

In 2012 44,621 tonnes of construction and demolition waste was disposed of at EPA licensed landfills (EPA, 2012). In the last 25 years there has been a dramatic change in landfilling in Ireland and in particular since the licensing of landfills started in the 1990's. Since 1980, when there were over 200 landfills operating in Ireland, the number of landfills operating has fallen to 32. The introduction of the EPA waste licencing in 1997, which required higher standards, made the operation of many landfills unfeasible (EPA, 2010).

There are, as of 2010, 32 landfills operating in Ireland and of these 32 landfills 27 accept construction and demolition waste (EPA, 2012). At the current fill rates 15 of these landfills are expected to close in the next three years and the remaining landfill capacity is 8 years (i.e. to 2020). At the end of 2010 the remaining licensed landfill capacity stood at 18 million tonnes or 12 years capacity (EPA, 2012). As a consequence of these closures there will be a significant inter regional movement of waste in Ireland and this movement of waste will need to be accommodated. Also reported in the 2010 Waste Report is that there are currently 443 waste facilities that are permitted to accept construction and demolition waste. The current lack of landfill space for construction and demolition waste should further encourage the industry to move towards better waste management practices and also waste minimisation.

2.8 Construction waste arisings

The definition of waste arisings is;

"*Materials forming the secondary or waste products of industrial/ commercial operations"*

(Oxford University, 2012)

Construction and demolition wastes can arise from a number of different sources. Symonds et al. 1999 classified the arisings of construction and demolition waste into a number of different possible sources;

Demolish and clear sites; "*Sites with structures to be demolished, but on which no new construction is planned in the short term."*

Demolish, clear and build sites; "*Sites with structures to be demolished prior to the erection of new ones."*

Renovation sites; "*Sites where the interior fittings (and possibly some structural elements as well) are to be removed and replaced.*"

Greenfield building; "*Undeveloped sites on which new structures 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.*"

(Symonds et al., 1999)

Waste can occur due to a number of factors including; over-ordering, poor design brief, changes to the construction programme, storage and transport of materials, site clearance, packaging and inefficient working practices.

2.9 Implications of construction and demolition waste

The construction industry has an impact on the environment through the waste it produces and the resources that it consumes (Mulder et al., 2007). The industry produces a wide variety of wastes and the type and quantity depend on the type of construction, the stage of the project and the waste practices on site. The impacts of disposing of construction and demolition waste to landfill include;

- The use of land that could be used for other purposes.
- The releasing of gases through decomposition of the waste.
- Greenhouse gas emissions caused by the transport of the waste.
- The depletion of natural resources by not reusing the waste.

Some types of waste will have a greater environmental impact than others, for example plasterboard made from gypsum when disposed of in landfill produces hydrogen sulphide which is poisonous.

The construction industry is a major consumer of resources and many of the materials that are used are often imported and sometimes come from companies with less environmental control and poor labour justice. If we continue our appetite for resources we will need multiple planets to sustain our consumption habits (Gonçalves, 2010). The global community exceeded the sustainable limits of consumption in the 1980's and at current levels it is not feasible to continue along this path. As a matter of urgency the western nations and in particular the construction industry need to reduce the consumption of resources. The impact of the construction sector on the production of waste and the use of resources is important in terms of environmental impact, climate change and non-renewable resource depletion. Climate change and carbon emissions will be two of the key drivers in changing the construction industry over the next 20 years. This will have a major impact on the areas of waste reduction, reuse and recycling. Increasing regulations in the area of construction and demolition waste disposal means that even common materials such as gypsum and mineral wool are now classed as a hazardous waste and require specific disposal methods (EPA, 2010).

While not immediately obvious an indirect impact of resource depletion is the affect that it has on habitat destruction, for example the deforestation in the Amazon Rainforests. It is hard to relate the construction industry in Ireland with habitat destruction but our construction industry relies on imported products such as chemicals, metals, minerals and timber and many essential materials that we require are in short supply. Some examples are Copper and Titanium Ore; Copper is mined in South America where whole mountains have been dug up and landscapes radically altered in the search for this mineral (Castro and Sanchez 2002). Titanium Ore is used to produce Titanium Dioxide, which is used in paints, and this is mined in Madagascar with consequential damage to habitats and ecology there (Sarrasin, 2005).

The environmental impact from construction is also felt from the pollution omitted during the processing of the materials required. Many of these processes are now controlled by legislation within the EU but we are also causing pollution by outsourcing our manufacturing to nations such as India and China (Huang et al., 2011). The products we use are often assembled in the West but the components are often manufactured elsewhere. We must start using fewer resources by building more simply with sustainable materials while producing less waste. We can also reduce high energy material use by using low energy and local materials where possible.

2.10 Sustainable waste management

The objective of sustainable waste management should be to protect human health and the environment by using fewer resources, producing less waste and when waste is produced; using that waste as a resource wherever possible. Moving the management of waste up the waste hierarchy will break the link between construction and the environmental impact of waste. This will require a change in the way waste is currently handled and new investment in waste infrastructure will be needed as well as adequate provision given to this infrastructure by the planning system. Positive planning will deliver sustainable waste management through providing opportunities for waste management facilities of the correct type, in the correct location and at the appropriate time.

2.11 What can be done?

The best option for any company do reduce waste is minimising the waste that arises in the first place. This means that even at the design stage waste minimisation needs to be considered so that during the construction stage there will be no wastage of materials. For example standardising building sizes to match product sizes will help reduce off cuts and subsequent waste. Prevention is financially advantageous as it reduces the purchase of materials and removes the need to remove waste from the site. Any material waste that is produced should be reused either on or off site where possible and disposal should only be considered as a last resort. Initiatives should be put in place to maximise the efficient use or reuse of materials and consulting the waste hierarchy will enable companies to choose the best option for them. In the subsequent chapters a number of waste management options will be discussed and explored.

2.12 Summary

It is clear from this chapter that there is adequate legislation in place or coming on line to deal with waste management now and into the future. Landfill capacity is running out and the cost of disposing of waste is constantly rising. Therefore the next chapter and subsequent chapters will look at how to manage and minimise the waste in order to avoid these costs. This chapter has given an outline of the waste legislation in Ireland and Europe and explained the waste hierarchy. The next chapter will discuss waste minimisation and the management of waste.

3.0 Chapter three – Waste minimisation and management

3.1 Aims and objectives

The previous chapter outlined the waste legislation in both Ireland and Europe and explained the waste hierarchy. This chapter contains information on waste minimisation and also the management of waste. Outlined in this chapter are also details of practical information on how to minimise and manage waste within a construction company and also on site. The information contained in this chapter can help contractors reduce resource waste and its cost.

This chapter will give an insight into:

- Materials resource efficiency.
- The benefits of waste minimisation.
- Roles and responsibilities for waste management and minimisation.
- Training and communication.
- Setting targets, KPIs and achieving quick wins.
- Good practice examples and guidelines.
- Modern methods of construction (MMC).
- Alternative details to reduce waste.
- Trade specific opportunities for waste minimisation.
- Waste management action plan and skip management plan.
- Barriers to achieving good practice waste management.
- Overcoming the barriers to achieve good waste management practice.

3.2 Introduction

Waste minimisation is a methodology used to achieve waste reduction, mainly through source reduction but also through the recycling and reuse of materials. Waste minimisation can be defined as;

"Measures and/ or techniques that reduce the amount of wastes generated during any domestic, commercial and industrial processes."

(EEA, 2012)

Waste minimisation can also be known as resource efficiency which includes the substitution of environmentally friendly materials into the production process. The minimisation of waste process involves the reduction of water, raw material and energy consumption and subsequently the reuse and recycling of waste on site (Greenwood, 2000). It focuses on the three R's – Reduce, Reuse and Recycle with disposal being the last resort. Waste minimisation can have financial benefits for a company because it can reduce the operating costs of the company. Implementing waste minimisation on site is about using common sense and a change in attitudes; it does not necessarily require the implementation of new technologies. It is often the case that implementing waste minimisation techniques incurs no cost and they can give benefits straight away (Begum et al., 2006). Typically the implementation of waste minimisation techniques requires three basic components; waste minimisation during the design stage, source reduction and recycling. Waste minimisation during the design stage has huge potential to impact positively on waste minimisation as it is during this stage that some of the major decisions are made such as the form of the building. Source reduction helps avoid waste generation while recycling helps to conserve natural resources and prevents wasted materials from entering the waste stream. There is huge potential for the minimisation of construction waste which arises through both design and the construction process. In order to reduce wastage rates it is important to focus on both issues.

Bossink and Brouwers (1996) found that between 1 per cent and 10 per cent by weight of materials purchased leave the site as waste. Their analysis found that sources of waste generation included the lack of attention paid to material sizes, lack of influence of the main contractor and a lack of consideration for waste minimisation at the design stage. This fact is also backed up by Osmani et al. (2007) who found that architects believed that waste is mainly produced on site and not during the design stages. Construction waste is generated from a number of different areas including; design, procurement, materials handling, operation and residual (Greenwood, 2000).

Teo and Loosemore (2001) found that a significant improvement could be made to waste reduction by changing people’s wasteful behaviour. It was also stated that waste is an inevitable by-product of the industry but its management is a low priority with an absence of appropriate incentives to support it. This finding is supported by Lingard et al. (2000) who stated that top management support is one of the most important factors for effective waste reduction. Lingard et al. (2000) recommends the use of clear communication, provision of necessary infrastructure and the cooperation of the workforce to help improve operative’s attitudes towards waste minimisation.

3.3 Improving materials resource efficiency

In order to achieve good practice waste management, designers of buildings and construction projects need to identify and then act upon a number of opportunities to help improve materials resource efficiency. This should be in the form of minimising the use of materials and its consequent waste generation through the planning and the design of projects. A significant amount of work in this area has been undertaken by WRAP, Envirowise and BRE which has shown that aiming to reduce the amount of waste being created will have a far greater positive effect on reducing the amount of waste sent to landfill compared to just trying to improve waste management on site during the construction phase. The research undertaken by these organisations has also found that reducing the waste in the first place is far more cost effective when compared to waste management. Simon (2006) states that materials resource efficiency can be achieved by; applying a number of different technologies, reduce wastage of materials, improved product quality and optimisation of the building design. Worrell et al. (1995) found that improving material efficiency will save energy, reduce the consumption of resources and reduce the amount of waste being produced. Odeleye and Menzies (2010) found that there is still a lot of work to be done in the UK to achieve a consistent and widespread improvement in waste recovery and the procurement of sustainable materials.

One of the principles of good practice waste management is to improve materials resource efficiency at the earliest possible stage of the construction project. If the client or contractor can work with the design team it will be a crucial stepping stone in achieving the target of good practice waste minimisation. Any decisions made during the design stage can have an impact on the amount of materials used on site and the subsequent waste.

If the layout or the form of the building is considered along with the specific design of the building elements, this can have a huge impact on materials resource efficiency. It is often the case that these decisions are made without considering how they will effect on materials resource efficiency.

3.4 Good practice waste management and minimisation

There is now an increasing awareness of the environmental impacts of construction waste and this has led to waste management being an integral function of construction project management (Shen et al., 2004). A construction project that implements good practice goes further than just complying with policies and legislation. Good practice requires the contractor to consider the waste hierarchy and waste minimisation at the design stage. Waste should then be monitored against standard industry KPIs and a review of the waste management on site should be carried out regularly and included in the WMP.

Contained in this chapter are a number of good practice measures that could be taken on site in order to reduce waste. The aim of investigating good practice measures is to compare the activities on the case study site as well as lessons learnt to developed good practice examples. Prior to outlining the best practice examples we must first understand the true cost of waste. This true cost of waste is the actual cost to the company for the disposal of the waste. The cost is not just the cost incurred by the hiring of a skip but is in fact as illustrated below:

Purchase cost of the delivered materials wasted.	+	Cost of waste storage, transport, treatment and disposal.	+	Loss of not selling waste for salvage or recycling.

As well as these factors there are also two additional costs not included in the above, these are;

- The time taken up by sorting, handling and managing the waste; and

- Incorrectly packing or overfilling of skips which causes the waste to be double handled, although this cost is very difficult to quantify. (WRAP, 2012)

When waste is produced on site at any stage of the project it translates into extra costs for the main contractor and consequently reduces the profits. An 8 cubic yard builders skip costs on average €350 , yet according to studies carried out by SEPA and CIRIA (2006) and published in *'The Small Environmental Guide for Construction Workers'* and in WRAPs document on *'Delivering good practice Waste Management'* the cost of what is actually being thrown away in a skip is over €1532*. This figure rises further to €1715* when all labour and material costs are taken into account. These costs can be broken down into the following percentages; (* Converted from GB pounds to euros for the purpose of this thesis.)

- Skip hire – 6.4% of cost
- Labour cost to fill the skip – 12.1% of cost
- Cost of the materials in the skip – 81.5% of cost

(WRAP, 2010)

If we apply these percentages to the case study then the figures are higher than the studies noted above;

Skip hire – 6.4% of cost = €350 (Source: Barna Waste)

Labour cost to fill the skip – 12.1% of cost = €661

Cost of materials in skip – 51.5% of cost = €4456

Total cost of skip = €5467

Estimates by WRAP suggest that the issue of waste can reduce profits on a project by up to 25 per cent. When a contractor is deciding on the waste management options the true cost of waste must be considered as well as the cost implications of the choice of waste container and the waste segregation choices.

The main objective of good practice waste management is to use the materials on site more efficiently and to aim to reduce the quantity of waste requiring disposal off site. If good practice waste management is implemented on site it will help to reduce the quantities of waste sent to landfill and make a positive contribution towards achieving sustainable development. If waste is to be reduced on site the contractor must address the design, logistics, procurement, and on site practices, aiming to improve the waste management activities in each stage. Achieving good practice will only work when everyone in the construction and design team work together to improve waste minimisation and management throughout the construction process.

Good practice waste management should be carried out in line with the waste hierarchy. This means that the quantity of waste generated should be reduced and then if waste is produced that the maximum amount of this waste can be recycled or reused. In order to minimise the amount of waste produced the best approach is to design out the waste in the first place. Following this waste management comes into play which involves identifying the potential waste streams, setting recovery rates and then managing the waste management process to ensure that the targets set are met. Achieving good practice will mean going beyond normal practice but will not require a fundamental change in working practice and will usually generate cost savings.

Good practice waste management can be applied to any form of construction regardless of the route of procurement that has been adopted. If the company is to benefit from good practice waste management then it should be adopted at the earliest stage of the project. Good practice principles should then be communicated and implemented throughout the entire project. It may not be practical to implement all the good practice measures at once. On certain projects there may be a restriction on time, space and resources. However if quick wins are implemented on site they have the potential to create benefits regardless of the type of project.

3.5 Why not aim for best practice?

In the context of the case study undertaken for this thesis it was decided that achieving best practice on site was currently not possible. For this reason it is proposed to aim for good practice on site. This is a more realistic goal for Carey Developments as their waste management practices on site previously have been limited to on-site source segregation. Going beyond this standard practice to achieve good practice involves the implementation of a good SWMP and the realisation of 'Quick Wins' on projects. These quick wins are benefits that are easy to achieve on most large projects without a change in working practice and are at least cost neutral. Achieving best practice reflects the leading approach being undertaken in the construction industry, but may incur a cost premium or require a change in working practice on some projects. It is planned to achieve best practice through a stepping stone approach with an intermediate goal of good practice.

3.6 Benefits of waste minimisation

- A reduction in materials ordered and waste disposal costs.

- An increased competitive advantage against other construction companies through differentiation.

- Lowering of the company's Co2 emissions.

- Assist in meeting planning requirements.

- Pre planning for the implementation of new legislation or an increase in landfill taxes.

- If the material entering the waste stream is reduced it will reduce the environmental impact of construction.

- Reducing waste can achieve cost savings. See the true cost of waste outlined above. The majority of respondents to the questionnaire carried out for this thesis stated that they believed that there are financial rewards for the minimisation, prevention and recycling of construction waste.

- A reduction in the amount of materials used due to waste minimisation will help to conserve natural resources.

Waste minimisation is at the top of the waste hierarchy pyramid, second only to prevention; hence it is one of the primary objectives in a company's waste management strategy. Waste minimisation will involve designing out the waste during the design stage of the project and then limiting the waste being produced on site during the construction phase. The management of any waste produced will then involve identifying waste streams, setting targets and KPIs and ensuring that the company meets these targets. There are opportunities to reduce waste throughout the design, procurement and logistics phases. As well as this effective communication is essential. If a company is to benefit from waste minimisation then waste management measures will need to be adopted as early as possible in the project timeframe. The first step towards achieving good practice waste management is implementing strategies to minimise waste. If waste is minimised it eliminates the need for the waste to be subsequently handled. Once the opportunities to minimise waste have been exhausted and waste is produced it can then be managed effectively.

3.7 Training and communication

Once the site waste management plan has been implemented, then the success of it will be based on providing adequate training and communication to all employees on site. This training and communication could be in the form of;

- Engaging with sub-contractors on the issues of waste management and minimisation.
- Introduce the site waste management plan during the site induction.
- The use of frequent tool box talks on site with regards to waste management.
- Putting a waste champion in place on site.
- The use of posters and visual aids to encourage good practice waste management. This can also help to overcome any language barrier's which may be present on site.

- Producing newsletters to inform the employees of their performance and any future waste management plans.

- Informal communication can also be used to get information across to the employees.

- Setting out the requirements in the contract documents for waste management and minimisation linked to specific targets can encourage good practice waste management on site.

- Adding the topic of waste onto the agenda of team meetings can ensure that waste stays within the scope of the project. If waste is discussed at each meeting then it cannot be ignored.

- If the construction and design teams can work together then the contractors can share their first-hand knowledge of what is causing the production of waste and how this could be reduced.

- Early engagement of sub-contractors ensures that they can contribute to helping achieve waste minimisation and also gets them involved in the decision making process.

- Holding waste workshops can be a good method of getting ideas from the employees. If participation is encouraged then it is possible to generate some useful ideas.

- Set up a partnering scheme between the construction and design teams. The on-site team have the knowledge of the waste causes and may have ideas on how this waste could be reduced. If they can share this knowledge with the designers it will greatly help with waste minimisation and management.

- Set up an incentives and reward scheme for good waste management practices.

- Provide all workers with support and aim to develop a strong relationship with sub-contractors. Choose sub-contractors who are more receptive to good waste management practices.

- Carry out regular waste management audits on site and provide feedback on any issues that need to be raised.

The questionnaire used as research for this thesis found that the majority of the respondents to the questionnaire had no formal waste management training. Almost all of the respondents were at a managerial level within the company. Further to this they believed that there is currently a lack of training and knowledge within the industry in relation to waste management. It is important that all staff members within the construction company receive training on waste minimisation and management along with all the points listed above.

3.8 Forecasting waste arisings

Waste can be generated on site in a number of different ways, these include;

- Changes in design specifications which leads to unused materials.

- Damage to materials caused by incorrect storage and handling of materials.

- Incorrect or lack of recording of materials supplied, delivered and used on site.

- Poor communication between the different subcontractors or workers on site causing work to be redone.

- Over ordering of materials.

- The use on unnecessary temporary works.

- Off-cuts from different materials used during the construction phase.

- Office and canteen waste (Welfare waste).

- Dumping of domestic waste on the site or in skips.

- Vandalism.

If we now know the likely areas where waste may arise on site then the type and amount of waste generated on site should be estimated for each part of the work programme. This will help to predict what type of waste containers will be needed and what segregation methods would be best implemented for the various waste streams.

Generally speaking the following list outlines at what stage of the project certain wastes may occur;

- Inert wastes such as concrete and blocks will be generated throughout the first phases of a project.

- Timber waste will usually be generated throughout entire length of a project.

- Plastic waste will usually increase as a project progresses.

- Packaging waste will increase as the project progresses and can be up to 35% by volume during the fit out stages.

- Certain types of waste are present throughout all stages of a project e.g. office and canteen waste.

3.9 Waste minimisation strategy

A waste minimisation strategy should include the following;

- The areas where waste arises in procurement, logistics and design.

- Waste reduction targets and opportunities to reduce waste.

- A plan to communicate waste management and minimisation issues to the project stakeholders.

- A plan to implement waste management and minimisation throughout the project.

- A mechanism to set out the lessons learnt to the design team.

3.10 Setting targets and KPIs

Prior to the setting of any targets the contractor must establish a baseline performance of waste management. Once this has been established then the contractor can set targets and KPIs to improve performance.

Setting targets and KPIs within a construction company will take the form of a two-step process;

Step 1: Implement standard industry KPIs to achieve good practice waste management.

The two most common KPIs are;

- A reduction of the volume of waste (m^3)/ €100,000 of the projects value.

- A reduction of the volume of waste (m^3)/ $100m^2$ of the projects floor area.

The following are some examples of KPIs which could be established by the main contractor on site. The sub-contractors will then be contractually bound to meet these targets;

Reduction in tonnage of waste per unit of construction activity.

The contractor should identify areas which are going to be targeted for improvement, such as recycling of plasterboard or a reduction in the amount of packaging waste. Once these areas have been identified then targets can be agreed in these areas.

Reduction in the percentage of waste sent to landfill.

An example would be setting a target of sending only 20 per cent of the waste generated on site to landfill. This could be achieved by on site segregation. If there is a problem with waste segregation on site the main contractor should issue an obstruction notice accompanied by photographic evidence. The subcontractor would be required to remove the waste within a designated time frame and if the waste was still in place once this time had elapsed then the cost of the labour for the removal of the waste would be deducted from the subcontractors' next or final payment. This should be included in the contract conditions issued prior to the sub-contractor working on site.

An increase in the percentage of recovery of waste materials for reuse and recycling.

For this KPI different targets may be applicable to different stages of the construction period. For example there would be different targets set for demolition as opposed to the fit out stage of a job.

An increase in the percentage of materials reused on site.

This KPI would be very relevant to a large scale demolition job where a lot of the materials could be reclaimed and reused on site.

A reduction in the waste created during a specific build phase of the project.

If the creation of waste is broken down by build phase then it will give a better indication of where the waste is being created and the problem areas that need to be focused on. KPIs should be set in tonnes per €100k of capital costs per build phase as this is a more accurate method then measuring waste production by volume.

Other KPIs that can be used include;

- A reduction in the number of skips per project.
- A reduction in the overall cost of waste per project.
- A reduction in the amount of waste produced per dwelling or unit.

Below is a diagram that has been developed by WRAP which sets out the standard, good and best practice recovery rates for waste materials produced on site. The recovery rates shown and for the total waste recovered both off and on site. These rates are based on a number of different project types that WRAP monitored in order to set recovery benchmarks for the industry.

Material	Standard Recovery	Good Practice Quick Win	Best Practice Recovery
Timber	57	90	95
Metals	95	100	100
Plasterboard	30	90	95
Packaging	60	85	95
Ceramics	75	85	100
Concrete	75	95	100
Inert	75	95	100
Plastics	60	80	95
Miscellaneous	12	50	75
Electrical equipment	Limited information	70*	95
Furniture	0-15	25	50
Insulation	12	50	75
Cement	Limited information	75	95
Liquids and oils	100	100	100
Hazardous	50	Limited information**	Limited information**

* This is a required recovery target for the type of WEEE likely to be produced from construction sites. e.g. lighting (the WEEE regulations, Jan 2007).
** This cannot be 100% as much hazardous waste (e.g. asbestos) must be landfilled.

Figure 3.1 Typical waste recovery rates for construction waste (WRAP, 2012)

Step 2: Establish KPIs specific to your own construction company, once the target of implementing good practice has been achieved and waste management has been embedded into the company. Any data then collected can be used within the environmental management system and for environmental reporting.

3.11 Waste recovery quick wins

The definition of a quick win is;

"….. an improvement in recovery (re-use or recycling) for a specific construction waste material, applicable on a range of construction projects, which will deliver a higher rate of

recovery than standard practice without increasing costs and preferably with a cost saving."

(WRAP, 2008)

Quick win opportunities for a specific waste stream should be identified by the main contractor prior to the start of the construction stage. In order for a contractor to achieve good practice waste management quick win targets should be identified regardless of the project type. A quick win is an improvement in recovery, reuse or recycling of a specific material which will lead to a higher rate of recovery without increasing costs and ideally leading to a cost saving for the contractor. If a quick win was implemented on three to four of the largest waste streams on a project there is an opportunity to increase the recycling rates of the construction waste from standard practice by more than 20 per cent (WRAP, 2012). For example, the usual top four waste streams by volume in a residential development would be concrete (including blocks and bricks), packaging, timber and plasterboard. In a commercial development metal would also be one of the key waste streams. It is also important for a contractor that these quick wins are achieved in a cost effective way. This can be determined by the amount of effort required and the type of technology used. The factors that could influence the waste recovery quick wins are;

- Waste recovery infrastructure. For example is there a company nearby that recycles plasterboard.
- Gate fees charged at landfill sites or processing facilities.
- The value gained from the sale of segregated materials.
- The location of the site and any space constraints on the site.
- Time constraints on the projects programme.

The benefits of quick wins are that the costs of waste disposal are lowered, the company's environmental impact is reduced, the corporate image of the company is improved and implementing quick wins can help to achieve sustainability targets and site waste management plans. Waste can become a quick win waste if it is; produced in significant quantities; is easily segregated; is of higher value when segregated versus mixed waste and if there is a recycling centre that accepts the waste close to the site. Quick wins can help to achieve cost savings for the project as well as environmental benefits. If quick wins are identified, targeted and delivered alongside an effective waste management plan, they can deliver financial benefits to the contractor.

3.12 Prevention, reuse and recycling

When managing construction waste it is important that practices reflect the waste hierarchy with waste prevention and minimisation being the top priority followed by reuse and recycling. The primary aim is to prevent waste generation in the first place which minimises the resources required to complete the job. Preventing waste is financially advantageous because it reduces the amount of materials being purchased and removes the need to transport waste off site. Waste prevention should be considered throughout all stages of the project especially during the design stage. This stage of the project offers the biggest opportunity to reduce waste by prioritising waste prevention from the beginning of the project. For example during this stage waste can be designed out, floor levels can be chosen to reduce excavation, modern methods of construction can be employed and recycled materials can be specified. Waste prevention can be carried out during the construction phase by ensuring that large volumes of materials are not delivered to site and through the use of a just in time delivery system. On the site waste can be minimised by careful storage, handling and the setting up of a central cutting station for some trades. Every sub-contractor working on site must be required to conform to the requirements set out in the waste management plan.

Any material waste generated on site should be reused where possible or salvaged for future reuse and the disposal of these materials should only be considered as a last resort. Materials such as excavated topsoil should be put aside to be used for landscaping towards the end of the project. Innovative initiatives that could reuse waste should be investigated and implemented where possible. Advantage should be taken to reuse all construction materials if possible for example the reuse of period architectural features can enhance the aesthetics of new buildings.

Construction waste can be recycled in a number of different ways and there are some markets available to do this in Ireland, as investigated in Chapter four. It is important that construction waste is recycled to the greatest practicable extent and construction waste can be reused in a number of different applications such as recycled hard core or aggregate. Where financially viable, crushers could be set up on site to reprocess construction waste into recycled aggregate.

3.13 Good practice examples and guidelines

3.13.1 Initial commitment, targets and company policy

Along with any initiatives taking place at site level it is crucial to the success of waste management within a company that a policy on waste management and minimisation is set into the corporate framework. High level support of waste management is crucial to the success of any good or best practice waste management targets or initiatives.

- Set a target for reducing waste to landfill and assign a team member with responsibility for delivery.
- Embed the target within corporate policy and processes.
- Set requirements in project procurement processes and engage with its supply chain.
- Measure performance at a project level relative to a corporate baseline.
- Report annually on overall corporate performance.
- The overall objective should be to reduce the waste the company generates and manage waste as a resource.
- Develop a waste minimisation policy.
- Allocate additional resources to bolster the environmental team.

- Carry out management training in order to instil the ideology of waste minimisation throughout the company.

The following documents should be revised to include waste management elements;

- Subcontractor pre-selection and procurement.
- Designer pre-selection.
- Checklist for use by site and project managers.
- Sustainability strategy to design out waste.
- SWMP to measure project and corporate level performance through monthly reviews and audits.
- Develop a project-specific environmental management plan.

The following is an example of targets that a company might implement to achieve zero waste to landfill, maximum reuse of materials and set industry standards for the use of recycled content;

Targets	2014	2016	2020	2025 Vision
Waste to landfill.	Send only 15% of waste to landfill.	Send only 10% of waste to landfill.	Send only 5% of waste to landfill.	Zero waste to landfill from all projects.
Minimising waste over the life cycle of products.	Specific targets to maximise reuse and recycling.	Specific targets to maximise reuse and recycling.	Reuse and recycle 70% of materials.	100% reuse or recycling of materials.
Recycled content.	20% recycled content of major materials for new build.	30% recycled content of major materials for new build.	50% recycled content of major materials for new build.	**2040 Vision** – 75% recycled content of major materials for new build.

Table 3.1 Waste minimisation targets

The first step towards implementing these targets will be to record and set a benchmark against which the targets can be measured. The targets compare to various guidelines and policies as set out below;

2014 target based on;

- Changing our ways target of 85 per cent recycling and recovery by 2013.

- International review of waste management policy target of 85 per cent recycling and recovery by 2014 and Recommendation 7 of that report that sets a target for 90 per cent recycling and recovery by 2014 to be set out in waste management plans.

- The draft statement of Irish waste policy 2011 target of 85 per cent recycling and recovery by 2014.

2016 target based on;

- International review of waste management policy target of 90 per cent recycling and recovery by 2016 and Recommendation 7 of that report that sets a target for 92 per cent recycling and recovery by 2016 to be set out in waste management plans.

- The draft statement of Irish waste policy 2011 target of 90 per cent recycling and recovery by 2016.

2020 target based on;

- The Waste Framework Directive target of 70 per cent reuse and recycling of materials by 2020.

- The EU Resource Efficiency target of 70 per cent reuse and recycling of materials by 2020.

2025 vision based on;

- The EUs proposal to gradually ban landfilling from 2014.

2040 vision based on;

- The EU Resource Efficiency target of 75 per cent recycled content in all products by 2040.

3.13.2 Pre design stage

During this stage the client should set a project requirement for good practice for waste minimisation and management. If the client sets this target then the contractor will be more likely to implement waste minimisation during the design stage.

3.13.3 Procurement

During the procurement and design stages the contractor should; Identify key opportunities for waste minimisation, plan waste management by developing a SWMP and set tender and contractual requirements for good practice SWMP implementation and targeting of quick wins. As well as this the following should also be noted;

- The main principle of waste minimisation during the procurement stage is producing accurate estimates of materials needed and then efficiently using these materials.

- The contractor should aim to achieve greater co-ordination of activities through the development of procurement procedures and documentation.

- The project brief should contain requirements to effectively manage and minimise waste.

- The main contractor should ensure that the consultants and sub-contractors have obligations set into their contracts to participate in waste minimisation.

- Appoint one waste management company to provide waste management services; the contract could include requirements and targets for waste reduction and recovery. There should be a stringent selection process for the appointment of waste contractors.

- For the waste management company; set contract terms, commercial rates and document controls. Define the disposal routes and the address and contact details of the waste destination.

- The waste management contractor can then be managed through monthly contract review meetings, where recycling and waste management KPIs are checked and issues and ideas are raised to improve performance.

- Formalise and standardise the supply chain requirements in relation to the procurement and selection of subcontractors and suppliers.

- When appointing subcontractors it is important to choose contractors that have waste minimisation at its core.

- Set up a materials and equipment procurement framework.

- Set up and outline a minimal packaging policy; only use suppliers that offer the opportunity of setting up take back schemes with the packaging.

- Implement a feedback system to the procurement team on the waste materials being produced and on the sub-contractors performance on site.

- A pre-qualification process could be used to identify contractors that will support the companies objectives for good practice waste minimisation and who will also help to develop the companies waste management further.

- Prospective sub-contractors will be required to indicate what they estimate the likely waste recovery targets and KPIs, which can be achieved on the project.

3.13.4 Design

During the design stage it is possible to eliminate waste before it reaches the site and because of this it has the greatest chance of success of impacting on waste minimisation on site.

- The design stage provides one of the best opportunities to reduce waste on the project. One of the principles of waste minimisation is ‘designing out the waste,’ through good design and planning to help reduce the volume of waste before it arises on the site and possibly the use of modern methods of construction.

- Aim to incorporate the use of modularisation, modern methods of construction and standardisation that enable off site fabrication of a wide range of components e.g. shower and toilet pods could be prefabricated and delivered to site fully fitted with sanitary ware and accessories to reduce the amount of waste generated on site through off cuts, packaging and reworking.

- The use of off-site manufacturing could also reduce construction phase waste and eliminate many of the site safety risks commonly associated with work of this kind.

- Incorporate the use of sustainable and/or recyclable materials and build waste minimisation into the design process.

- Ensure the early involvement of the waste management contractor.

- Produce a SWMP using good practice guidelines.

- Design the buildings size and space to eliminate unnecessary elements, reduce off-cuts resulting from the construction process, and ensure compatibility between market supply and specification.

- Ensure flexibility in design for building adaptation, expansion, and dismantling in the future.

- Reduce the complexity of the design to standardise the construction process and reduce the quantity of materials required.

- Avoid over specification and minimise variation in components and joints; evaluate the reuse and recycling opportunities for the specified materials before specification.

- Ensure that materials recovery from demolition is included as part of the project planning.

- With regards to the minimisation of waste on site, the design team need to plan ahead. For example if the ceiling heights of the building are designed so that they are the same height as a sheet of plasterboard then there will be no need for off cuts, in particular when constructing partition walls. The board can then be ordered in bulk and manufactured to match the floor to ceiling height.

- Design the building for change; this can be achieved be accommodating flexibility for materials usage. Materials that can be used for more than one purpose should be considered.

- If the site has a stock of existing materials that can be reused such as existing buildings or aggregates, then the designer should consider accommodating these materials into the new building design. Reclaimed materials should also be considered, such as reclaimed bricks or salvageable timbers. If these items are incorporated into the design then it will help towards reducing the waste on site.

- Design for deconstruction could also be considered so that there can be a reuse and recovery of the materials used in the future.

- There is also a chance for designers to design the building to fit the dimensions of certain material sizes that will be used. This will prevent any off-cuts being produced on site.

- Avoid over specification and where possible minimise the variation between components. Prior to choosing a material investigate whether that material has reuse and recycling opportunities.

- Standardise the use of materials on site. For example use one type of cladding rather than a whole different range of cladding options.

- When developing the project programme, plan the construction of elements that use the same or similar materials to take place at the same time.

3.13.5 Pre-construction stage

During the pre-construction phase the contractor should;

- Set targets and key performance indicators for waste minimisation.

- Define responsibilities and set these into the contracts.

- Identify waste arisings and reuse and recycling routes along with which waste handling company will be used.

- Site design should be environmentally friendly and training should be incorporated into site inductions and tool box talks.

- Develop a logistics plan for the effective and efficient transport of materials to and from the site and their relevant storage requirements.

3.13.6 Construction stage

During the construction phase the contractor should constantly monitor for waste management and report the outcomes and quick wins that were achieved. If there is a lack of waste management on site with poor planning then this will end up producing waste and not contribute positively to materials recovery. None of the following points are currently being implemented on site but all the points should be considered and introduced where feasible.

- Monitor and programme the construction activities.
- Set up a performance based incentive scheme with rewards if targets are met.
- In order to minimise the space taken up by compactible waste the use of space saving equipment such as balers could be used on site.
- Use of good materials resource planning in order to minimise on site storage of materials.
- Place a ‘waste champion’ on site; this is a person who will deal solely with the waste management on site.
- Engage with the suppliers to supply products and materials that use minimal or reusable packaging.
- Hold regular meetings on site waste management.
- Ensure all necessary staff read and understand the waste management plan.
- Place signage around the site to ensure locations of waste specific collection points are clearly marked for site operatives.
- Consider a number of waste options for the waste that may be generated on site. These options should adhere to the waste hierarchy and consider minimisation, reuse, recycling, recovery and the final option of landfill disposal.
- Take back schemes should be established wherever feasible. Take back schemes are normally cost neutral or result in some cost savings. Take back schemes could be established for plasterboard, bricks/blocks, insulation and packaging.

- Any waste produced on site should be segregated into individual waste skips. This will produce a cost saving as the price for a skip with segregated waste is usually lower than if the skip contains mixed waste.

- All waste containers should be clearly labelled and the appropriate signage should be put in place. Ensure that the distance from the workplace to the skip is not too great a distance.

- Once the appropriate skips have been put in place it will be necessary to enforce the segregation of the waste. This should be done through the monitoring and auditing of the skips and other waste containers regularly to ensure that segregation of waste is occurring and will help the main contractor identify whether there is adequate compliance on site.

- It is important that the skips are regularly picked up and replaced by the waste contractor. An empty skip will encourage waste segregation, whereas if a timber skip, for example, is over flowing the subcontractor may revert to using the closest skip with space in it regardless of its contents.

- Carry out a periodic audit of the waste contractor to establish the movement of the waste once it has left the site.

- The use of balers or shredders on site should also be considered. Materials such as cardboard or plastic could be compressed in order to save space. Theses bales can then be sent to a recycling facility.

- Incentives and rewards schemes could be introduced for when targets and KPIs are met on site.

- Monitoring and reporting of the waste generated on site is extremely important. Waste quantities which were forecast should be compared to the actual waste generated on site.

- The waste management must be regularly audited on site by an appropriate person, for example someone from the environmental department of the company. Following audits it is important to remove the blame culture as this will discourage the workers from achieving good practice waste management on site.

- Freezing the design at critical milestones during the construction phase can ensure that work is not unnecessarily undone.

- If the cut and fill required on the project of carefully analysed then excavated material from one part of the site can be used as fill elsewhere on the site. It is also possible to use any excess excavated material as fill on other projects.

- As the construction project progresses reviews should be carried out on each individual trade following completion of their works package and feedback provided to each trade.

- Train and educate people about waste management and minimisation.

- Use materials with a recycled content where possible. The following products have the opportunity to use recycled content as part of their make up; sub-base and capping, materials used for fill, concrete, fittings and fixtures, asphalt, drainage products and topsoil. The use of materials can be cost neutral up to the use of 50 per cent of recycled content materials. (WRAP, 2011)

- If wetting is required to keep down dust, consider installing water butts and recycling rain water for this task.

- Audit the waste carriers and treatment facilities to ensure appropriate licenses and waste treatment is being carried out.

- Order goods in economical quantities. This will reduce the number of deliveries and maximise the sending back of packaging waste to the supplier. Avoid over-ordering.

- If plant maintenance is carried out on site, used oil shall be stored in a bunded area for collection. Oil and fuel filters should also be stored in a designated bin in a bunded area for separate collection and recycling.

- Recycle materials that are already on the site into the building and use products with a recycled content or use more recycled materials.

- Look for a supply chain commitment to deliver materials to site that make it easier and safer to off-load and therefore avoid damage.

- General mixed waste is the most difficult to segregate at source and different options for dealing with it should be considered. One option could involve waste being graded, and shredded, then dried and composted to produce a clean solid fuel (Refuse Derived Fuel), used in kilns which produce cement in a nearby factory.

- Materials should be stored carefully on site and out of the way of site traffic.

3.13.7 Logistics

Without the correct storage and handling of materials they will inevitably get damaged and therefore will contribute to the waste problem. It is imperative that materials are handled and stored correctly on site. According to WRAP around 15 per cent of materials, by value, delivered on site are wasted. Most waste could be reduced by 1 per cent to 2 per cent without having any knock on effect on the construction programme. The wastage rates could also be reduced by reducing over ordering and using a better ordering system.

- Develop a logistics plan at the start of the project to ensure that consideration is given to material requirements through the construction phase, enabling efficient management of the delivery and storage of materials and ensuring that effective logistic methods are adopted.

- Logistics techniques employed on site could be; just in time delivery, consolidation centres, take back schemes, fourth party logistics, site demand smoothing, integrated communication technology and reducing packaging.

- The main contractor should develop a materials handling strategy.

- Placing a logistics specialist on site can achieve an improvement in logistical techniques. This person can receive the deliveries and co-ordinate the distribution of the materials around the site.

3.13.8 Materials procurement

When ordering materials it is important to calculate the amount required correctly, over ordering materials by 10 per cent is not acceptable when trying to achieve good practice waste minimisation. Materials should be ordered in standard sizes and should contain a recycled content whenever possible. The use of hazardous products should be avoided in order to protect the environment and also cut down on hazardous waste disposal costs. Materials should be delivered to site using a just in time system and the packaging should be minimal.

3.13.9 Post construction stage

- After the construction stage is finished the contractor should review the performance of the SWMP and any lessons learnt from the project. This will help to implement WMPs correctly on future projects of a similar nature.

- When the site waste management plan has been implemented it is then necessary to make sure that the plan is being followed. It is also important to amend the plan if necessary. This can be achieved by including the site waste management plan as one of the topics in any regular meeting which the contractor holds, for example a fortnightly meeting.

- The main contractor should carry out post completion reconciliation. This is where the net quantity of materials used is compared to the net quantity of materials used plus the amount that have remained un-used. This simple formula provides a measure of how efficiently materials have been used on site.

- Record any data gathered on this project for the use on future projects of a similar nature. It is also important to share the lessons learnt, promote innovation and continue to raise awareness.

- By continuously improving performance the company can achieve good practice waste management for the ability to deliver projects for a lower cost and to improve their reputation with their clients.

3.13.10 Measuring and reporting

- The company should measure itself qualitatively and quantitatively through a sustainability roadmap and a series of key performance indicators.

- Carry out regular self-assessments to report on progress, and carry out periodic reviews. These reviews should involve interviews with senior employees and sustainability practitioners to identify challenges, successes and best practice.

3.14 The segregation of common waste streams

Soil;

- The best option for soil is to reuse it as soon as it has been excavated. However this is usually not possible.

- The soil should be stored carefully so that it can be re used on site for landscaping at the end of the job.

- If the soil cannot be reused on the same site then perhaps it will be possible to reuse the excavated material on a site that is nearby.

- The soil should be protected from contamination by other wastes by setting aside an area exclusively for the storage of soils. Soils should be kept as dry as possible.

- The soil should be stored no more than 2 metres high. Storing soils above this height can damage the structure of the soil.

Concrete, concrete blocks or bricks;

- Crushed concrete, blocks and bricks can be used as a sub fill material. A crusher can be hired to crush these materials on site prior to reuse. Reusing this recycled material will mean that for every tonne of concrete recycled; one tonne of virgin excavated material can be saved.

- It may be possible to reuse bricks on site depending on their condition.

- If this waste needs to be sent to a recycling centre then it is imperative that the materials are not mixed with plaster or plasterboard. The reason for this is that the sulphate content in the plaster makes the concrete unrecyclable as a raw material for the production of new concrete.

- In order to increase the possibilities for recycling concrete should be separated from brick waste as the concrete is a higher grade product that can be used as recycled concrete aggregate in the manufacturing of new concrete.

Timber;

Timber and wood can be easily recycled by the waste management contractor. The wood may need to be de-nailed and the waste contractor may not accept wood where glue has been used in the manufacturing process, such as MDF. It is recommended that the waste contractor is contacted in order to see what type of timber products they are able to accept. Timber can be recycled into a number of different items such as chipboard or mulch. In order for timber to be successfully reused then it must be properly sorted prior to recycling.

Metals;

Metal is the easiest waste to recycle because of its value. Waste metal should be stored separately from other wastes. Nonferrous metals such as copper or aluminium should be sold off to a metal re-processor because of their high value.

Plastics;

Plastic waste from construction is currently not widely recycled because of its poor condition when presented at a waste recycling facility, for example the presence of dirt on the plastic. There is an opportunity however for this waste to be used as a refuse derived fuel (RDF). The RDF is then used as a fuel to fire cement kilns.

Plasterboard;

Plasterboard is often disposed to landfill, however if it is separated correctly then it may be possible for the contractor to set up a take back scheme with the plasterboard supplier.

Asphalt and bitumen;

Asphalt and bitumen can be recycled using a hot or cold process. The recycled mix can be used in a number of applications such as road edges and filling potholes. The asphalt should be stored separately from other materials.

3.15 Modern methods of construction (MMC)

When possible the use of pre-fabricated components should be considered because off-site construction can lead onto economies of scale and programme reductions (Sardén and Engström, 2010). The advantage of off-site construction in the context of waste management and minimisation is that the waste can be better regulated at the factory level than it can be on site. Pan et al. (2007) and Pan et al. (2008) state that despite the wider concerns of the need to improve the construction industry performance; there is currently reluctance in adopting off site methods of construction on building sites. Tam (2007) found that the use of prefabricated building components is considered to be an effective measure to encourage the implementation of the waste management planning method. The perceived barriers are that MMC have a higher capital cost, it requires complex interfacing, long lead in times and that there may be delays in the planning process. Goodier and Gibb (2005) also found that the main barrier for the increased use of MMC is the belief that off-site construction is more expensive. Sardén and Engström (2010) found that the advantages of MMC include predictability of the time schedule, increased speed of the construction process, improved quality assurance, improved working conditions and predictability of the costs of the project. Monahan and Powell (2011) state that the use of MMC can reduce the embodied carbon of the building; when compared to traditional construction MMC can reduce the embodied carbon by up to 34 per cent.

The type of construction used will have a direct impact on the quantity and type of waste produced on site. If materials are cut then it leads to the inefficient use of the off cut and is one of the primary sources of waste on construction sites. Waste will also be produced if materials get damaged and consequently become un-useable.

The waste reduction potential of modern methods of construction is outlined below;

- Volumetric building system 70-90 per cent.
- Framing systems 40-70 per cent.
- Pods 40-50 per cent.
- Panel Systems 20-60 per cent.
- Other MMC 30-60 per cent. (WRAP, 2011)

For example if a designer was to specify precast concrete instead of the use of in situ concrete it will reduce the concrete wastage and also create a faster construction time along with less weather dependence and assured quality of the materials being used. The use of off-site construction will reduce the production of on-site waste. All off cuts are eliminated and if the materials are handled correctly then on site breakages and damage to materials is reduced. Another example is the use of plasterboard. Traditionally plasterboard sometimes requires re-working because of the need to cut it and can also be easily damaged on site. The application of plaster on the board then further produces waste. An alternative to plasterboard is Fermacell, which is made up of cellulose and gypsum. The board does not require a wet plaster finish and is also more impact resistant.

Modular construction can be made to measure and numbered for their installation. This prevents over ordering and wastage of materials. The use of MMC should be considered in the procurement and design phase of the project. Studies and research carried out by WRAP in the UK have identified the following modern methods of construction as possible solutions to reduce the levels of waste on a construction site in the short to medium term. All of the examples outlined below could be implemented on the case study site, had they been considered at the design stage.

3.15.1 Volumetric modular

The volumetric system of modularisation is the ultimate method of off-site manufacturing and is an effective and efficient method of constructing highly serviced areas in buildings such as bathroom, kitchens and structures to house mechanical plant and equipment (Taylor et al., 2009). The use of this system can virtually eliminate all material wastage on site bar the excavation spoil required for the ground works. A volumetric building is a building that is fully assembled off site in modules which can be used as a stand-alone unit or linked on site to produce a complex of units. The units can also be linked and stacked to form a modular building with the appropriate cladding features. Anson et al. (2002) found that the use of volumetric module systems have the following advantages; it allows maximum value to be added in the factory, it allows a factory standard of construction, it removes the need for high labour usage on site and it speeds up the construction process.

Picture 3.1 Volumetric modular construction

3.15.2 Panellised modular building systems

Vaidya, (2009) states that the use of modular building systems can increase the efficiency of the construction process and is a good method of applying modern technology on site. The key features of this type of building are that the external wall and roofing panels is factory assembled and delivered to site in a flat pack form. These panels then form the buildings structure and are also load bearing. On arrival on the site the panels are lifted into position onto the foundations. On the case study site there is a lot of use of in-situ concrete. This concrete work could be replaced by the use of a panellised system.

Under the heading of panellised modular building systems there are three different types of construction methods;

- Steel frame and timber frame systems.
- Wood based (SIPS) - structural insulated panel systems and (SIRPS) - structural insulated roofing panels.
- Panellised building systems and pre cast structural panels.

Picture 3.2 Timber frame construction using SIPs

3.15.3 Pods

Pods are usually used for prefabricated bathroom or kitchens. The use of Pods eliminates that generation of waste from the fit out of the bathrooms and kitchens. The pods are factory built and include all the lighting, plumbing etc. required in the room. Pods are an established method of modern construction in place of traditional methods of construction. The only waste generated will be the waste from the installation of the pod itself which includes cardboard packaging and shrink wrap for the door units. Pan et al. (2010) compared bathroom pods with in situ bathroom construction and compared the maintenance requirements of both methods. It was found that in situ bathrooms required a greater amount of maintenance over its lifetime when compared with bathroom pods. Pods could be used on the case study site for the installation of the bathrooms and kitchens.

Picture 3.3 Bathroom Pod

3.15.4 Building envelope components

Building envelope components are prefabricated components that will form part of the building, for example the roof or the external façade. There are three products included in this method;

- Composite panels.
- Pre-cast concrete external cladding.
- Light steel framing (LSF) systems.

Picture 3.4 Composite panel cladding

3.15.5 Structural pre-cast concrete building components

The components covered under this heading are structural pre-cast components which are not used in the building envelope. These products are listed below;

- Pre-cast hollow core floors.
- Beam and block flooring.
- Tunnel form construction.

- Insulating concrete formwork.

- Thin joint masonry (TJM).

Picture 3.5 Hollowcore flooring

3.16 Practical applications of MMC on the 'Taylors Hill Site'

- Mechanical and electrical systems along with ductwork could be fabricated off site in a modular form and then transported to the site and fitted.

- Wall cladding could be fabricated off site in panels made to size and then fitted on site.

- Flooring and ceilings could be delivered on site pre-fabricated into cassettes that can be placed together on site.

- Volumetric rooms could be manufactured off-site.

- Bathrooms could be pre-fabricated off site and can include all plumbing and fittings. They are then delivered to site in either a 2D or 3D format.

- Kitchen areas could also be manufactured off site and delivered similar to bathrooms.

- Plant rooms could be pre-fabricated off site and delivered to site and fitted into position with minimal disruption.

Anson et al. (2002) state that in order for MMC to be considered the following points must be achieved; the product must be either the same price or cheaper than traditional construction methods, the product must satisfy the customer, the product must comply with standards and regulations and it must be sustainable.

3.17 Alternative details

The following are some design details that could be considered on a project in order to reduce waste. All the details below could be considered for use on the Taylors Hill case study site during the design stage. It is at this stage that the design team should incorporate these details in order to reduce waste.

3.17.1 Aerated concrete blocks with thin joint mortar

Aerated concrete blocks or aerated autoclaved concrete (AAC) is a lightweight precast material that can provide good insulation, mould and fire resistance. In this example we will be using the AAC blocks but other products manufactured in this form and wall, roof and floor panels and lintels. Fried et al. (2005) found that the use of AAC blocks with thin joint mortar had four times the lateral load capacity of a traditional masonry wall constructed of block work and conventional mortar. The blocks can be used for both internal and external construction and its main advantage is its quick and easy installation. This is because of their lightweight and the fact that it only uses a thin bed of mortar. In addition to this most of the AAC blocks manufactured are made using recycled content. The thin mortar is a cement based product that only needs the addition of water and when applied the joints can be 3mm or less and because of this thin bed of mortar the air tightness, thermal bridging and sound insulation are all improved. The mortar is also quick setting which speeds up construction time. The blocks can be used in load bearing walls up to five storeys high and can be easily cut and shaped by hand. There is a potential to use this product on the case study site in place of traditional methods of block laying.

Picture 3.6 AAC blocks with thin joint mortar

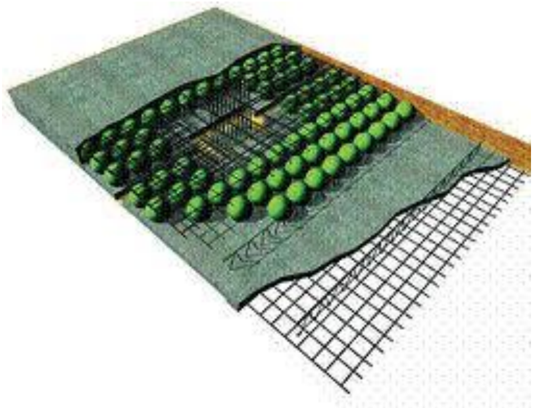
Table 3.2 Potential benefits of aerated concrete blocks with thin joint mortar

High strength to weight ratio.
Requires low amounts of mortar.
Off cuts can be reused.
The blocks can be left as an exposed finish. This eliminates the need for plasterboard and plaster.
The lower weight placed on the foundations can lead to a reduction in the foundation size.
There is a modest price increase in using the blocks but this cost can be recouped through labour and programme savings.
Waste disposal costs are reduced.
Reduced transportation costs because of their lightweight.
The blocks are available in larger sizes hence speeding up construction.
The mortar is quick setting.
Less Co2 emissions in their construction compared to standard blocks.
Very good thermal qualities.
Contains recycled content called PFA, a by-product from coal fired power stations.
The blocks are 100 per cent recyclable.
The blocks are lightweight and consequently easier to handle, lay and level.
Easily cut by hand. The blocks can be cut, shaped or sanded.
Available on the market in Ireland in the form of Quin-lite blocks.

3.17.2 Voided biaxial slab

The use of a voided biaxial slab (VBS) is a design which is resource efficient for concrete slabs because it incorporates voids which reduce the amount of materials used. VBS technology is primarily used to help reduce the weight of buildings but the design also has comparable strength to a solid slab. Lai (2009) states that the use of a biaxial slab has the advantages of lower costs, reduced use of materials, enhanced structural efficiency, shorter construction time and is also a green technology.

A typical system uses a hollow plastic sphere which is placed inside a modular grid. The spheres are fixed in place using only reinforcement mesh and solid concrete is placed above and below the voids to give greater strength. VBS is also available in a semi precast state which offers a faster and more straightforward construction. This system does not require and formwork and a smooth finish are guaranteed. The lightweight slabs allow materials savings in the buildings structure and foundations. Brown (2005) states that the use of a voided biaxial slab reduces the amount of concrete required by 30 per cent, which means that less materials, are required in its construction thus lowering Co2 emissions. As well as this the lower weight of the material means fewer crane lifts leading to reduced risk on site. If post tensioned cables are placed inside the VBS then it is possible to achieve a span of 50 times the thickness of the deck. Other systems include Airdeck, U-boot, bubbledeck and polystyrene voiding blocks. This system could be used on the case study site in place of the use of hollow core slabs.



Picture 3.7 Voided Biaxial Slab

Table 3.3 Potential benefits of voided biaxial slab

A reduction of the use of concrete in the slab by 30-50 per cent.
Weight reduction in the reinforcement and further reductions in size of the columns, beams, load bearing walls and foundations.
Potential cost saving due to the use of less concrete and cost savings in the support structure.
Time savings because of its quick installation time.
Potential embodied carbon reductions for the slab and supporting structure.
Heating systems can also be incorporated into the slab.
Spheres made from recycled HDPE are also available; this along with specifying concrete with a recycled content will have positive environmental impact compared to traditional practice.
Can be used to construct most buildings including car parks and hotels.
The system can be fitted in Ireland by SDG construction technology company.

3.17.3 Door Jambs

One of the materials with the highest wastage rate on site is plasterboard. The waste created from the plasterboard results in environmental impacts and increased waste management costs. Changing the construction of a door opening can have a major positive effect on reducing this waste. The traditional construction of a door opening involves placing the plasterboard sheet fully or half way over the opening and then cutting the required opening. This method results in a large amount of off cuts. If a more efficient door jamb is used the amount of waste generated can be significantly reduced. This can be achieved by positioning a full sheet at each side of the door opening and then using an off cut from elsewhere for above the door. Waste can be further reduced by taping and skimming over the joints instead of applying a plaster skim over the entire wall. The use of partitioned walls is not being implemented on the case study site but this detail can be incorporated on future projects.

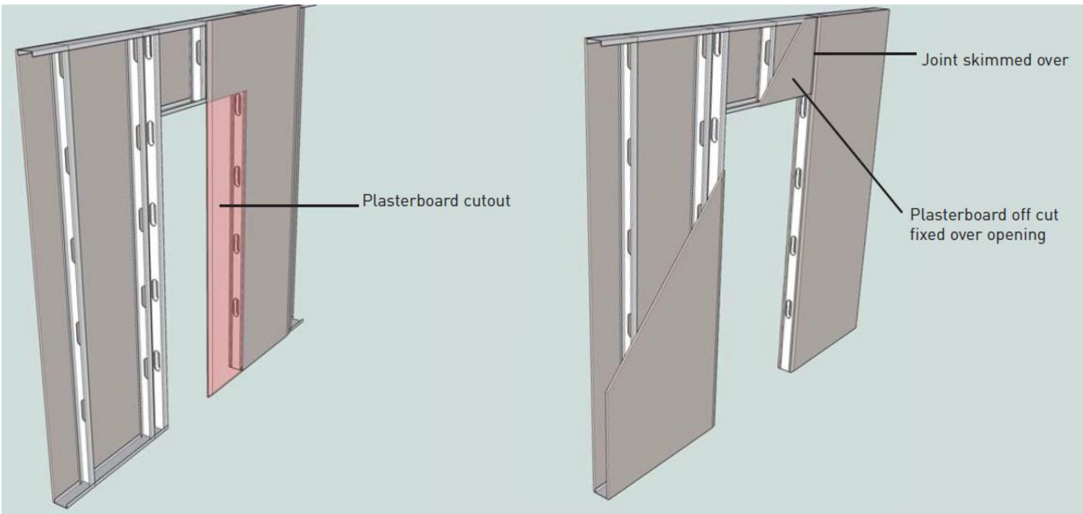


Figure 3.2 Low waste door jamb (Source: WRAP UK)

Table 3.4 Potential benefits of low waste door jamb

According to WRAP this alternative detail can lead to a 27 per cent reduction in plasterboard wastage.
A reduction in the amount of plasterboard required.
A reduction in waste management costs.
The speed of installation is not affected.
Reduced handling of materials, storage requirements and waste.
Reduced transport emissions because of fewer materials required and waste movements.
If the plasterboard waste is uncontaminated, the waste is recyclable.

Standard plasterboard sheets can be used without affecting the appearance of structural aspects of the door jamb.
There is no training required for installers.
This system is extremely efficient for buildings that contain many door openings so as hotels or apartment blocks.

3.17.4 Post tensioned floor slab

In a traditional slab the strength of the slab is dependent on the thickness and the amount of reinforcement in the slab. This is to overcome the low tensile strength of a concrete slab. The use of post tensioning increases the carrying capacity of the slab through the use of high tensile steel cables to apply compressive forces in the slab once it has set. All the forces from the tendons are applied through the slab and no additional stress is applied through the formwork. The use of these slabs has been popular in America and Australia for several decades and they are now becoming more popular in the UK. The slab is thinner than a traditional slab, therefore minimising the weight of the building and also reducing its height.

Efficient use of materials is achieved in the slab but also in the walls, columns and foundations which now have to carry less weight. The greater strength of the post tensioned slab also means that longer spans are possible between walls or columns. A post tensioned slab is only economic up to 12m. If the soffit of the slab is exposed it will improve the thermal mass of the building and contribute towards the cooling and heating requirements. The reduction in the thickness of the slab may cause problems for sound insulation so care must be taken to avoid the need for an increased ceiling structure to compensate for this. This detail could be used on the case study site but only up to a maximum of a 12m span.

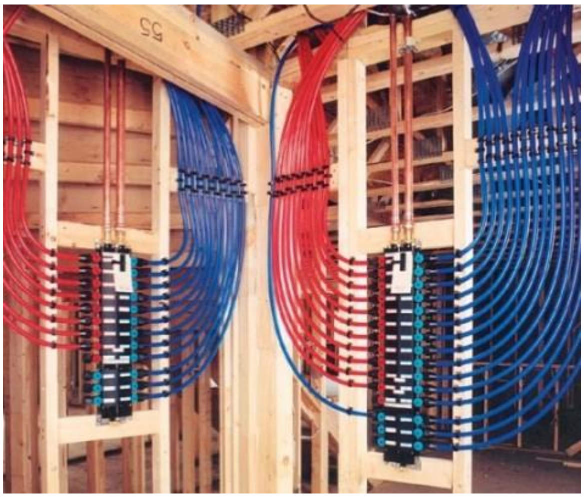
Picture 3.8 Post tensioned floor slab

Table 3.5 Potential benefits of post tensioned floor slab

The thickness of the slab can be reduced by 75mm and the steel reinforcement can be reduced by 50 per cent.
The light weight of the slab and longer spans mean fewer columns and smaller foundations. Down stands may also be eliminated.
The reduced materials requirements mean fewer transport costs.
The construction programme time can be reduced because of the time reduction in the installation and concrete pour.
If the tendons are prefabricated it will speed up the fixing time required.
Embodied carbon is reduced.
If the screed is minimised it will offer further savings.
Concrete with a recycled content can be specified, further reducing the carbon footprint.
Using post tensioned slabs has no effect on the recyclability of the slab.
The construction methods for this slab are well established and the design methods can also incorporate irregular grids.
This construction method is suitable for any situation where a traditional slab may have been used.

3.17.5 Flexible plumbing system

Traditionally plumbing in buildings has been constructed with the use of copper piping. There are a number of reasons for this; copper is a proven method of construction, it is reliable and has been proven safe to supply clean potable water. However the installation of a copper system can often involve complex layouts and uses a number of components, bends and branches. The installation and maintenance of the system can be labour intensive and require a plumber to carry out the installation with a number of specialist tools. Plastic plumbing systems have been developed in recent years and now offer performance levels akin to copper piping. Plastic systems are available for cold and hot applications along with above and below ground drainage. The flexible piping is available in long rolls and less waste is created in comparison with copper piping because of the reduced number of off cuts. Less joints and fittings are also required with the plastic system and these are easily detachable and reusable. The modern flexible piping comes with a 50 year or more guarantees and the piping has good insulation properties. Along with this vibration and noise is eliminated and most systems are easy to dismantle and replace even if the person carrying out the work is a non-professional. Plastic piping could be used on the case study site in place of the current copper pipe system. Use of such a system would cut down on waste and labour costs.



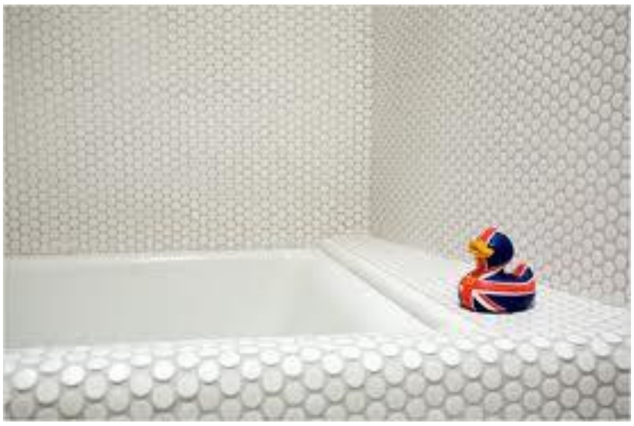
Picture 3.9 Flexible plastic piping

Table 3.6 Potential benefits of flexible plastic piping

Plastic piping is 75 per cent lighter than copper piping.
The lengths can be supplied up to 100m which means there will be fewer off cuts and fittings required.
The piping is a good thermal insulator and reduces the requirement for lagging.
Cost savings on installation and maintenance.
The installation is simple with push joint fittings; this also speeds up the installation process.
The embodied carbon is reduced when compared to copper.
The fittings can be rotated in situ and there is no need for the pipework to be earthed.
The pipework can be brought along complex routes and the fittings are compatible with copper pipes.

3.17.6 Tile detailing

A significant amount of waste is produced from the installation of wall and floor tiles at the fit out stage of a project, typically the amount wasted is between 8 and 10 per cent. If larger tiles are used the amount of wastage can be significantly higher because of the increased amount of off cuts produced and a higher damage rate. It is possible to reuse these off cuts but the majority of them end up as waste. If the type and the size of tiles are carefully chosen for the space they are to be used in then it can have a major impact on the amount of waste produced. Large tiles are appropriate if they are placed on a large area with no interruptions. However if it is a small area or an area where there are fixtures and fittings then the use of a small tile can result in a reduction in the amount of waste produced. Sheets of tiles such as mosaic tiles offer further benefits and allow for better workability along with the fact that even the small off cuts can be reused. If pre-fabricated bathroom pods are used, this can further reduce tiling waste as the tiles are pre fitted in a factory production environment. It is difficult to reuse reclaimed tiles as the tiles may break when trying to remove them. Broken tiles could be used to produce a mosaic which will provide a distinctive finish. Correct detailing for the bathrooms and kitchens on the case study site would reduce tiling waste. If the dimensions of a room are made to match the size of the tile then all waste could be eliminated.



Picture 3.10 Mosaic tiles

Table 3.7 Potential benefits of tile detailing

The rate of wastage could be reduced from 15 per cent to 8 per cent. The reduction of waste will depend on the dimension of the tile, the layout of the room, the amount of fixtures and fittings in the room and the skill level of the installer.
If smaller tiles are used then the damage to tiles can be reduced. This reduction of waste helps to reduce the costs required.
The use of sheets of tiles to cover a large area will lead to time savings.
The embodied carbon of the waste is reduced.
If ceramic tiles are used then they can be recycled. Ceramic tiles can have a recycled content of up to 46 per cent and this figure is even higher for glass tiles.

3.18 Trade specific opportunities for waste minimisation

The results from the questionnaire carried out as part of this thesis show that the majority of respondents believe that work processes are designed to facilitate waste reduction. However some work processes monitored on site as part of the case study need some simple modifications in order to be effective. The following are some opportunities for waste minimisation that could be used on the case study site. The points listed here would require little or no investment and a major change in working practices would not be required.

3.18.1 Contractor

Reduce

Task	Current practice on case study site	Future possibility on case study site
Plan ahead and use standard sizes to reduce the amount of off-cuts produced.	Standard sizes being used but materials are not ordered to fit.	Ordering material sizes to fit the job and thus preventing off-cuts.
Consider the use of off-site construction or prefabrication.	Hollow core, concrete stairs and roof trusses are prefabricated off-site.	Pods for bathrooms and kitchens as well as modular construction.
Only order the correct amount of materials that are required.	Materials ordered as per specification.	Consult with sub-contractors on material requirements.
Return or sell back the unused materials to the supplier or another source.	Not in place unless material has been unused.	Seek to set up such a scheme with suppliers.
Avoid storing materials on site for longer than required; consider using ‘Just in time’ delivery.	Currently in use.	
Ensure the correct handling and storage of materials.	Some poor handling of materials taking place on	Provide additional training to staff through

	site.	tool box talks.
Choose materials with minimal packaging over those with over engineered packaging.	Currently no consideration given to this.	Yes.
Set up take back schemes with suppliers for packaging.	None in place.	Yes.

Table 3.8 Contractor waste reduction opportunities

Re-use

Task	**Current practice on case study site**	**Future possibility on case study site**
Set up a certain area on site to store unused or off cut materials for possible reuse.	Some in place but no central area exists.	Yes.
Segregate waste and unused materials for reuse or recovery.	Waste currently not segregated except timber waste.	Waste segregation is important and should be carried out for key waste streams.
Try and coordinate the work programme so that if materials are left over from one trade, they can be used by the next.	Some materials are kept but storage of them is poor.	Yes.
Never throw away fixtures and fittings as these can be returned to the supplier or used on the next project.	Currently in use.	
A crusher on site could crush leftover concrete, bricks, blocks and hard-core for reuse as aggregate.	A crusher was used at the beginning of the job.	Can only be used if adequate quantities of waste are available.
Select a supplier who uses returnable packaging such as crates and pallets.	Some suppliers use them but no consideration is given to packaging.	Yes.
Donate unused materials and salvaged items to charity groups or the local community. An example would be half empty paint tins.	Not current practice.	Yes.

Table 3.9 Contractor waste reuse opportunities

Recycle

Task	**Current practice on case study site**	**Future possibility on case study site**
Segregate waste into the appropriate skips on site and ensure that no hazardous waste in mixed in with the mixed waste.	Waste not segregated. No hazardous waste has been seen in skips.	Segregation of the main waste streams. This method must be based on a cost benefit analysis.

Ensure that the skips are sent to a materials recovery facility and not to landfill.	Yes	
Select a waste contractor who will recycle the waste that you have segregated.	Yes	
Use suppliers who use recyclable packaging or a supplier who will take back the packaging and recycle it.	Not current practice.	Set up take back schemes with suppliers.

Table 3.10 Contractor waste recycling opportunities

3.18.2 Dry-liners and plasterers

Reduce

Task	Current practice on case study site	Future possibility on case study site
Ensure that the supplier you are using will take back any unused plasterboard.	Not current practice.	May not be possible in Ireland due to market availability but Barna Waste will ensure that it is recycled.
Only order the correct amount of materials that are required.	Yes.	
Inform the client and design team that costs could be reduced if standard sizes were used or if the boards were pre-cut off site.	Not current practice.	Yes.
Ensure that the delivery and handling of the plasterboard is carried out correctly in order to avoid damage to the material.	Yes.	
Avoid storing materials on site for longer than required; consider using 'Just in time' delivery.	Yes.	
Consider the use of a central cutting station to store the off cut materials for reuse.	Not current practice.	A central cutting station on each floor would benefit waste reduction.
Make sure that the plasterboard and bags of plaster are stored in a dry secure location.	Some poor storage of materials such as cement bags.	Provide additional training to staff through tool box talks.
Select suppliers that will take part in a take back scheme for packaging. Also consider buying materials with less packaging.	Not current practice.	Yes.

Table 3.11 Dry-liners and plasterers waste reduction opportunities

Re-use

Task	Current practice on case study site	Future possibility on case study site
Set up a certain area on site to store unused or off cut materials for possible reuse.	Large sizes are kept for reuse, smaller sizes are discarded.	Yes.
Inform your employees about the availability of the off cuts for reuse.	Currently no additional training provided on waste reduction and reuse.	Provide training through the initial induction and tool box talks.
Ask the plasterboard supplier whether they can use re-useable packaging for the delivery of the materials such as pallets.	Pallets are in use.	
Use leftover plasterboard from one job on the next job.	Only for large sizes.	Yes.

Table 3.12 Dry-liners and plasterers waste reuse opportunities

Recycle

Task	Current practice on case study site	Future possibility on case study site
Plasterboard should not be sent to landfill, segregated it from other waste and store it for recycling.	Not currently segregated but it is sent for recycling.	On large jobs segregation is necessary as Barna Waste only allow 5% gypsum waste per skip.
Try to prevent the plasterboard from getting wet as it becomes difficult to handle and recycle.	Skips are uncovered.	Covered skips for gypsum waste as well as cardboard and paper.
Select a waste contractor who will recycle the plasterboard waste or set up a take back scheme with the supplier.	Plasterboard is being recycled. No take back scheme in place.	Yes.
Use suppliers who use recyclable packaging or a supplier who will take back the packaging and recycle it.	Not current practice.	Yes.

Table 3.13 Dry-liners and plasterers waste recycling opportunities

3.18.3 Fit out contractors

Reduce

Task	Current practice on case study site	Future possibility on case study site
Select a supplier who will take back or buy back unused	Not current practice.	Select a supplier who will take back unused

materials.		materials
Use standard material sizes where possible and aim to reduce the number of off cuts.	Yes, kitchens and bedroom furniture and made to order.	
Consider the use of off-site manufacture.	Not current practice.	Bedroom furniture could be manufactured off-site.
Only order the correct amount of materials needed.	Yes.	
Handle and store the materials appropriately to avoid any damage.	Yes.	
Select a supplier who will engage in a take back scheme for packaging and try and select materials with minimal packaging.	Not current practice.	Ensure that suppliers take back packaging waste. Choose suppliers who provide materials with minimal packaging.

Table 3.14 Fit out contractors waste reduction opportunities

Re-use

Task	Current practice on case study site	Future possibility on case study site
Set up a certain area on site to store unused or off cut materials for possible reuse.	Not current practice.	Yes.
Inform your employees about the availability of the off cuts for reuse.	Not current practice.	Ensure adequate training through tool box talks to highlight this issue.
Use leftover materials from the job on the next project.	Not current practice.	Bring reusable materials to the next project.
Partitioning, doors and frames, glazing frames, timber boards, tables, desks, cupboards and floor coverings can all be reused.	Not current practice.	Yes.
Ask the supplier whether they can use re-useable packaging for the delivery of the materials such as pallets.	Not current practice.	Engage with suppliers to ensure re-useable packaging is used.
Donate salvaged items to charity shops or local community groups.	Not current practice.	Yes.

Table 3.15 Fit out contractors waste reuse opportunities

Recycle

Task	Current practice on case study site	Future possibility on case study site
Ensure the segregation of all waste produced.	Not current practice.	All packaging waste and timber waste should be segregated.

Select a waste contractor who will recycle the waste materials or set up a take back scheme with the supplier.	The waste contractor recycles the waste. No take back scheme in place.	Investigate the possibility of setting up a take back scheme for packaging waste produced during the fit out stage.
Ensure that the waste is sent to a materials recovery facility and not to landfill.	Yes.	

Table 3.16 Fit out contractors waste recycling opportunities

3.18.4 Carpenters and wood workers

Reduce

Task	**Current practice on case study site**	**Future possibility on case study site**
Select a supplier who will take back or buy back unused materials.	Not current practice.	Yes.
Use standard material sizes where possible and aim to reduce the number of off cuts.	Standard material sizes are in use, off cuts given some consideration.	Use standard sizes that can match door frame heights etc. to reduce off cuts.
Aim to use a better quality of timber even though the purchase price may be higher it may produce a better yield, saving money and time.	Not current practice.	Yes.
Purchase materials with less packaging.	No consideration given to the amount of packaging.	Yes.
Consider the use of off-site manufacturing.	Roof trusses are manufactured off-site.	
Only order the correct amount of materials needed.	Yes.	
Handle and store the materials appropriately to avoid any damage.	At times storage is poor.	Provide additional training through tool box talks.
Reduce off cuts wherever possible. Plan ahead to use off cuts and be selective of the lengths used.	Some instances of large off cuts remaining unused.	Provide additional training through tool box talks.

Table 3.17 Carpenters and wood workers waste reduction opportunities

Re-use

Task	**Current practice on case study site**	**Future possibility on case study site**
Set up a storage area for off cuts	Off cuts are being stored	Yes.

ready for reuse.	but there is no central storage area.	
Inform all staff that off cuts should be used first.	Some off cuts are being reused.	Provide additional training through tool box talks.
Use leftover materials from one job on the next project.	Yes.	
Ask the supplier whether they can use re-useable packaging for the delivery of the materials such as pallets.	Pallets are in use but no additional consideration given to packaging.	Yes.
Donate salvaged items to charity shops or local community groups.	Not current practice.	Yes.

Table 3.18 Carpenters and wood workers waste reuse opportunities

Recycle

Task	**Current practice on case study site**	**Future possibility on case study site**
Segregate timber waste in treated and untreated timber. Untreated timber has a higher value as it can be reused.	Not currently in place.	Can be segregated or leave timber unsegregated. Barna Waste can recycle both types.
Ensure that the waste is sent to a materials recovery facility and not to landfill.	Yes.	
Select a waste contractor who will recycle the waste materials or set up a take back scheme with the supplier.	Waste contractor recycles the timber. No take back schemes in place.	Set up take back schemes.
Use suppliers who use recyclable packaging or a supplier who will take back the packaging and recycle it.	Not current practice.	Yes.

Table 3.19 Carpenters and wood workers waste recycling opportunities

3.18.5 Electricians

Common causes of waste by electricians;

- Cable, conduit and trunking off cuts.
- Damage to materials during storage or handling.
- Reworking because of incorrect phasing.

- Packaging.

The wastage rate according to good practice should be 2% for PVC cable ducts and 1% for office lighting equipment. The wastage rate is equal to the difference between the material requirements used for the job compared to the amount ordered. Good practice assumes that an effort has been made to reduce the amount of wastage. An example would be a more accurate length estimation before cutting the cable from the reel. Cable termination tails must be kept to a minimum. Excessive tails are unacceptable.

Reduce

Task	Current practice on case study site	Future possibility on case study site
Prior to starting on site, estimate the amount of waste that you will produce so that a plan can be made of what to do with this waste.	Not current practice.	Yes.
Only order the correct amount of materials required.	Yes.	
Return or sell back unopened materials to the supplier.	Yes.	
Purchase materials with less packaging.	No consideration given to the amount of packaging.	Yes.
Handle and store the materials appropriately to avoid any damage.	Electricians have their own store on site.	It is important to avoid getting the materials wet once they leave the store.
Work with the contractor to ensure that the phasing is carried out correctly in order to avoid reworking.	Yes.	
Use standard cable in place of armoured cable on the inside of buildings	Yes.	
Plan ahead so that off cuts of conduit, cable and trunking is minimised.	High number of off cuts.	Yes.
Keep cable termination tails to an absolute minimum.	Tails are unacceptably long.	Yes.

Table 3.20 Electricians waste reduction opportunities

Re-use

Task	Current practice on case study site	Future possibility on case study site
Select suppliers who will provide	No packaging is currently	Yes.

returnable packaging. For example pallets, crates and cable drums.	being returned.	
Don't throw away any useable materials; take them to the next job for reuse.	Yes.	
Set up a storage area for materials that can be reused.	Some materials retained for reuse but storage is often poor.	Yes.
Maximise the use of off cuts of conduit, cable and trunking.	Not current practice.	Yes.

Table 3.21 Electricians waste reuse opportunities

Recycle

Task	**Current practice on case study site**	**Future possibility on case study site**
Separate the electrical waste from the general waste for recycling.	Not currently segregated. Waste is mixed into general waste skip.	Yes but only if large quantities of waste are produced.
Use small portable containers at the working location for transfer to the waste segregation area.	Not current practice.	Yes.
Ensure that the waste is sent to a materials recovery facility and not to landfill.	Yes.	
Select a waste contractor who will recycle the waste materials or set up a take back scheme with the supplier.	Waste contractor recycles waste but no take back scheme in place only for unused materials.	Yes.
Any metal waste should be sold for its scrap value or placed in the metal container on site.	Not current practice.	Yes.
Use suppliers who use recyclable packaging or a supplier who will take back the packaging and recycle it.	No consideration given to packaging.	Set up a packaging take back scheme with the supplier.

Table 3.22 Electricians waste recycling opportunities

3.18.6 Plumbers

Common causes of waste by plumbers;

- Tube, pipe and insulation off-cuts.
- Damage caused to materials during storage or handling.
- Reworking.

- Packaging.

The wastage rate according to good practice should be 2 per cent for copper pipework, 2 per cent for iron and steel pipes, 1 per cent for radiator heating systems and 2 per cent for water installations. The wastage rate is equal to the difference between the material requirements used for the job compared to the amount ordered. Good practice assumes that an effort has been made to reduce the amount of wastage. An example would be planning ahead to use off-cuts prior to cutting pipe lengths.

Reduce

Task	**Current practice on case study site**	**Future possibility on case study site**
Prior to starting on site, estimate the amount of waste that you will produce so that a plan can be made of what to do with this waste.	Not current practice.	Yes.
Only order the correct amount of materials required. This applies in particular to perishable materials such as sealants.	Yes.	
Return or sell back unopened materials to the supplier.	Yes.	
Order the correct size of materials in accordance with the specifications for the job.	Yes.	
Use a 'just in time' delivery system and pre-fabricated pipework.	Just in time system in place. All pipework fabricated on site.	Consider the use of pre-fabricated pipework.
Buy materials with none or minimal packaging.	No consideration given but pipework comes with minimal packaging.	Consider the amount of packaging on radiators and bathroom suites.
Ensure that materials are delivered, handled and stored correctly.	Storage of materials can be poor.	Provide additional training through tool box talks.
Minimise off cuts from copper pipes, pipe insulation and plastic pipes.	Off cuts given some consideration but could be improved on.	Provide additional training through tool box talks.
Avoid reworking by working with the client to ensure that the phasing is correct.	Yes.	

Table 3.23 Plumbers waste reduction opportunities

Re-use

Task	**Current practice on case study site**	**Future possibility on case study site**
Select suppliers who will provide returnable packaging. For example pallets, crates and cable drums.	Not current practice.	Yes.
Don't throw away any useable materials; return them or take them to the next job for reuse.	Valuable materials are not discarded.	Retain all reusable materials.
Set up a storage area for materials that can be reused.	Not current practice.	Yes.
Maximise the use of off cuts of pipe, tube and insulation.	Some off cuts are reused, could be improved.	Yes.

Table 3.24 Plumbers waste reuse opportunities

Recycle

Task	**Current practice on case study site**	**Future possibility on case study site**
Separate all waste for recycling. There may be just one skip for metal but it may also need to be separated into different types such as copper, brass and steel. Plastic and packaging should also be separated for recycling.	No segregation of waste on site.	Provide a metal skip and a skip for packaging waste.
Ensure that the waste is sent to a materials recovery facility and not to landfill.	Yes.	
Select a waste contractor who will recycle the waste materials or set up a take back scheme with the supplier.	Waste contractor recycles waste but no take back scheme in place only for unused materials.	Yes.
Any metal waste should be sold for its scrap value or placed in the metal container on site.	No metal waste container on site.	Yes. This could provide revenue for the contractor.
Use suppliers who use recyclable packaging or a supplier who will take back the packaging and recycle it.	No consideration given to packaging.	Set up a packaging take back scheme with the supplier.

Table 3.25 Plumbers waste recycling opportunities

3.18.7 Painters and decorators

Common causes of waste by painters and decorators;

- Over ordering materials.
- Improper storage
- Spillage and damage to materials during handling.
- Reworking.
- Packaging.
- Vandalism and theft.

Typically 10 per cent of paint purchased is wasted or unused. This quantity must be reduced. Please also note that some paints and solvents may be considered hazardous and should be separated accordingly. To date painters and decorators have not been present on site so details of current practice are unknown. Below are some examples of things that could be done to lower their wastage rates (please note that this is a different format to the above examples as painters and decorators have not been observed on site);

Reduce

- Ensure that the supplier will take back any unopened materials.
- Order the materials in larger quantities i.e. larger tins as this will reduce the amount of waste tins.
- Store all materials in a safe and secure place to prevent damage and spillages.
- Make sure lids are securely fastened in order to prevent the paint drying out.
- Soaks brushes in water overnight to save time on washing them.
- Wrap rollers in a carrier bag overnight.
- Use a ‘brush mate’ wet storage system.
- Buy materials with none or minimal packaging.
- Avoid reworking by working with the client to ensure that the phasing is correct.

Re-use

- Mix the unused paints together for use as an undercoat.
- Allow cleaning fluids and solvents to settle so they can be reused.
- Donate any unused materials to community groups or charities.

Recycle

- Use suppliers who use recyclable packaging or a supplier who will take back the packaging and recycle it.
- Remove the lids off tins of paint so that the paint can harden, these can then be disposed of at the appropriate licensed waste sites.
- Segregate hazardous waste from mixed waste to enable better recycling.
- Ensure that the waste is sent to a materials recovery facility and not to landfill.

3.18.8 Labourers on site

Task	**Current practice on case study site**	**Future possibility on case study site**
Aim to reduce the amount of waste you produce. This can be done be correctly storing materials and taking extra care when handling them.	Very little consideration given to wastage rates. Some storage of materials is poor.	Provide additional training and monitor the wastage rates on site.
Reuse material wherever possible instead of using new ones.	Some materials are reused.	Yes.
Reuse any off cuts before using new materials.	Some off cuts are reused however some large off cuts are ending up in the waste stream.	Yes. Provide additional training to ensure this point is achieved.
Recycle waste into the correct skips. Each skip will be labelled for its individual waste.	No segregation of waste on site. No labelling of skips.	Segregate the key waste streams on site.
Separate any hazardous waste from the general waste.	No hazardous waste seen on site to date.	Yes.
Make sure that the skips are packed well – an average skip can contain as much as 70% air.	Skips are un-compacted.	Compact skips with the bucket of a digger or loadall.
Reuse pallets for various applications on site. A pallet should never be thrown into a skip.	Some pallets are reused but some end up in the skip.	Save reusable pallets are repair damaged pallets for reuse.
When sweeping damp down the dust with water.	Unknown.	Yes.
If waste equipment and power tools need to be thrown out, do not throw them into the skip. These need to be recycled separately.	Assumed to be current practice.	Yes.
Avoid littering on site and place all waste into waste containers.	Some wind-blown litter on site.	Provide covered skips.

Never burn waste on the site.	Yes.	

Table 3.26 Labourers good practice waste management opportunities

3.19 Good practice checklist

This checklist has been developed based on the information contained in this chapter. Each action has been addressed within current practice and also the possibility of implementing these actions in the future.

Action	**Current practice on case study site**	**Future possibility on case study site**
Materials resource efficiency.	Currently the materials resource efficiency is poor on site and changes need to be made in this regard.	In the future one of the goals of the waste management plan will be to improve materials resource efficiency.
Roles and responsibilities for waste management and minimisation.	There are persons responsible for waste within the company.	This information needs to be published in the waste management plan and outlined to all staff working within the company.
Training and communication.	Training and communication in relation to waste management.	A training package will be provided to Carey Developments and it is anticipated that this will improve the training and communication.
Setting targets and KPIs.	No current targets or KPIs in place.	Targets and KPIs will be outline in the waste management plan. Targets have also been outlined in this thesis based on current government targets.
Waste recovery quick wins.	The benefits of quick wins are not being realised on site.	Quick wins will be implemented for the major waste streams on site.
Prevention, Reuse and recycling.	Practices are poor at present.	All of these practices need to be improved in line with information contained in this thesis.
The segregation of common waste streams.	No segregation taking place.	The segregation of the major waste streams must occur as waste generation rises on site.
Modern methods of construction	Some methods	Investigate the use of

(MMC).	incorporated include pre cast stairs, hollow core and roof trusses.	bathroom and bedroom pods on similar projects in the future.
Alternative details to reduce waste.	All details used are standard industry details.	The details outlined in this chapter could be considered on future projects.
Trade specific opportunities for waste minimisation.	Trades are not encouraged to reduce waste.	The opportunities outlined in this chapter could be used on future projects to reduce waste.
Waste management action plan.	None currently in place.	The use of the waste management action plan outlined in this chapter should be used and then adapted for future projects.
Skip management plan.	None currently in place.	The use of the skip management plan contained in this chapter should be used and then adapted for future projects.

Table 3.27 Good practice checklist

3.20 Waste management action plan (Table 3.28)

Waste type	Waste producer	Waste minimisation	Onsite reuse	Off-site reuse	Disposal
Metal	Steel frame, temporary works, decking, roofing.	Pre-fabrication, correct ordering, JIT delivery, correct storage.	Temporary works.	Metal recycler.	Landfill.
Timber	Formwork, carpentry, roofing.	Use steel shuttering, reuse shuttering, minimise off cuts.	Shuttering, temporary hoardings, general carpentry.	Wood chipped or mulched.	Landfill.
Plasterboard	Dry lining, partitions.	Adhere to specs, store correctly.	Keep off cuts for reuse.	Sent back to manufacturer.	Landfill.
Packaging.	Mech and elec, cladding, fit out.	Ask supplier for minimal packaging, buy products in bulk, take back schemes.		Segregate for recycling.	Landfill.
Insulation	Various stages.	Order correct amount, reuse off cuts.	Reuse off cuts.	Supplier take back scheme.	Landfill.
Cable wiring	Electrician.	Keep tails to a minimum.		Send to recycling facility.	Landfill.
Mixed waste	All stages.	MMC, pre fabrication, pre assembly.	Reuse materials where possible.	Send to waste transfer station.	Landfill.
Organic waste	Earth works, landscaping.	Re plant trees.	Chip wood on site for reuse as mulch.	Send for composting.	Landfill.
Pallets	Various stages.	Return to supplier or use plastic pallets.	Reuse for material storage or movement of materials.	Send for reuse.	Landfill.
Office waste	Site management.	Print double sided, send electronic documents.	Reuse paper.	Segregate and recycle.	Landfill.
Canteen	Site operatives.	Use reusable cutlery, crockery and cups.	Compost on site. (Food waste)	Send for composting.	Landfill.
Hazardous waste.	Various stages.	Use solvent free paints, minimise use of adhesives and mastics.	Use a lockable COSHH container for storage.	Incinerator.	Landfill.

3.21 Skip management plan

It is expected that the construction phase will result in the generation of a number of waste materials including; excavated material, steel, rubble, timber, cardboard, plastic, office and canteen waste, packaging and some small quantities of hazardous waste such as mastic and paint containers. If applicable these waste materials will be reused or recycled and any remaining waste will be sent to landfill and be disposed of in accordance with national and EU waste legislation by a licensed waste contractor. Waste that can be recycled includes timber, cables and cable trays, aluminium and steel off cuts, glass, plastics, packaging waste and pipe off cuts. Generally the materials that will be sent to landfill include insulation, cladding waste, plasterboard off cuts and other miscellaneous construction waste.

On site the system for waste segregation will be in the form of separate skips for different materials. These skips are:

- Timber.
- Metal.
- Paper/ Cardboard.
- Plastic.

Along with these skips there will be smaller bins for other wastes. These wastes are:

- Canteen waste (biodegradable waste).
- Office waste.
- Minor hazardous waste bins for oils, paint tins etc.

Each skip or bin will have a colour coded sign which will indicate to the user the content of each skip/ bin. At tender stage and pre appointment meetings subcontractors will be informed of the on-site waste segregation requirements. All subcontractors are obliged to comply and will be required to provide a method statement for their work prior to commencement. Any earthworks contractors used will have to produce the licence for their proposed landfill along with their waste transport permits. The waste segregation will be monitored and enforced by the waste manager or waste champion on site. All disposal of waste will be monitored throughout the duration of the contract.

It is also anticipated that a number of hazardous wastes will be produced during the construction and fit out phase of the project. The hazardous waste generated on site will be from miscellaneous minor sources. These include UV and fluorescent light tubes, batteries, waste oils, mastic tubes, paint tins and oily or greasy rags. As with any construction project hazardous waste arises from time to time. These hazardous wastes will be stored on site and managed as a hazardous waste. These wastes will then be removed by a licensed waste management contractor and sent for recycling, recovery or disposal.

The management strategy for generated waste is outlined in the table below:

Waste type	Hazardous	Storage/ Treatment (On site)	Disposal/ Treatment (Off site)
Paint tins	Yes	Hazardous waste bin	Return to supplier
Batteries	Yes	Hazardous waste bin	Return to supplier
Fluorescent tubes	Yes	Specialised container	Off-site recovery
Waste oil	Yes	Oil drum	Off-site recovery
Timber	No	Segregated skip	Recycle*
Metal	No	Segregated skip	Recycle*
Paper/ Cardboard	No	Segregated skip	Recycle*
Plastic	No	Segregated skip	Recycle*
Office waste	No	Into Paper skip	Recycle*
General waste	No	Segregated skip	Landfill or recovery
Canteen waste	No	Segregate into skips	Compost food waste. Recycle other wastes

Table 3.29 Waste management options

* Recycle in this instance means separating the waste into individual skips. This waste is then removed by Barna Waste to their materials recovery facility. Here the waste is processed for recycling. An audit of the Barna Waste recycling facilities has been carried out as part of the thesis; this also identified the recycling markets where these materials end up. A waste stream colour coding system is also outlined in an appendix to this document.

3.21.1 Skip management - current practice compared to future (good) practice

Current practice	**Future (good) practice**
Currently only timber waste is being segregated with all other wastes entering the mixed waste skip.	Waste will be segregated into; timber, metal, paper/ cardboard and plastic. As well as this smaller bins will be provided for canteen, office and hazardous wastes.
Skips are not colour coded.	Skips will be colour coded in line with standards developed in the UK (Appendix E)
No waste management method statements produced by sub-contractors.	All sub-contractors will be required to produce method statements. A method statement is contained in the appendices of this thesis.
There is no copy of the waste contractors' waste permit available on site.	The waste management contractors' waste permit for the transfer and handling of waste should be kept on file on the site.
No monitoring and enforcement taking place to ensure good waste management practices.	The appointed waste manager or waste champion must ensure that the details contained in the SWMP are enforced.
Hazardous waste is not segregated.	All major and minor hazardous wastes such as paint tins and empty mastic tubes will be segregated and stored on site prior to removal off site by the waste management contractor.

Table 3.30 Current practice compared to future (good) practice

3.21.2 Mini skips

Mini skips are in use on the Carey Developments site in Taylors Hill, Co. Galway. These skips are used at the work location and when full transferred to the larger skips. According to a case study carried out by WRAP on a site in Armadale, Scotland the use of mini skips can have a number of positive impacts on waste management on site; These benefits include;

- Collection of waste close to the waste material source.
- Efficient segregation of waste due to the reduced volume of waste in the mini skips.
- Improved waste handling which lead to labour and time savings.

- Improved waste segregation which leads to better recycling rates and reduced landfill costs. (WRAP, 2010)

The report states that the mini skips are suited to large sites where the waste skips are located a good distance from the working location. The mini skips allow the waste to be transported to the larger skips safely and efficiently. There were some issues on the case study site with contaminated waste streams but this could be overcome by providing clear waste signage along with education through tool box talks. Regular monitoring of the waste management on site is also important. The use of mini skips by Carey Developments is a positive step towards good practice waste management but the waste needs to be segregated at source, this is something that is currently not happening but may be introduced at a later stage of the construction period.

3.22 Barriers to achieving good practice

Embedded culture – it is often the case that certain working practices are embedded in the culture of companies and individuals and it is often difficult to overcome this in order to implement a new initiative. The questionnaire carried out for this thesis found that the majority of respondents stated that waste was an inevitable by-product of the construction industry. This is an example of embedded culture and beliefs such as this need to be changed in order to successfully implement good practice waste management.

Language barrier – with the employment of foreign labour on sites it is difficult to implement good waste management practices. The contractor must ensure that training such as tool box talks is adequate to communicate the desired message.

Management initiative – a new initiative within the company could be viewed as a management fad. Unless every member of the company is informed of the management's intentions regarding waste management change is unlikely to occur.

Corporate attitudes – commitment from the higher levels of management within the company is essential if a new working practice is to become accepted by the workers. The questionnaire carried out for this thesis found that waste management is currently not a goal for major stakeholders within the construction industry in Ireland. However it was also found that 100 per cent of the respondents felt motivated to reduce waste as part of their job.

Lack of training and communication – A lack of training and communication are two barriers to achieving good practice. The majority of the respondents to the questionnaire carried out for this thesis believed this to be true.

Lack of a waste management policy – The questionnaire carried out for this thesis found that a lack of a waste management policy within a construction company was one of the barriers to reducing waste on site and thus achieving good practice.

3.23 Overcoming the barriers to achieve good waste management practice

Provide incentives for the employees;

Site managers should be given the authority to hand out rewards on site for good performance, these rewards should be set out by the company's directors. The incentive scheme should be advertised within the company and each employee should be informed of its existence. It is important that below average performance should not be punished as this will cause a blame culture to emerge on site. If this happens it will be a big blow in trying to achieve good waste management practice.

Ensure that there is a support structure in place and that champions are in place throughout all levels of the company;

The champions' responsibility will be to ensure that waste management issues are in place throughout all levels of the company. The appropriate training should be provided to these employees through internal or external courses. The waste champion on site will be the centre point of waste management issues. It is important to draw up a clear list of the champions responsibilities on site. It is also important to assign responsibilities in relation to waste management as this can reduce waste. The majority of the respondents to the survey carried out for this thesis believed that poorly defined responsibilities can cause waste.

Get the workforce involved in contributing to good waste management practices;

Arrange feedback meetings where employees can raise any issues or provide feedback on the waste management on site.

Hire sub-contractors who contribute positively to good practice waste management;

A selection criterion should be set up for the hire of subcontractors. This criterion could include a questionnaire at tender stage and following selection the sub-contractors performance could be measured against internally developed KPIs.

Carry out regular random waste audits on site;

An appropriate person should be trained in carrying out site waste audits and be aware what to look for during an audit. If a site is performing poorly then improvement targets need to be set in order to achieve good practice. Subcontractors on site should be made aware of the audits and should be told what the auditor is looking for.

Highlight the senior management's commitment to the waste management plan;

An article should be placed in each edition of the sites newsletter or on the site notice board which shows the corporate commitment to the waste management initiatives on site. The newsletters should be distributed to employees to communicate the corporate commitment to the waste management procedures taking place on site.

Use visual aids or signs to assist with waste management;

Display the appropriate signage in suitable areas on site and ensure that the graphics are visually appealing to encourage interest.

3.24 Summary

It is clear that a change in the current waste management practices is needed in order to eliminate waste on site. This will require a shift form thinking of construction waste as something that is unwanted and destined to be discarded to thinking of these materials as a resource that can be reused, recycled or recovered (Del Río Merino et al., 2011). A main contractor can set a good example by setting waste minimisation, reuse and recycling into company policies and demonstrating a will to change. The culture of waste management can only be changed by main contractors working in partnership with sub-contractors, designers and suppliers to achieve good practice waste minimisation. It cannot be expected that a sub-contractor or labourer on site will change their mind set on construction waste on their own but rather that the main contractor must make it clear from the outset that waste reduction, reuse and recycling will be expected from all construction parties on site.

This chapter has provided an outline of practical information on how to minimise and manage construction waste within a construction company and on site. The next chapter will outline information on site waste management plans and their contents.

4.0 Chapter four - Site waste management plans

4.1 Aims and objectives

The previous chapter has provided an outline of practical information on how to minimise and manage construction waste within a construction company and on site. This chapter contains information on site waste management plans and their contents along with information on waste recording tools and the role of the various stakeholders within the industry.

This chapter will give an insight into the:

- Benefits of implementing a waste management plan.
- Difficulties involved in implementing a plan.
- Roles and responsibilities of the various stakeholders.
- Requirements when dealing with waste.
- How to implement a waste management plan.
- Content of a typical plan.
- Procurement strategies.
- Costs involved and the cost benefits.
- Waste recording tools.

4.2 Introduction

The costs of disposing of construction and demolition waste are constantly rising (DECLG, 2012) causing contractors to re-evaluate their position on waste disposal methods and to choose whether to see waste as rubbish or as a possible resource. The need to implement a waste management plan stems from both a concern for cost and for protecting the environment (Showalter et al., 1997). The increasing awareness of waste management has led to the development of waste management plans as an integral part of construction project management. Waste management plans focus mainly on the on-site management of waste; however there are opportunities to link a waste management plan into other stages. A waste management plan can also be embedded in a company’s site procedures, for example; designing out waste, more efficient procurement strategies and management of sub-contractors. Planning for waste management should be included during the design and procurement stage in order for good practice to be achieved. A waste management plan could contain adequate details in line with the type and size of the project. The plan can also include the working hours, the transport routes and any other information that adjoining property owners may be interested in. The waste hierarchy must be applied to all phases of the project from conception to construction. A waste management plan should be formulated at the earliest possible stage of the project. The formal production of the waste management plan can be at a later stage but a waste management philosophy ought to be adopted by the designer at the earliest possible stage. During the preliminary planning stage attention can be given to implementing a waste management approach that establishes the targets for the quantity of waste to be diverted from landfill and focus upon preventing waste, the reuse of materials and the recycling of any waste produced.

The waste management plan must be supported by management and have a buy in requirement from the project team including sub-contractors. The plan can be constantly evolving and be reviewed at the appropriate stages. The person implementing the plan must be able to communicate, motivate and train the staff in good waste management practices. The aim of the plan is for it to become common practice on-site and eventually merge into day-to-day activities. The preparation, implementation and documenting of a waste management plan will enable all parties to learn how to achieve good practice waste management. This can be achieved by recording summary information and performance outcomes along with lessons learnt. A waste management plan is an important document for construction companies and their clients, regardless of the company's size. A waste management plan will help improve the company's environmental performance and reduce rising disposal costs as well as meeting regulatory controls.

4.3 Best Practice Guidelines – Ireland

The *'Best Practice Guidelines on the Preparation of Waste Management Plans for Construction and Demolition Projects'* published in 2006 aim to promote an integrated approach to construction and demolition waste management (DECLG, 2006). The document provides guidelines on how to prepare a construction and demolition waste management plan and sets out the threshold limits for implementing a plan. The emphasis is placed on the waste management hierarchy (illustrated in chapter two) with waste prevention and minimisation being the top priority. Disposal is considered the last resort once all other options have been exhausted. The guidelines aim to promote a sustainable approach to the management of waste which will help towards environmental protection and the best possible use of resources. The document introduces the concept of project based waste management planning and promotes a ‘cradle to grave’ approach across all stages of a construction project. The guidelines also suggest appointing a construction and demolition waste manager to oversee activities at site level.

The guidelines are operated on a voluntary basis but planning authorities have the power to insist on a waste management plan being produced. Under section 34 (4) (1) of the Planning and Development Act 2000 the planning authority is permitted to attach conditions in relation to construction and demolition waste management. For example when the Luas A1 line was being developed the local authority requested a waste management plan to ensure that the waste arising during the construction phase would be managed and disposed of in a way that ensures the regulations applicable to construction and demolition waste are complied with (RPA, 2007).

4.4 Best practice guidelines – UK

There are numerous guidelines available in the UK on the implementation of waste management plans. The Defra *‘Non-statutory guidance for site waste management plans’* explains the purpose of WMPs, the legal duty to write and implement a plan and how construction costs can be reduced through the use of a plan. It demonstrates that using a waste management plan will improve materials resource efficiency therefore making construction more sustainable (Defra, 2008).

The Dti *‘Guidance for construction contractors and clients’* explains the structure of a waste management plan and provides details of how a construction company can use a plan to improve and manage the waste management operations on and off-site. The document also includes checklists and other guidance that can make the waste management plan into a practical tool.

WRAP in the UK have a huge amount of guidance documents and reports that can help contractors achieve good practice waste management and develop an appropriate waste management plan. Their document *'Good and best practice use of site waste management plans'* identifies standard, good and best practice use of waste management plans and will enable a construction company to take a step by step approach to resource efficiency.

Netregs have produced; *'A simple guide to site waste management plans'* and this is a simple guide that explains the information required to produce an effective waste management plan. The guide also contains information on how to reduce, reuse and recycle waste on site.

The ICE *'Demolition Protocol'* was first published in 2003 and since then it has been incorporated into planning guidance in the UK as well as through organisations such as WRAP. The 2008 Protocol provides a framework on the approaches of how to manage buildings at the end of their use phase. The Protocol also provides an integrated approach on how to develop a waste management plan that includes targets and approaches that will deliver major benefits.

There is also a useful website – sitewastemanagementplan.com which is a useful tool that provides details of how to create and maintain a site waste management plan. There is also a template available for download from the site.

4.5 Waste management plans for planning

If a project exceeds the thresholds outlined below an outline waste management plan must be submitted as part of the planning application. A detailed plan is submitted to the environmental or waste management section of the local authority where the plan must be agreed upon prior to the commencement notice stage. The developer is then allowed to proceed with the plan unless the authority indicates that there is a problem with the submitted plan within six weeks.

The local authority may request that a formal implementation report be submitted to the waste management or environmental department of the authority. The local authority may also request the submission of summary reports from the contractor that detail the reuse and recycling taking place as well as an estimate of the amount of waste that has been diverted from landfill. The local authority also has the power to carry out a periodic monitoring and inspection of a construction or demolition site.

A waste management plan should be produced for projects which exceed the following thresholds;

- New residential development of 10 houses or more.

- New developments other than above, including institutional, educational, health and other public facilities, with an aggregate floor area in excess of 1,250 m^2.

- Demolition/ renovation/ refurbishment projects generating in excess of 100m^3 in volume, of construction and demolition waste.

- Civil Engineering projects producing in excess of 500m^3 of waste, excluding waste materials used for development works on the site.

(DoEHLG, 2006)

4.6 Site waste management plans

A site waste management plan is a tool used to manage waste on-site. However it should also be used during the early stages of the project to identify potential waste streams in order to minimise waste and to identify the appropriate methods of recovery. Producing a site waste management plan before construction begins will help to achieve good practice waste management.

According to WRAP the benefits of implementing a site waste management plan have been found to be;

- 15 per cent less waste on-site.
- 43 per cent less waste to landfill.
- 50 per cent savings in waste handling charges.
- 40 per cent saving on costs compared to landfill disposal. (WRAP, 2008)

In order to achieve good practice a waste management plan should be developed and implemented according to good practice standards. The site waste management plan should include details on how to comply with legislation, guidance on how to reduce, reuse and recover the waste generated and state that disposal is the least favoured option.

The key features of a good practice waste management plan are;

- Identify a person who is responsible for the implementation of the waste management plan. This could result in a noticeable improvement in record keeping and appropriate waste segregation

- Produce an estimate of the likely types of waste that will be produced on site and their approximate quantities.

- Implement a training programme for all personnel to improve waste awareness on site. It is also important to get all the sub-contractors to sign and formally agree to the waste management plan.

- Set out recovery rate targets for each type of waste and if the targets are not achieved investigate why this has not happened.

- Identify where materials can be reused on the site or if they can be reused off site.

- Identify the site practices such as how waste will be separated and the measures required to do this.

- Measure and record the amount of waste reduced and recovered and outline lessons learnt at the end of the project.

- A site waste management plan should be specific to the site and should cover the design stage, on-site practices, procurement and logistics.

Implementing a waste management plan on site should be considered as a tool towards achieving good practice waste management rather than an end in itself.

4.6.1 Benefits of a waste management plan

A waste management plan is a plan that details the amount and type of waste that will be produced on site and how that waste will be reused, recycled or disposed of. Waste management plans give the contractor an opportunity to streamline the site activities and achieve a number of business and environmental benefits. A good practice waste management plan should be designed to encourage better waste management practices as well as improving the environmental performance of the company and reducing the cost of waste management. Tam (2007) found that the main benefits gained from implementing a waste management plan are that methods are proposed for on-site reuse of materials as well as methods for reducing waste. However it was also found that the major difficulties facing the implementation of a WMP is that the contractor believes that there is a low financial incentive and an increased overhead cost. Previous studies by Tibor (1996), Jasch (2000), Kuhre (1998) and Tam et al. (2006) found that implementing a waste management plan will have numerous benefits including; preventing pollution, allocating resources more efficiently, complying with regulations, risk evaluation and preventing potential waste problems.

Adopting a waste management plan will help the contractor to measure the cost of waste more accurately. Once this cost in known it is then possible to start benchmarking and setting targets as well as identifying and implementing cost saving measures. Feedback can then be provided to the designers and procurement team to help minimise waste arisings on future projects. A waste management plan encourages the effective use of materials and ensures that waste management is considered through all stages of a project; from the design to completion. Through the use of good practice and the use of a waste management plan on construction and demolition sites the quantity of waste being sent to landfill can be reduced by a large quantity (WRAP, 2010). The improved use of materials will make a contribution towards reducing the environmental impacts of the construction industry including resource depletion and disposal of waste. The plan will help to make cost savings through better management of the materials supply, improved methods of material storage and handling, decreased disposal costs, a decrease in labour time and better management of waste prior to its recovery or disposal (WRAP, 2010).

Once a waste management plan is in place it allows the contractor to have more control of the risks relating to the materials and waste on the site. Good housekeeping improves site safety as well as improving the overall appearance of the site. The use of a waste management plan will also demonstrate the contractors' ability to comply with relevant legislation and the duty of care. The plan is also a mechanism to demonstrate to current and potential clients how the waste is managed on site and how costs and risks are minimised as well as being a tool to help fulfil the requirements of environmental management systems such as ISO 14001. A waste management plan can increase the company's competitive advantage through differentiation, lower the company's carbon emissions and help to meet planning requirements if a waste management plan is requested from the authorities.

Constructing Excellence (2008) estimates that if a waste management plan is implemented correctly then it can provide savings of at least 3 per cent on build costs and 20 per cent of materials cost on site. Segregating waste on site can result in a saving of at least 0.2 per cent of the total cost of the project (DTI, 2004). An effective waste management plan can add value to construction projects by; reducing the amount of waste generated, reduced labour and transport costs, reducing the cost of the procurement of additional materials, achieving savings by reclaiming and recovery of their monetary value by selling them on and reusing materials on site that would have otherwise been disposed of. A waste management plan can also add value in terms of health and safety by reducing the risks of transporting waste (especially hazardous waste), providing better control of risks from waste materials on site and reducing the risks from vermin (such as Weil's disease from rats).

The environmental benefits of a waste management plan are another positive aspect of the implementation of a plan. Proper control of the waste management process through the use of a waste management plan can reduce the amount of illegal dumping, reduce landfill requirements, lower the rate of depletion of natural resources and reduce carbon emissions.

4.6.2 Difficulties in implementing a waste management plan

As outlined previously there are numerous benefits to be achieved in implementing a waste management plan but there are also some difficulties that may be encountered during the process. Shen and Tam (2002) found that one of the major reasons for not implementing a waste management plan is the perceived high investment cost and the requirement to send employees on training courses. Chan and Li (2001) found that other difficulties include; lack of expertise, lack of staff involvement and poor co-ordination between the government and the construction industry. In order to be successful a waste management plan needs to be supported by top management and Kuhre (1998) found that this is crucial to the success of the plan. Ling and Lim (2002) found that in order for a waste management plan to succeed, a commitment from the top level of management was essential and that senior site personnel need to be involved in the process. This shows that waste management must be initiated from the top down as workers by themselves are not motivated to minimise waste.

Padfield et al. (2011) found through interviewing contractors that the main factors preventing the use of waste management plans was that there is a lack of encouragement and promotion from the Government and also the view that waste management plans reduce the contractors profits. The contractors also stated that the apparent cost implications of a waste management plan were another reason why they were not being implemented. Other barriers identified were the lack of available information and incentives for the use of waste management plans. Tron (1995) found that the lack of relevant experience on the implementation of a waste management plan was one of the barriers to its implementation. Shen et al. (2004) identified that the lack of an organisations policy or appropriate training for the staff that actually handles the waste was one of the problems for the implementation of waste management plans on site.

The low financial incentive and the increase in overhead costs are two of the burdens of implementing a waste management plan. The facilities and equipment that may be needed on site cost money in the short term but in the long term these difficulties can be alleviated because when the waste generation is reduced the cost savings will improve (Tam, 2007). Oladiran (2004) found that the barriers to implementing a waste management plan were; poor execution of a waste management plan, lack of understanding by site staff, lack of awareness on site, time constraints, poor waste sorting, lack of space, illiteracy among site operatives, language barriers, poor attitude towards waste, poor communication, lack of commitment from staff and poor monitoring of the waste management plan.

4.6.3 Summary of benefits and difficulties in implementing a WMP

Benefits	**Difficulties**
Reduces waste on site and prevents pollution	Belief that there is a low financial incentive
Allocates resources more efficiently	Lack of expertise and staff involvement
Helps the company comply with regulations	Needs a commitment from management
Prevents potential waste problems	Lack of experience and training
Can measure the cost of waste more accurately	Poor understanding of WMP by staff
Ensures waste is considered through all stages	Lack of awareness on-site
Produces cost savings	Time constraints
Better waste management practices	Poor attitudes towards waste
Improved site safety	Poor communication
Environmental benefits	Lack of monitoring and auditing

Table 4.1 Summary of benefits and difficulties

4.7 Roles and responsibilities for waste management

Through the information gathered through the questionnaire used for this thesis it was found that the majority of the respondents believed that the responsibility of waste management was mainly the main contractor and sub-contractors responsibility. As well as this the majority of respondents agreed that the main contractor has an important role to play in reducing waste on a construction project. However each party within the construction process has a part to play, which are outlined below;

4.7.1 Role of designers

Price (2010) (a) carried out a survey that found that the designers' involvement in reducing waste during the design stage showed a lack of understanding and commitment to the waste reduction process. A second survey carried out by Price (2010) (b) found that the information required by the main contractor on the types and quantities they are expected to manage, is lacking. As a result any waste reduction achieved during the construction phase would be at the initiative of the main contractor and this places an unreasonable responsibility on them to reduce waste resulting from a design that is out of their control. It was also found that this may cause an increased health and safety risk and environmental risk because the main contractor has no previous knowledge of the waste management requirements until the construction phase begins. Osmani et al. (2007) carried out a survey of designers and the findings showed that waste management is not a priority in the design process. As well as this it was found that the designers believed that most waste is produced during the construction stage and rarely during the design stage.

The initial decisions on the building shape and construction type can have a huge effect on the amount of waste that is likely to be generated. At the design stage the designer has a good opportunity to influence the waste arisings and this includes the reuse and recycling of materials into the building. The designers should consider the shape and form of the building so that it does not create unnecessary waste and should try and incorporate the use of reclaimed or recycled materials into the design. The type of construction and the construction process should also to be considered as there are opportunities to minimise waste during the construction phase.

As the design evolves opportunities to eliminate waste should be identified and good design coordination is required so that reworking and modifications are avoided. In this regard the designer needs to work with the client and the contractor in a concerted effort to design out the waste from the outset. The waste management plan should also be developed during the design stage so that it can act as a tool for the design process and help eliminate the waste problem at its source. The waste management plan will contain information about the different waste streams and their quantities so that decisions can be made regarding the design and also the supply chain. The designers could also be involved in the waste management plan so that waste can be considered from the outset of the project.

4.7.2 Role of clients

A survey carried out by Osmani et al. (2007) found that one of the constraints in implementing a waste management strategy was the lack of interest from clients. The client should set out a waste minimisation agenda early on in the project as this will provide a clear mandate to all the parties involved that good practice must be implemented at every stage of the project. This will ensure that the benefits of adopting good practice waste management are realised. Prior to the appointment of the design team or the main contractor the client should determine their awareness in relation to applying waste minimisation methods and their ability to reuse and recycle materials. The setting of Key Performance Indicators (KPIs) for the recovery of materials and setting a clear design brief that is aimed at avoiding waste production by the client will also help to achieve good practice.

4.7.3 Role of main contractor

The contractors' main role is developing the site waste management plan and logistics plan which should focus on waste reduction and waste management on site. The main contractor should also develop a waste reduction strategy in order to reduce the total volume of waste produced on site. This strategy will include the considerations and design decisions that are taken at the start of the project.

The contractor should support the design team in looking for ways to reduce the waste in the design as it is the contractor who sees where the waste is generated on site. The contractor must appoint a responsible and knowledgeable individual who is in charge of the development and implementation of the waste management plan. It is good practice to set out the requirements for waste management in the tender documents so that it is known what the minimum requirements are on site. As with the client the contractor can also set KPIs for the recovery of waste and seek to achieve a number of quick wins. It will then be a contractual obligation for the sub-contractors to reach these targets and it also enables the waste management performance to be measured and monitored throughout the project. It is the main contractor's responsibility to provide an area or waste compound where waste can be segregated and then reused on or off site, sent for recycling or safely stored. The waste compound must be managed to ensure that the waste is being segregated correctly and ensuring that materials are used to maximise their reuse and recycling potential. The main contractor must also ensure a development of lessons learnt in order to achieve continuous improvement. This can be done by gathering waste data and comparing it against targets and benchmarks.

The main contractors' role in waste management will be largely conducted through the waste manager or waste champion, who will carry out the objectives set out in the waste management plan. Osmani et al. (2006) found that contractors are actively pursuing a proactive approach to waste management on site through the development of waste management and environmental policies. Begum et al. (2009) conducted a survey of main contractors and found that the behaviours towards waste management differ depending on the size of a project. The factors affecting contractor attitudes towards waste management were found to be; source reduction, recycling and reuse measures, the frequency of waste collection, the level of participation in training programs and the methods of waste disposal. These factors should be addressed in order to improve waste management and help to reduce environmental degradation.

4.7.4 Role of sub-contractors

The subcontractors are the individuals who actually handle the materials and sometimes order their own materials; because of this the subcontractor has a role to play in delivering waste management objectives and should also be involved early in the waste planning process. For example, some subcontractors such as dry-liners and flooring subcontractors will be able to provide very accurate estimates of the materials they require and will be able to identify how much waste will be produced and in turn provide recommendations on waste minimisation. Saunders and Wynn (2004) found that there is willingness beyond what might be expected that some sub-contractors are willing to accept some of the costs of waste management. Teo et al. (2000) found that sub-contractors attitudes towards waste management are positive but any goodwill is impeded by a lack of management commitment to waste reduction. The subcontractors are responsible for segregating their own waste into the correct skip and maintain a safe and tidy work area

The subcontractor should also minimise waste brought onto site such as pallets, plastic wrapping and cardboard. If the sub-contractor is ordering their own materials then it is their responsibility to organise take back schemes with their individual suppliers. Prior to construction the subcontractor should outline the expected waste quantities for each waste stream. If this is done then the main contractor can agree a waste level with the sub-contractor and if this level is exceeded then the sub-contractor will have to pay a penalty charge. If damage to materials through improper handling by the subcontractor can be attributed to them, then the sub-contractor should be made financially responsible. The subcontractor should give feedback to the main contractor on their ideas to reduce waste on site along with figures for the actual waste produced and how this waste could be minimised in the future. The results of the questionnaire carried out as part of this thesis show that 63 per cent of the contractors surveyed have asked sub-contractors or operatives for feedback which is good.

In order to minimise over ordering of materials the subcontractors need to produce an accurate estimate of the materials that they will require. If the sub-contractor is to do this accurately then the information that they use to produce their own take off must be accurate. The take-off can be done with the help of CAD, digital estimating software and on site measurements. The waste allowance added by subcontractors must be project-specific and not just be based on historical data or data from previous projects. It is essential to the success of the waste management plan that all staff members are committed to achieving the goals set out in the plan. Training on waste segregation and its importance in terms of financial benefits should be outlined to all staff at the start of the project. Good practice dictates that sub-contractors should be responsible for the segregation of their own waste on site rather than the main contractor. For some projects it may be necessary to require sub-contractors to participate with waste segregation and management through contractual obligations or even require them to be responsible for the removal of their own waste.

4.7.5 Role of waste management contractor

The waste management contractor should supply and remove any required waste containers to the site and maintain legal compliance of the transfer and management of waste once it leaves the site. Reports on waste production on a weekly or monthly basis could also be supplied by the waste management contractor. The waste management contractor could also provide reports that outline the composition of the waste leaving the site and inform the contractor of the end uses for the waste.

4.7.6 Role of a waste champion

The waste champion on site will have the following key responsibilities;

- Implement the waste management plan and carry out any administrative or planning duties associated with the plan.
- Increasing awareness of the plan and engaging with site operatives.
- Monitoring waste generation on site and producing the appropriate reports.
- Monitoring the effectiveness of the waste management plan.
- Engaging with and monitoring the waste management contractor.
- Monitoring and enforcing waste segregation and minimisation on site.
- Encouraging suggestions for better waste management on site.

4.8 Implementing a waste management plan

The type and level of detail required in a waste management plan depends on the company's practices and procedures and also the type and size of the project. For example, a waste management plan will need to contain less detail for a small project in comparison to the detail required on a large project. Achieving good practice waste management is relatively easy to achieve without a change to the fundamental working practices on site and are at a minimum cost neutral good practice aims to take waste management practices a step further than compliance with the law.

Good practice dictates that waste management issues should be considered during the planning or in the pre contract stage. Considering waste management at this stage allows for adequate planning for waste prevention, minimisation and recycling during the project programme to be taken into account. It is important to consider these aspects at the early stages as it is during these stages that important decisions can be made in relation to waste management such as building shape, form and layout. The formulation of a waste management plan needs to be undertaken at the earliest possible opportunity, preferably during the design stage. The waste management plan should be written to a scope and level of detail appropriate to the size of the project. The plan should also include information about the hours of work, transport routes and other issues which might affect neighbouring properties or persons during the course of the project.

The waste management hierarchy should be taken into account throughout each stage of construction including; the projects conceptual stage, preliminary design and planning stage, procurement and tendering stage, pre-construction stage and the construction stage itself. During the preliminary planning stage of the project, attention should be given towards the development of a construction and demolition waste management approach. This approach should outline the targets for diversion of waste from landfill and aim to focus on waste prevention, minimisation, recycling and reuse. The person responsible for writing the waste management plan should have a good knowledge of waste management issues and also the details of the construction project. The waste management plan can also be written in partnership with the client, design team, environmental team, regulatory bodies, sub-contractors and suppliers.

A waste management plan can be prepared using the following nine steps;

Figure 4.1 Steps in producing a waste management plan (Source: DTI, 2004)

4.8.1 Step one – Prepare and plan

It is essential that the waste management plan is considered at the design stage of the project. It is during the design stage that decisions are made that can have a significant contribution to reducing and preventing waste. Waste that will be generated on site should also be considered for reuse. If these steps are planned in advance then it will help to get the most out of the materials and stop the materials becoming waste. All decisions made at the design stage that will minimise the amount of waste produced should be recorded. An example would be if the size of a bathroom was built to fit the size of the tiles so that there are no off cuts, this would be a waste minimisation that should be recorded. If the measures to reduce waste are recorded then it will allow the contractor to quantify the amount of waste that has been reduced along with the cost savings. It must again be emphasised that this early stage provides the best opportunities to reduce the amount of waste that might be produced. Planning ahead will help identify areas where waste can be minimised. For example, if the height of the ceiling corresponds to the length of a sheet of plasterboard then there should be a reduced number of off cuts. Good on site storage, improving the method of working and employing a skilled labour force will help to minimise the potential wastage of materials. If these points are put into practice then the targets for recycling and diverting waste from landfill can be achieved.

4.8.2 Step two – Allocate responsibility for the waste management plan

One person must be appointed for the overall responsibility of the waste management plan. This will typically be someone working for the main contractor and this person is responsible for updating the plan and monitoring the waste management. The person responsible must understand their responsibilities and possess the authority to ensure that other persons cooperate.

4.8.3 Step three – Identify the waste that will be produced

The types and quantities of wastes that the project will produce need to be identified. It is important to think through each stage of the work and calculate what materials will be used and consequently wasted. The waste should be broken down into the relevant work package or sub-contractor carrying out the works. Once the quantity of waste is established then realistic targets must be set for the reuse and recycling of that waste. Estimating the waste quantities will help to estimate what type of waste containers will be required and will help in determining the waste segregation required as well as the costs involved. Waste quantities from any demolition or enabling works should also be estimated. Estimating the quantity of demolition waste can be done using the ICE Demolition Protocol pre-demolition audit. Estimating waste quantities is useful when dealing with waste management contractors as they may work on economies of scale. As well as this it may be possible to send waste to another site requiring that materials, for example crushed aggregate made from concrete. The template in the appendices can be used to estimate waste quantities. A best estimate of the quantities is sufficient and this will help to prioritise the waste streams. The total volume of waste can then be summarised. It would be advantageous to then produce weekly or monthly summaries of the waste produced.

4.8.4 Step four – Identify how to manage the waste

The best options need to be established for the recycling and disposal of all waste that will be produced on site. All waste must be stored and disposed of responsibly. If waste is segregated as it is generated then it will save time and money. Waste transfer notes or consignment notes should be kept as a record of waste disposal. Various options must be considered in advance of the waste arising on site. Consulting with the waste management contractor will help to establish what happens to the waste once it is taken off-site. Identifying how to manage the waste will help identify any specialised equipment that might be required, e.g. a mobile crusher, space requirements and the need for any licenses to manage waste on-site.

4.8.5 Step five – Identify how and where the waste will be disposed

It is essential that the contractor knows how and where the waste will be disposed of. If a waste contractor is being used then the contractor must ensure that they dispose of the waste legally and safely. The contractor must check that the waste contractor is a registered carrier of waste and their waste carrier licence number should be recorded in the waste management plan. Any other sites receiving the waste must have the appropriated licence or permit and these details should be recorded in the waste management plan.

Prior to segregating waste on site the main contractor should discuss the various options available with the waste management contractor. Once the method of sorting, storing and collecting the waste has been chosen the waste containers can be labelled in order to ensure that the correct waste is placed in each container. It is also important for the main contractor to carry out a periodic audit of the waste movement from the site to the wastes final destination.

4.8.6 Step six – Plan the effective organisation of materials and waste

A number of things can be done in order to make savings on the materials needed for the project;

- Avoid the over ordering of materials.
- Reduce materials wastage.
- Pre order materials to specification. This can reduce the amount of off cuts and the labour costs.
- Take into account any limitations of the location of the site.
- Consider the use of salvaged materials or materials with a recycled content.
- Record any decisions made about waste minimisation.
- Record the waste management plan targets for effective materials management.

4.8.7 Step seven – Communication and training

Once the waste management plan is in place, everyone needs to be informed of its existence. A copy of the waste management plan should be kept on site and all work personnel should be aware of its location. All workers need to have the correct training and information to carry out their work in accordance with the waste management plan. Waste management issues should be included in the site induction and also through toolbox talks. A training programme can be developed in order to ensure that everyone understands the waste issues and the effective use of materials. As the project progresses it is important to carry out regular spot checks and audits to make sure that the staff are following the correct procedures. Appointing a waste champion can have a major positive effect on the success of the waste management plan. The success of the waste management plan rests on the ability of the person responsible for the plan to communicate it to the staff on site. Different methods can be used including; Induction talks, toolbox talks, workshops, site meetings, posters newsletters and informal methods such as a suggestion scheme. Staff and sub-contractors should be provided with regular training where appropriate and the waste management plan should be discussed at the pre-meeting stage in particular with sub-contractors and waste management contractors. A record should be kept of any staff that have provided with training and the training records should be audited regularly.

4.8.8 Step eight – Measure the quantity of waste and update WMP

Once the project is underway the waste management plan should be updated regularly, for example when waste leaves the site. All movements of waste should be recorded along with the type of waste removed, who removed it and where it was taken. The waste documents should be kept as an appendix to the plan. Measuring the type and quantity of waste being produced allows an insight into how well the plan is working. Recording measurements of waste produced can allow a comparison to projects in the future. Measurements could include the number of skips, the cost of disposal and the weight of the skips. The cost of the waste should then be recorded against the value of the project, the area of the floor space and the volume of the building. Software tools such as SMARTWaste developed by the BRE can help in monitoring the amount of waste being generated and the quantities can then be benchmarked against other projects. Regular audits of the skips should be carried out to ensure that the waste is being segregated correctly and that the skips are not being contaminated with mixed waste. If a skip has become contaminated it is important to find out who contaminated it and carry out retraining if necessary.

4.8.9 Step nine – Review the success of the plan and any lessons learnt

At the end of the project the waste management plan will provide a record of how effectively materials were managed on site and whether or not the waste management targets were met. The information gathered during this project will then be useful for future projects. It could be beneficial to draw up a report with the results of the waste management plan and future points of action. The waste management plan should be retained for two years after the project has finished. Lessons learnt and any recommendations can be applied to future projects within the company. The estimated waste forecast should be compared to the actual waste produced and the client and project team should be debriefed in terms of the successes or improvements needed. New targets and benchmarks can be based on the waste management plan experience and the company should aim for continuous improvement. The results from the review report can be fed into annual reports as well as company newsletters.

4.9 Content

A construction and demolition waste management plan should take into account the following aspects;

- Description of the project along with the location, size, design and scale of the proposed development.
- Responsibility for waste management.
- An analysis of the quantity and type of waste which will arise and any material surpluses.
- Waste management objectives.
- Methods to be used to prevent, minimise, reuse and recycle any waste.
- The handling procedures for materials.
- Where can the waste be used on this project or other projects and how is this waste tracked.
- Training schemes for the workforce.
- Which contractors will be used and how to ensure they comply with waste management no site.
- A dissemination plan for the programme.

(WRAP, 2010)

A waste management plan does not need to be a complicated document and should concentrate on reasonable measures that can be taken to improve waste management on the project. The effectiveness of a waste management plan can be monitored through checks and audits which should concentrate on the materials input versus the waste output. The audits should also investigate the factors that contribute to the generation of waste on site and what corrective actions could be put in place. This auditing should be carried out by the waste manager and these audits should be carried out throughout the projects duration. If these audits are carried out correctly then waste management plans developed in the future can be based upon previous plans and then modified based on the audit findings. A waste management plan should outline the waste management procedures as concisely as possible.

4.10 Cost of waste management

It will benefit a contractor to establish the costs associated with waste production and management as once these costs have been identified it is then possible to undertake cost control procedures to ensure that unnecessary waste management costs are eliminated. When establishing this cost it is important to consider the true cost of waste. The cost is not just the cost incurred by the hiring of a skip but is in fact as illustrated below;

Purchase cost of the delivered materials wasted.	+	Cost of waste storage, transport, treatment and disposal.	+	Loss of not selling waste for salvage or recycling.

It is then possible to estimate the total waste management costs and this will be of benefit to the contractor. In research carried out by Skoyles and Skoyles (1987) established that 18-19 per cent of materials purchased are never paid for by the client in accordance with the specifications for the project.

The main contractor should establish the commercial rates for the waste services offered by the waste management contractor and it should be established if any of the waste has a scrap value as this can be recorded as a credit for the main contractor. The value of the waste should be considered as the waste management contractor may benefit from the resale value of the waste. Once the waste forecasts and the waste management rates have been established then it is possible to estimate the cost of the waste.

4.11 Responsibilities when dealing with waste

4.11.1 Duty of care

Duty of care means that any waste that is produced remains the responsibility of the person or company that has produced it until it can be disposed of. A chain of custody ensures that the responsibility for the waste is shared by all participants in the chain i.e. the producer, the waste carrier and the waste treatment facility. The company (producer) will remain responsible for the waste until it has been disposed of, even when the waste is transferred to the waste collector. It is the company's responsibility to ensure that the waste collector is legally permitted to collect the waste and that the waste facility is licensed to handle or treat the waste. A waste transfer note should be produced and all reasonable steps should be taken to avoid unauthorised handling or incorrect disposal of the waste, such as fly tipping. Ferguson (1994) states that it is important to apply the duty of care in order to avoid the illegal disposal of construction waste.

4.11.2 Waste transfer note

If waste is passed from the site to a waste contractor then the person receiving the waste should have a written description of the waste and fill in a transfer note to be signed by both parties.
The transfer note should include;

- Type and quantity of the waste and its EWC.
- The type of container the waste is in.
- The date, time and location of the waste transfer.
- Names and addresses of the persons involved.
- The waste management licence number.
- The signature of both parties.

The waste transfer note should then be kept for two years. An example of a waste transfer note is contained in the appendices of this document.

4.12 Demolition plan

If demolition is to occur as part of the project then a demolition plan must be put in place in order to ensure that an appropriate dismantling or demolition of the building can occur. The segregation of the demolished structure into specific waste streams needs to be addressed along with the transportation and reception arrangements for the waste. If hazardous waste is found it must be dealt with accordingly and procedures for this must be outlined in the waste management plan. Estimating the quantity of demolition waste can be done using the ICE Demolition Protocol pre-demolition audit.

4.13 Training and responsibilities

The waste manager has the responsibility of implementing the waste management plan throughout the entire project. On site the waste managers' role is carrying out audits and checks and ensuring that the maximum amount of waste is being reused or recycled on site. The waste manager must also educate people on site about the alternatives to the conventional disposal of waste on site. The waste manager must train the site personnel in materials management so that they can distinguish useable materials from waste materials and that waste segregation is being carried out at source. Training can be delivered to all operatives and contractors during site inductions and toolbox talks. Specific waste and environmental training should be delivered and feedback should be encouraged through incentive schemes.

4.13.1 Construction and demolition waste manager

Along with the implementation of a waste management plan it is important to nominate a waste manager or a waste champion. A waste manger should be nominated to take responsibility for every aspect of waste management throughout the project. This person will be responsible for the management of all waste arising on site throughout the entire project. The person nominated should be a reliable person chosen from the planning, design or contracting team. The chosen nominee should also be technically competent and have the appropriate training along with being able to ensure that the measures and objectives of the waste management plan are delivered and achieved. The waste manager must communicate with colleagues all aspects of waste management on site. The waste manager should also maintain records of the quantities of waste being produced and the real cost associated with this waste and its management.

Choosing an appropriate manager will ensure that waste management issues is given an adequate priority throughout the project. During the pre-construction stage the manager should require the designers to take advantage of all possible waste minimisation opportunities. Once the project commences the adherence to the plan must be outlined to all relevant parties by the waste manager. If it is not possible to employ a waste manager then a responsible individual on site should be given the role of waste champion. This person will have the authority to ensure that staff and sub-contractors are complying with the waste management plan and should be supplied with the necessary resources. The waste champion should then report regularly to the author of the waste management plan.

4.14 Record keeping procedures

As part of the waste management plan procedures for the recording, monitoring, movement and treatment of construction waste. A waste management tool such as BRE SMARTWaste can be used to do this. This computerised tool can conveniently record information and contribute to waste reduction through a benchmarking process of the waste arising's. The system allows the contractor to measure and record the amount of waste being generated and then helps to identify where wastage is occurring. Once waste quantities have been recorded they can be used to compare waste quantities on similar projects in the future and enable the setting of benchmarks for these projects. As well as this any waste leaving the site should be documented and tracked so that the waste disposal routes can be tracked and verified.

There are numerous types of data that can be collected from a project including;

- The type and quantity of waste generated.
- The segregation rates.
- The reuse or disposal options for the waste.
- The wastage rates of materials.
- The costs involved and the savings made.
- The sources and movements of waste.
- A waste profile throughout the entire project.
- The amount of materials wasted through damage.

Waste data can be attained from the waste management contractor and the information can include the type of waste generated and its tonnage and the amount of the waste that was recycled. Any data that is collated should be analysed and targets can then be set for future waste management plans.

4.15 Waste auditing

Waste auditing will highlight any problems in relation to waste management on site along with the benefits of good practice waste management. The audit will also determine the types and quantities of waste being produced on site and allow the contractor to monitor waste being produced by various sub-contractors. This section should contain an audit plan and each audit should be carried out in accordance with this plan. The audit should identify obvious waste reduction opportunities and outline any corrective actions required. Examples of waste auditing tools are SMARTAudit and the skip volume analysis form that was developed by the CIRIA. Other waste auditing tools are outlined below;

4.15.1 The Net Waste Tool – WRAP UK

The Net waste method that has been developed by WRAP is a standard metric that can be used to measure the company's progress towards waste neutrality. The tool focuses on the environmental and commercial costs of waste and highlights areas where costs can be reduced through increased efficiency. The tool calculates the potential waste quantities and shows how the use of recycled content can be improved as well as giving an overall net waste figure. The benefits of the tool are that it can help with the development of the waste management plan because it is possible to compare the forecasted figures against the actual performance which helps to improve on site practices and provides information to develop good corporate benchmarks and KPIs. In order to use the tool basic project information must be entered and requirements for waste and recycled content must also be entered. The tool then compares the materials in versus the materials out to give a net waste figure (see figure below).

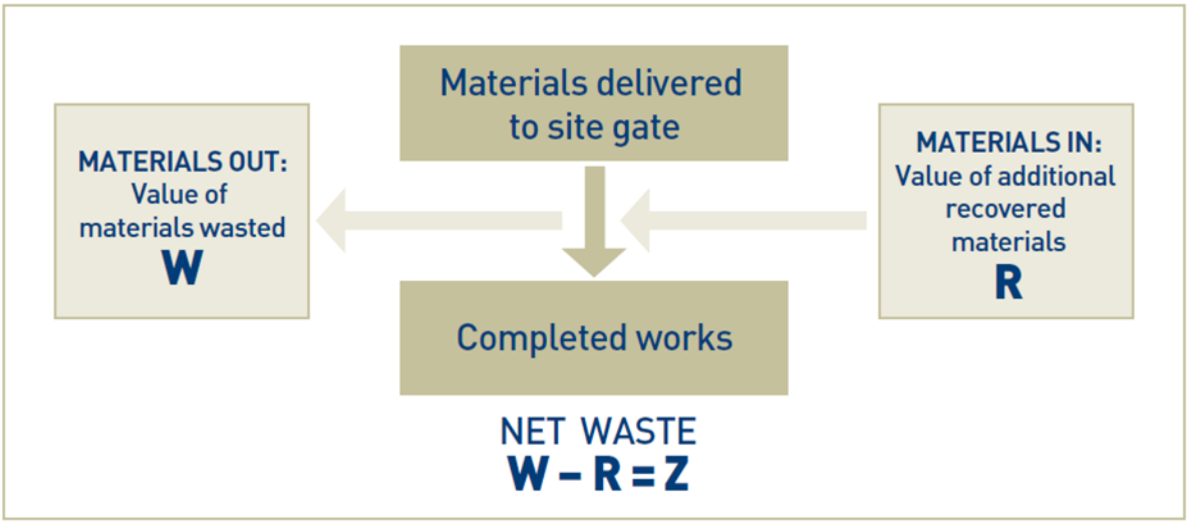


Figure 4.2 Net Waste method (Source: WRAP, 2011)

Note:

W is the cost of the wasted materials.

R is the value of the additional recovered materials.

Z is the Net Waste that should be reduced to achieve waste neutrality.

It is possible to identify options for improvement on each project at the design stage as well as assessing the waste after construction is completed in order to make improvements on future projects. The net waste method is specifically related to the materials efficiency on site i.e. it compares the materials entering the site to those leaving the site as waste and is aimed at optimising a projects design and delivery instead of trying to influence the types of materials used.

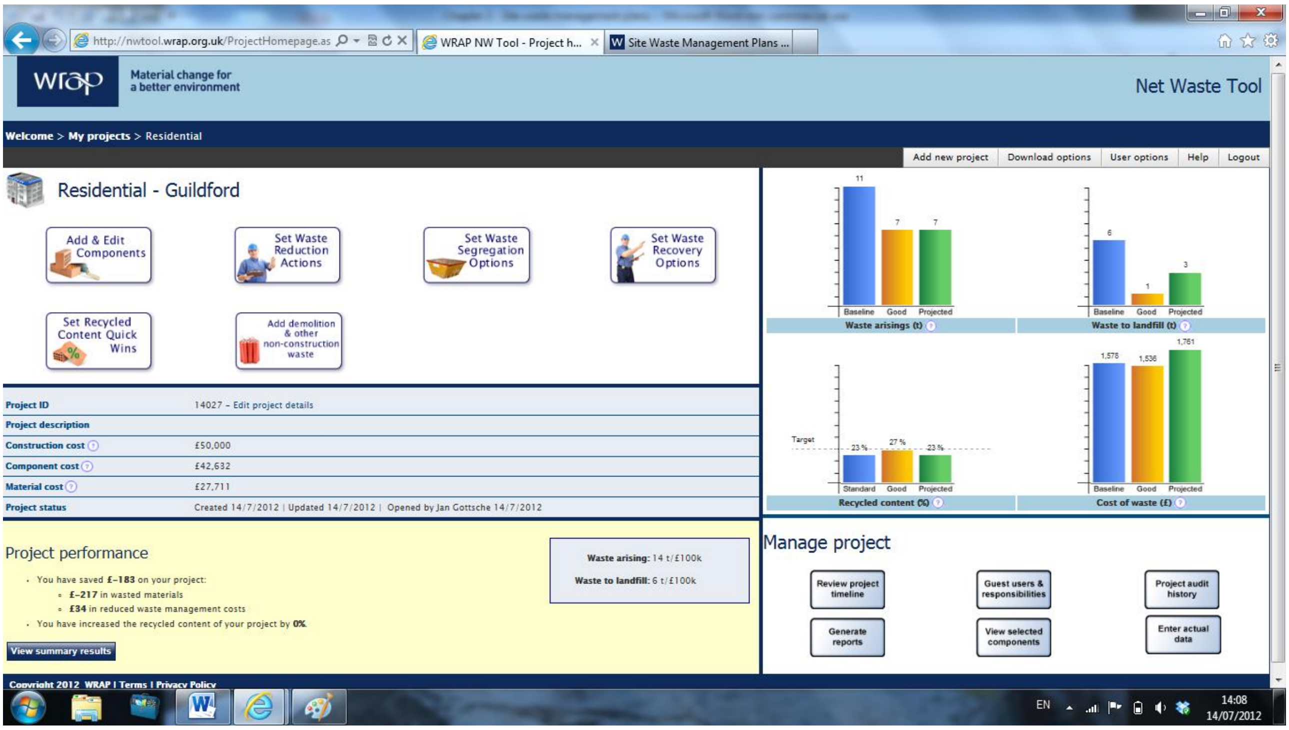


Figure 4.3 Net Waste Tool screenshot

4.15.2 Site waste management plan template – WRAP UK

WRAPs waste management plan template is free to download and is Excel based. The template contains six stages and enables contractors to identify good and best practice opportunities to minimise waste and identify cost savings. The template can assist in producing a waste management plan and help to set out actions to prevent, reduce and recover waste. Using the template it is also possible to forecast waste arisings and prepare for waste management actions as well as recording the waste movements and setting benchmarks. There is also a simplified version for smaller projects called SWMP 'lite.' This tool aims to help achieve good practice on smaller projects.

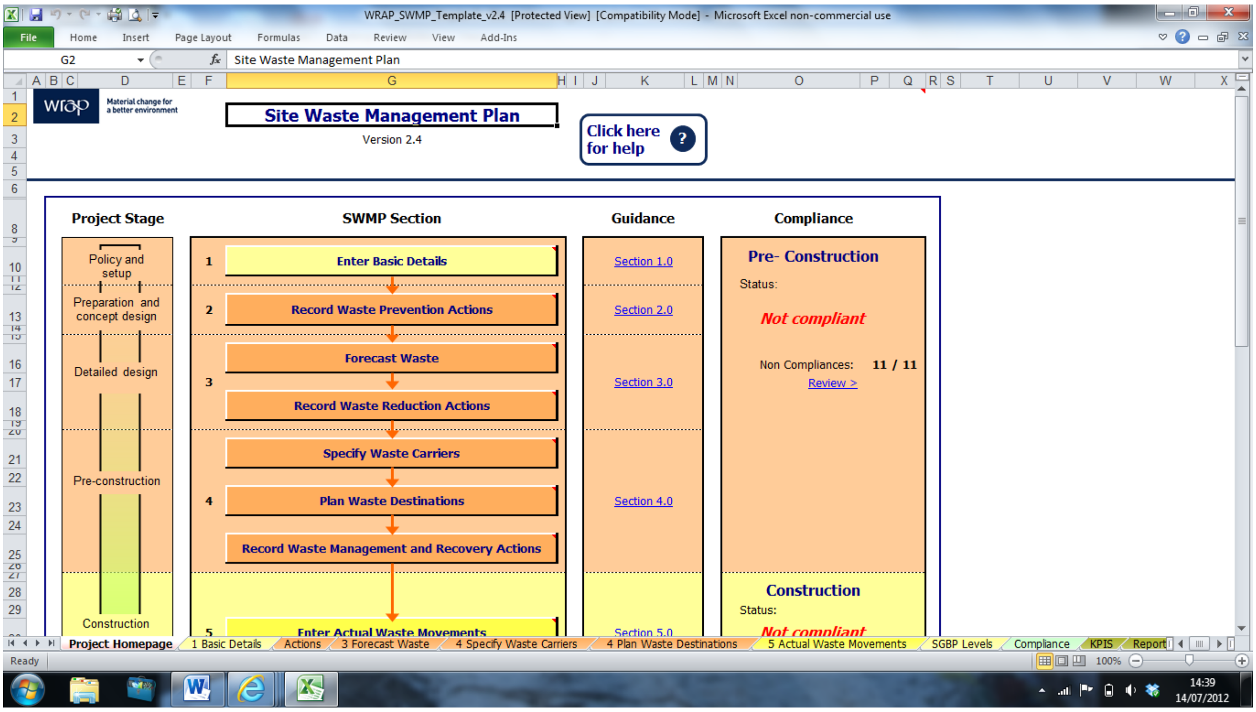


Figure 4.4 WRAP waste management plan template screenshot

4.15.3 Waste management plan tracker – WRAP UK

WRAPs waste management plan tracker is a tool that allows the user to collate, aggregate and analyse data from a number of different waste management plans. The user uploads their waste management plans and can then download an Excel based analysis report allowing the consolidated data to be analysed.

4.15.4 Site specific waste analysis tool (SSWAT) – WRAP UK

The SSWAT tool from WRAP calculates the recovery rates of construction waste at materials recovery facilities and waste transfer stations. The tool can assist waste management contractors in their reporting of recovery information to their clients.

4.15.5 The designing out waste tool for buildings (DoWT-B) – WRAP UK

The designing out waste tool is available on WRAPs website and it can help contractors to identify opportunities to design out waste, record design solutions and calculate their impact on waste and compare the performance of different projects. As well as this the tool can provide a waste forecast for the waste management plan. The time and effort put in to using the tool can result in financial savings and environmental benefits. A version is also available for civil engineering projects.

4.15.6 SMARTWaste – BRE Group

Smart waste is a web based tool that can assist in preparing, implementing and reviewing waste management plans. The tool can manage all aspects of a waste management plan and there are nine steps involved in writing the waste management plan. Smart waste allows for the measurement of waste arisings along with the waste management routes and allows for the setting of benchmarks for forecasting waste arisings. Mc Grath (2001) states that using the SMARTWaste application or similar tool can reduce waste arisings and result in better materials efficiency.

4.15.7 SMARTWaste tools and add-ons

There are a number of add on tools that have been developed by BRE that can be used in conjunction with smart waste. These include;

SmartER – This tool can measure site energy use, water use and procurement of sustainable timber.

CALIBRE – This tool can measure the efficiency and productivity of the construction process.

SMARTAudit – This is an on-site waste measurement tool that works in conjunction with SMARTWaste and CALIBRE. Masudi et al. (2011) states that the use of a software tool such as SMARTAudit can provide an effective and reliable waste quantification.

True Cost of Waste Calculator – This is a free tool that can determine the embodied carbon of waste materials as well as the true cost of waste.

BREMAP – This tool is GIS based and can help to define the best environmental options for waste.

Timber waste reporting tool - A measurement and reporting tool for all timber waste.

Flooring waste reporting tool – A measurement and reporting tool for the flooring sector.

4.16 Procurement strategies

In order for the waste management plan to encourage the greater use of recovered materials on site the procurement route must involve specialist contractors and suppliers during the design and planning stage of the project. The best procurement option is for the client, designer, contractors and suppliers to work together as one team. It is important for a client to take charge and encourage innovative waste minimisation techniques. The choice of procurement route will set out the perception of the clients' requirements from the outset. Gamage et al. (2009) carried out a survey questionnaire of contractors in the UK and found that contractors believe that the procurement route has an effect on waste generation. The results also indicated that procurement has major potential to impact on waste minimisation strategies.

4.16.1 Pre tender/ qualification stage

Prior to issuing the tender documentation potential suppliers who are willing to support the waste management requirements should be identified. This can be achieved by using a pre-qualification exercise where the supplier has to demonstrate credentials against criteria that are not readily quantifiable. Only companies that meet the criteria will be asked to submit a full tender. The pre-qualification is based on technical capacity, financial assessment and past performance. Suppliers will have to show that they have the technical knowledge and financial capacity required to undertake the works and that they have appropriate systems in place such as quality assurance and environmental management. The contractor may wish to visit suppliers to verify their claims.

4.16.2 Tender requirements

The requirements for waste management should be clearly set out in the tender specification. It is preferable to set the requirements at this stage as all those tendering must then comply. This is the stage where policy objectives such as sustainability can be applied. During the evaluation stage credits can be awarded to the tenders that contribute to the waste management requirements. Some weighting can also be given for waste minimisation techniques and recovery objectives.

4.16.3 Forms of contract

Forms of contract that have higher levels of design management, a capacity to incorporate change and clear lines of responsibility are more likely to achieve good practice waste management. Partnering agreements can then be set up after the formal contract is awarded.

4.17 Cost benefits

Šelih (2005) found that effective construction and demolition waste management can contribute to decreased costs as well as a more efficient management of the construction site. Based on the findings, it can be concluded that effective C&D waste management contributes to decreased costs and more efficient overall management of the construction site. If we consider new build projects then there is more savings potential if the value of the materials wasted is reduced. This can be achieved by reducing wastage allowances. In a refurbishment project potential savings can be made through segregating the waste or reusing the materials that have been stripped out. As well as the financial benefits, being more resource efficient will create changes to the company's environmental performance. These savings will only be achieved if management actions are taken to change the behaviour towards waste management during the design stage and on site practices.

Areas where cost savings can be taken into account are;

- Developing a good practice waste management plan.

- Developing a good practice logistics plan.
- Training and education.
- Storage of materials.
- Updating and developing the waste management plan.
- On site segregation of waste.

When considered on paper there are cost savings applicable to most projects but in order to achieve some of these savings costs must also be incurred. Good practice waste management should result in a net benefit on most projects. In general the more waste that is going to be generated, the greater the potential savings. Oladiran and Olatunji (2009) found that the application of a waste management plan will lead to waste minimisation. WRAP in the UK have carried out a cost benefit analysis study of reducing construction waste and found that if construction waste is reduced that it can save up to 1.5 per cent of the value of the construction project and up to 9.5 per cent on individual sub-contractor work packages (WRAP, 2010).

Whichever party takes the risk for supplying the materials will see the cost savings. This is normally done by the main contractor or sub-contractor. If this reduction in waste is to be converted into a reduced price for the client then the contractor must include a wastage rate in the tender or procure fewer materials, therefore saving money. Normally the main contractor pays for the waste disposal so therefore the savings are usually made by the main contractor. If the client is to have a share of these savings it must be outlined during procurement.

Showalter et al. (1997) states that a contractor must be able to address construction waste without losing any competitive advantage that might impact on the company's economic performance. The majority of the costs involved in waste management are paid for by the main contractor. The costs are made up of two things; management costs and planning costs.

Planning for waste management involves low cost but it has a high impact. It is during this stage that opportunities can be highlighted and focused on. One example might be that during the planning stage it might be found that better materials storage is required. The second stage is the management stage, which is carried out during the construction stage.

This management ensures that the plan is delivered successfully. The management time taken up also includes management time for deliveries, storage, installation and waste disposal along with a time allowance to monitor materials storage and waste segregation.

Symonds et al. (1999) sets out a formula that can be used to calculate the financial benefit of using recycled materials versus the use of virgin materials. Assuming that the two materials are equally capable of meeting the required needs, recycled aggregates should be used when;

$$\mathbf{Qp + Tq > Er + RCp + Tr}$$

Where:

Qp = Price of newly quarried product.
Tq = Cost of transport from quarry to site.
Er = Any extra costs created by using recycled aggregates.
RCp = Price of recycled product at the recycling centre gate.
Tr = Cost of transport from recycling centre to site.

(Symonds et al., 1999)

4.18 Summary

All parties in the construction industry need to be proactive in relation to waste management and minimisation. A waste management plan should be used for all projects except minor site developments. Once the plan is developed it is imperative to its success that it is implemented on site and adhered to. In order to ensure that plans are successful summary reports along with audits need to be carried out at regular intervals on the project. The reports should consist of the actual reuse and recycling taking place along with an estimate of the amount of waste diverted from landfill. When the cost of gate fees, labour costs and haulage costs are considered then effective waste management and minimisation can lead to substantial cost savings. High transport and disposal costs serve to make the recovery of materials economical. This chapter has provided information on site waste management plans along with their content, costs and implementation. The next chapter will outline the details of an online survey which was carried out in order to assess the main building contractors in Ireland attitude towards waste management.

5.0 Chapter five – Main contractors' attitudes towards waste management

5.1 Aims and objectives

The previous chapter provided information on site waste management plans along with their content, costs and implementation. This chapter discusses and analyses the questionnaire results and findings.

This chapter will give an insight into the:

- Target audience for the questionnaire.
- Questionnaire development.
- Research limitations.
- Administration of the questionnaire.
- Response rate.
- Designation of respondents.
- Results and analysis of the questionnaire.
- Conclusions reached.

5.2 Introduction

This chapter seeks to analyse the data gathered through the questionnaire and display the results in a graphical manner and also through written text. Each question is analysed separately and the results are discussed in relation to each question.

The use of a questionnaire is a cost effective method of gathering data from a large geographical area in a small amount of time. The advantage of using a questionnaire is that most people are familiar with questionnaires and have had some experience in completing them. This tends to make people a little less apprehensive about providing answers. Once the respondent has received the questionnaire he or she is free to complete the questionnaire in their own time unlike other research methods where the respondent is interrupted by the research instrument. A questionnaire is an important tool when trying to investigate the main contractors' attitude towards waste. If a range of different contractors answer the same questions then it will be possible to make a judgement of the trends within the industry. The use of a questionnaire provides a quantitative method of gathering data and the evidence can be expressed in numerical terms. The respondent can only choose from the range of answers provided and therefore it is possible to accurately analyse the data and express it visually on a graph.

5.3 Target audience

The target audience for the questionnaire was medium to large sized construction companies in Ireland. The contact details were obtained from the Construction Industry Federation (CIF) website, by assessing which companies were still in business and likely to answer the questionnaire. Medium to large size companies were chosen as it is more likely that they would have experience with waste management compared to smaller companies. It was decided to send the questionnaire electronically as it was found that this would generate a greater response rate (Schaefer and Dillman, 1998). The first point of contact with the companies was through the use of a phone call in order to obtain contact information for someone who could answer the questionnaire. This was seen as essential as once contact was made it became more likely that a response would be received. Following the phone call an email was sent with the link to the survey, which was hosted on 'survey monkey'. If a response was not received a reminder email was sent out, following this a final reminder was also sent to those who had failed to respond. In total 49 questionnaires were sent out following 65 phone calls. The other possibility was to mail out the questionnaires and wait for a response. It was anticipated that this method would produce fewer responses due to the effort required in mailing back the questionnaire.

5.4 Research knowledge gap

Following a review of previous studies carried out in relation to good practice waste management it was found that no extensive study into main contractors' attitude towards waste had been carried out in Ireland. Due to this knowledge gap it was decided that this was a good area to investigate.

5.5 Questionnaire development

The questionnaire was developed as part of a project funded by the EPA under the STRIVE programme which forms part of an industry review by the Department of Building and Civil Engineering at the Galway-Mayo Institute of Technology. The survey aims to investigate main contractors in Ireland perceptions, attitudes and experiences of waste management on construction projects within the country. The questionnaire was developed following a review of related studies and prior to its implementation a pilot study was carried out by a previous student. The survey consists of 27 questions which are answered through tick the box type answers. The questionnaire only takes about ten minutes to complete. The anonymity of the survey participants was protected and all data which was collected is confidential.

The aim of the questionnaire was to gain an insight into the waste prevention awareness of main contractors as well as their perceptions, attitudes and experience of waste management. The questionnaire is divided into four sections; Section A contains general questions about construction waste and then looks at current practices and experiences on site by the respondent. Section B sets out nine statements which set out various scenarios for the respondent to agree or disagree to. Section C contains five ranking questions, with 1 representing the highest ranking and 5 representing the lowest, and the respondent is required to answer questions about barriers, incentives and responsibilities in relation to waste management. The final section of the questionnaire, section D, asks some questions about the respondents experience within the industry and their position within the company.

There are a number of important aspects in relation to how a survey is designed and the survey that has been used as part of this thesis is well designed and should assist in getting the correct information. The following are the points which should be considered;

Questionnaire length: The length of the questionnaire should not be too long and should require no more than fifteen minutes to answer it. The reason for this is that a respondent may be intimidated by a long questionnaire and the person may be busy and unwilling to appoint more than fifteen minutes towards answering the questionnaire. If the questionnaire is too long it would affect the response rate. The questionnaire used for this thesis appears at first to be quite long at nine pages, but the tick the box style questions and answers enable the respondent to complete the survey in less than fifteen minutes.

Layout: The layout and presentation of the questionnaire should be in an easy to read and easy to answer format enabling it to be user friendly. This questionnaire is seen as user friendly because it has an appropriate font size and the tick the box style answering system is easy to use.

Questions: It is important to ask the right questions so that the answers provided can contribute to the research topic. The types of questions used are necessary to provide the data for this research and are considered appropriate to obtain this data.

Language: It is essential that the language used is simple and concise. The questions used in this questionnaire are clear so that the answering of the questionnaire can be carried out easily and not be misunderstood.

Pilot survey: A pilot survey is important because it allows the researcher to obtain information on the clarity of the questions asked. A pilot study was carried out by a previous student (Hands, 2011). The questionnaire was given to seven subcontractors and the results were then analysed. Following this analysis some questions were changed to reflect the findings of the pilot survey.

5.6 Research limitations

The main research limitation for this questionnaire was the number of respondents to the survey. As well as this the questionnaire survey is on-going so it was not possible to enter the results into a statistical package as it was felt that the results would not be accurate. Instead it was decided to briefly analyse the answers and draw some conclusions. As well as this the evidence gathered is used throughout the text as examples. It is considered that this survey has provided a good snapshot of current industry practice in relation to attitudes towards waste management by main contractors. It is a common limitation for surveys not to be answered online and considering the amount sent out the response rate is considered good. However the research into main contractors attitudes will be on going after this thesis is finished so more responses will be gathered so that the results can be analysed statistically. Another limitation is that the majority of respondents were managerial staff within the company so the answers may be biased. Due to the number of respondents it is considered that the conclusions reached should not be considered definitive but could be used as a basis for further study within the area.

5.7 Bias

One disadvantage of carrying out a survey when it is not done face to face is that people may not always tell the truth when answering a questionnaire. There is also the possibility that they may think they are telling the truth but that this might be a false perception. This survey related to the current attitudes of main contractors in Ireland towards waste management so it is possible that the respondents answered in a way that would make their company appear more environmentally friendly because that's what they would like to think of themselves. There is no solution to this problem and it must be accepted that bias will always exist within a questionnaire survey such as this one. To minimise the influence of bias the answers are limited to a number of possibilities which tries to ensure that there is no particular right or wrong answer.

5.8 Response rate

The response rate for the survey was almost 39 per cent which was seen as a good response rate. Of the initial 65 phone calls that were made, contact details for 49 respondents were provided. Of the 49 questionnaires sent out, 19 were returned complete.

Results	Number of respondents	Percentage %
Questionnaires returned	19	39
Questionnaires unreturned	30	61
Total sent out	49	100

Table 5.1 Responses from main contractors' survey

5.9 Designation of respondents

The table below provides a breakdown of the job roles of the respondents. The results indicated that all the respondents held positions within middle or upper management within their company.

Job role	Number of respondents	Percentage
Managerial staff	13	68
Foreman	-	-
Tradesman	-	-
Labourer	-	-
Other	6	32
Skipped Question	-	-
Total	19	100

Table 5.2 Designation of respondents

Due to the companies chosen and the job roles of the respondents to the questionnaire it is clear that all respondents should be well aware of construction waste generation within the construction process and because of this they are considered suitable for this study.

5.10 Results and analysis of questionnaire

It should be noted that the questionnaire consists mainly of qualitative type questions which had a limited number of possible answers; therefore the analysis of the results is limited. The analysis provided is qualitative and comments are made on each question. The results are presented below with section D shown first as these questions outline the experience and qualifications of the persons answering the questionnaire;

SECTION D

Question 24

How long have you worked in the construction industry?

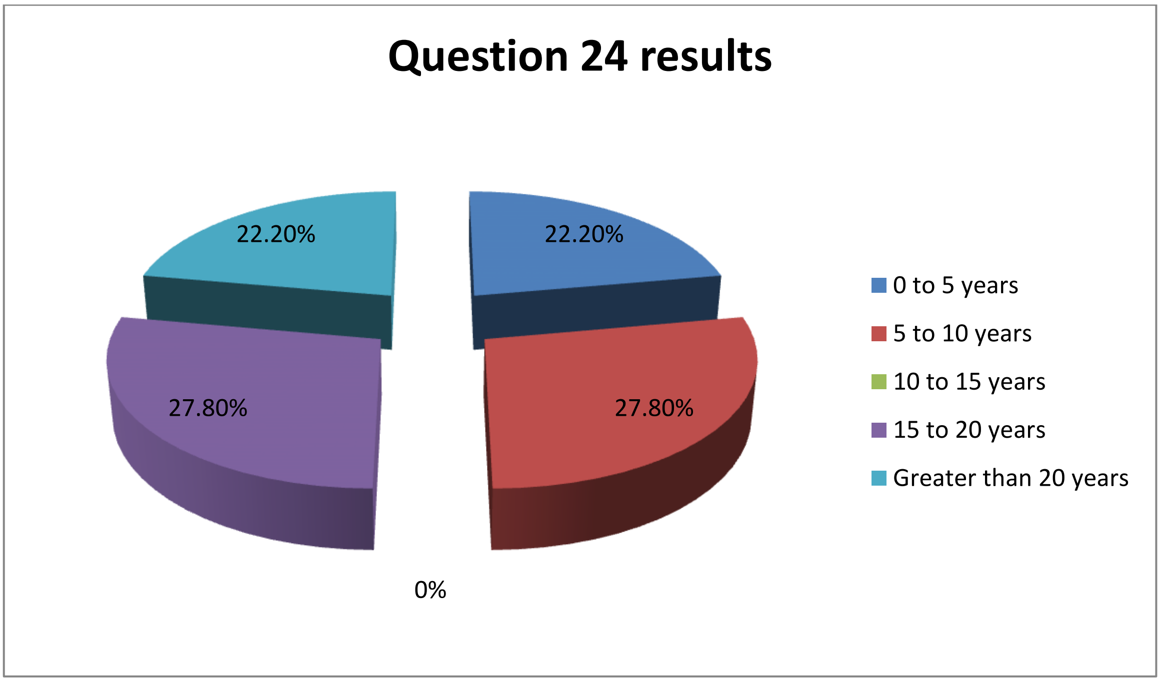


Figure 5.1 Question twenty four results

Analysis

The aim of this question was to ascertain how long the respondents had worked in the construction industry. The results show that 22.2 per cent had zero to five years' experience, 27.8 per cent had five to ten years' experience, 27.8 per cent had fifteen to twenty years' experience and 22.2 per cent had in excess of twenty years' experience. This shows that the majority of the respondents had a significant amount of experience within the industry and were in a good position to answer this questionnaire. The people with more experience have also witnessed the waste legislation changes in Ireland over the last number of years and should be well aware of their requirements in relation to the law and legislation.

Question 25

What is your current position in the industry?

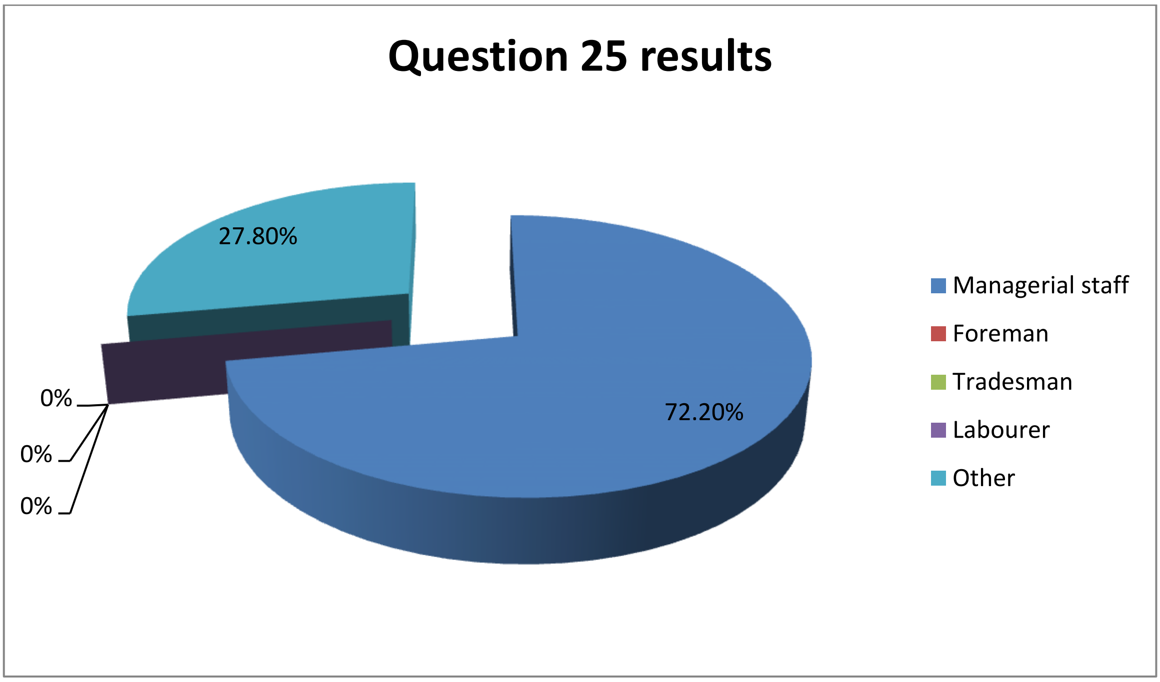


Figure 5.2 Question twenty five results

Those who chose other had the following job roles:

- Environmental officer.
- Placement student.
- Quantity surveyor (x3).

Analysis

The aim of this question was to find out the respondents position within the company. The results show that thirteen of the respondents were managerial staff while three were quantity surveyors, one was an environmental officer and one was a student on placement within the company. This means that each respondent was well capable of carrying out this survey and their answers can be considered as accurate for the use for this study.

Question 26

How long have your worked in your current position in the industry?

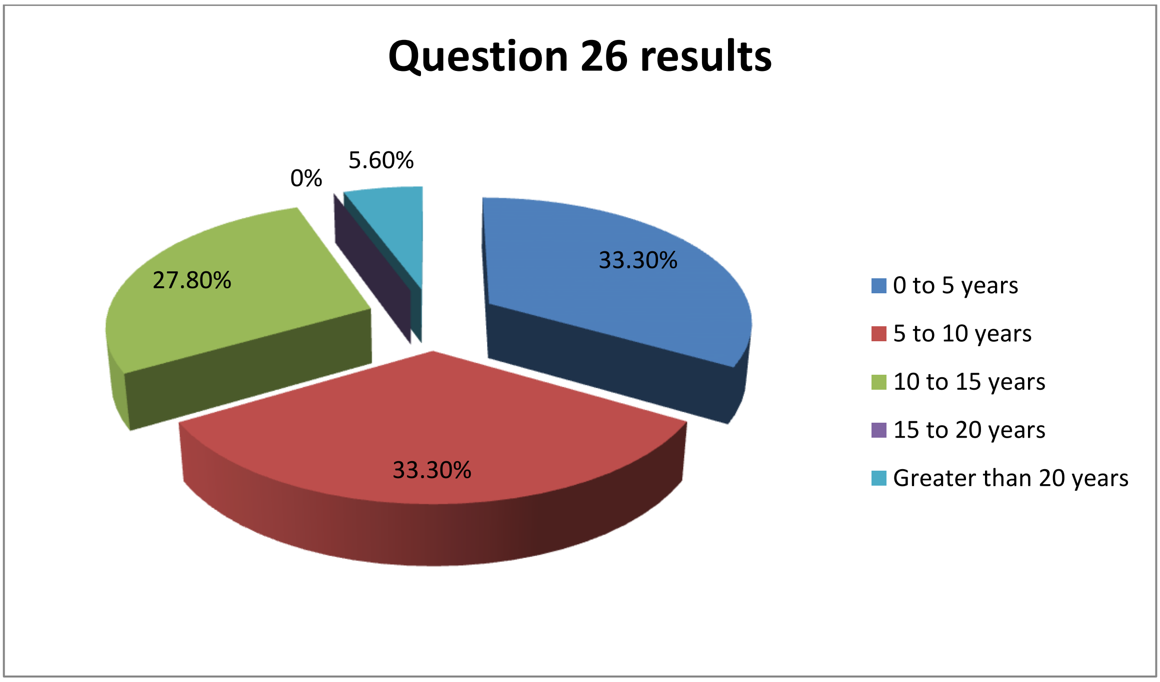


Figure 5.3 Question twenty six results

Analysis

Again the answers to this question show the level of experience of the respondents and shows that they are well capable of providing the answers to this questionnaire.

Question 27

What is your highest academic qualification?

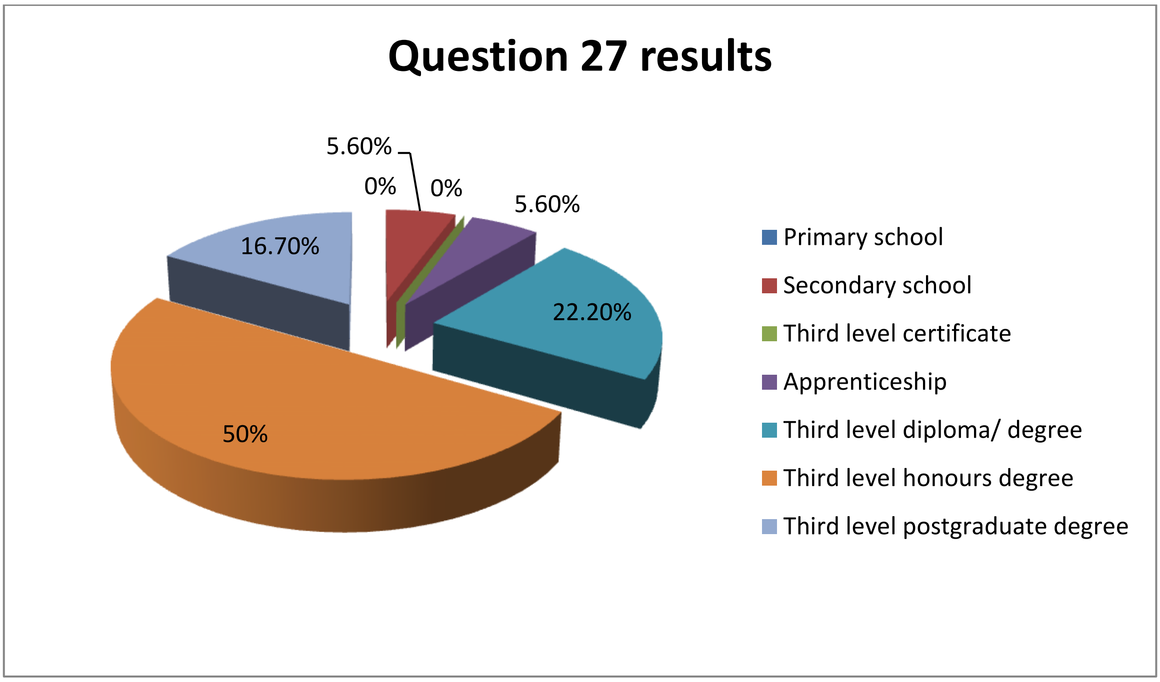


Figure 5.4 Question twenty seven results

Analysis

The aim of this question was to establish the respondents' academic qualifications. Similar to the previous questions the results of this question show the ability of the respondents to answer this questionnaire. Only two of the respondents have a qualification lower than a degree level showing that the majority of the respondents to this survey are well qualified to deal with the issue of construction waste.

SECTION A

Question 1

Do you recycle at home?

The answers provided show that 100 per cent of the respondents to the survey do recycle at home.

Analysis

This question provides some background information on the respondents' previous level of recycling outside of the workplace. Of the three options listed 100 per cent of respondents stated that they recycle at home. This is a positive start as it shows that everyone who is answering the questionnaire has at least some background with recycling albeit a small capacity within the home. Recycling in the home will begin to instil a recycling culture within the respondents and it may make them more likely to implement recycling and waste reduction measures within the workplace.

Question 2

Does your company have a written/formal waste management policy/system?

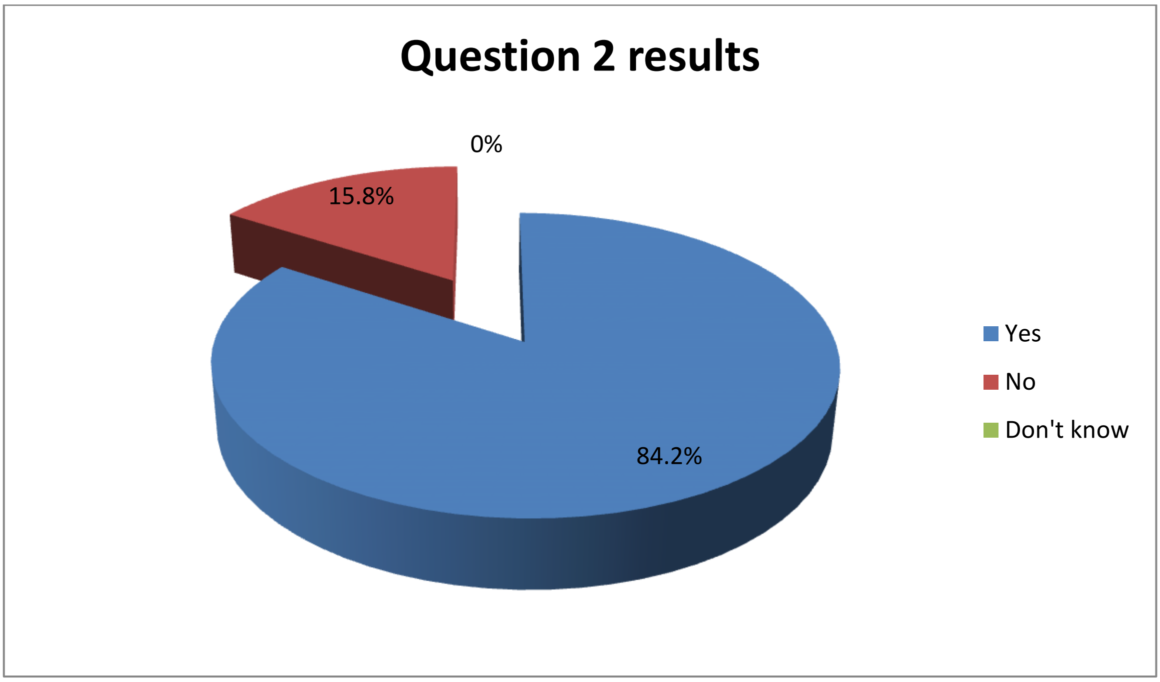


Figure 5.5 Question two results

Analysis

The aim of this question was to establish whether or not a company has a written/ formal waste management system in place. It is considered necessary within good practice waste management that a company should have a written policy in order for it to carry out waste management successfully. 84.2 per cent of respondents stated that their company had this system in place while 15.8 per cent stated that there was no such system in place within their company. While it is good that the majority of the companies surveyed had this system in place it is important that once the system is in place that it is monitored and constantly being updated as necessary. The results are in line with previous studies carried out, such as Teo and Loosemore (2001) and Osmani et al. (2006) who also found that the majority of construction companies surveyed in their study had a written waste management policy in place.

Question 3

Are you personally motivated to reduce waste as part of your job?

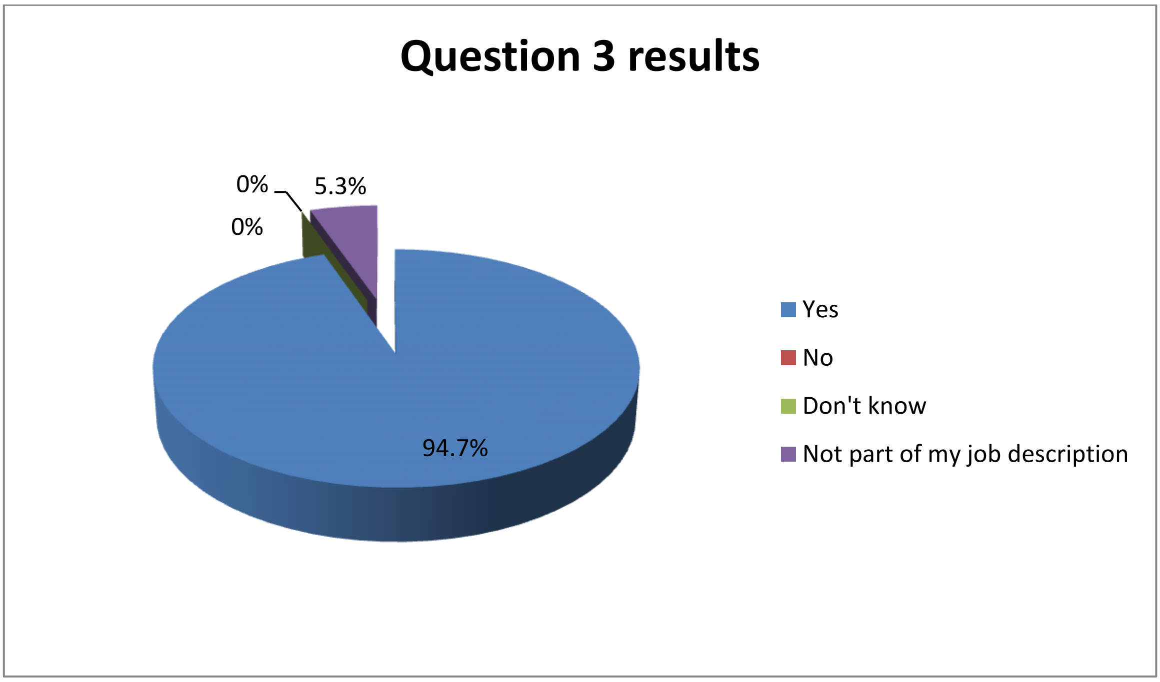


Figure 5.6 Question three results

Analysis

The results of this question show that 94.7 per cent of the respondents are motivated to reduce waste as part of their job, while only 5.3 per cent or one respondent stated that it was not part of their job description. These are very positive results as almost all the respondents are motivated to reduce waste; this may be related to their position within the company as the majority of respondents hold managerial positions and thus it is their responsibility to reduce project costs and one way of doing this is to reduce waste.

Question 4

Have you ever received formal waste management training?

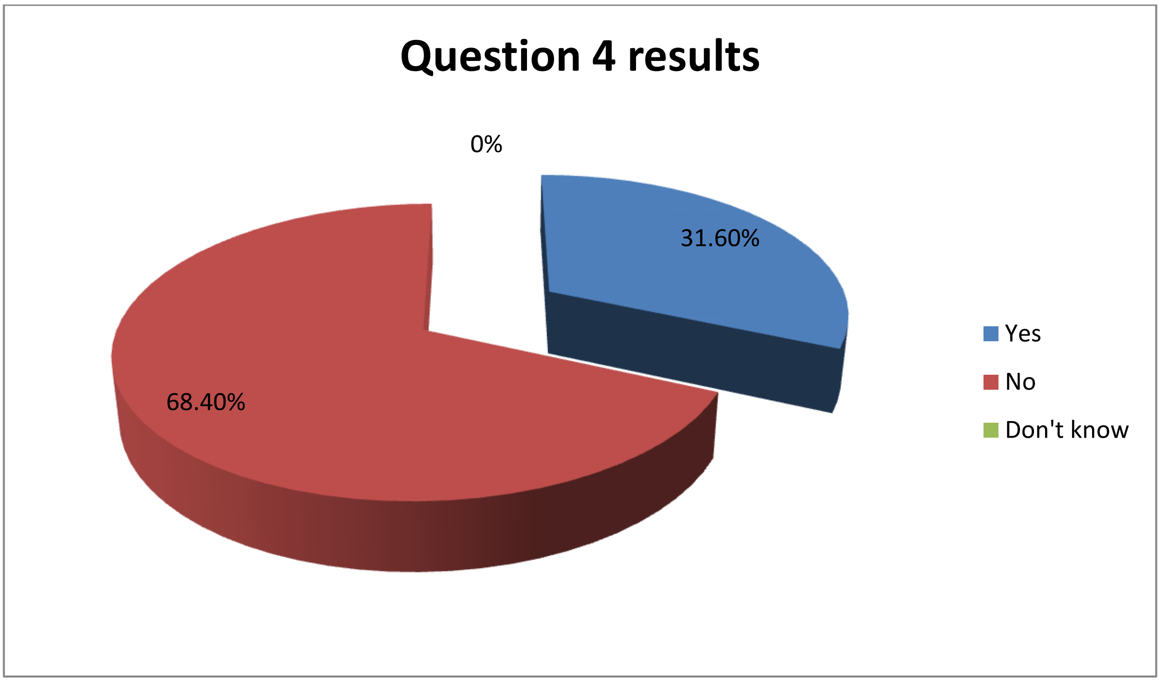


Figure 5.7 Question four results

Analysis

The aim of this question was to establish the level of training that has been provided to the respondents to the survey. The results show that 31.6 per cent of the respondents have received some form of training while the majority at 68.4 per cent have not. It is interesting to note that some managerial staff has received formal training which is a positive step but the majority have not. It is important that all staff including staff at management level have received training in relation to waste management so that the correct information is being passed down by the management to the employees.

Question 5

Have you ever been required to prepare a waste management/minimisation plan as part of the tendering process?

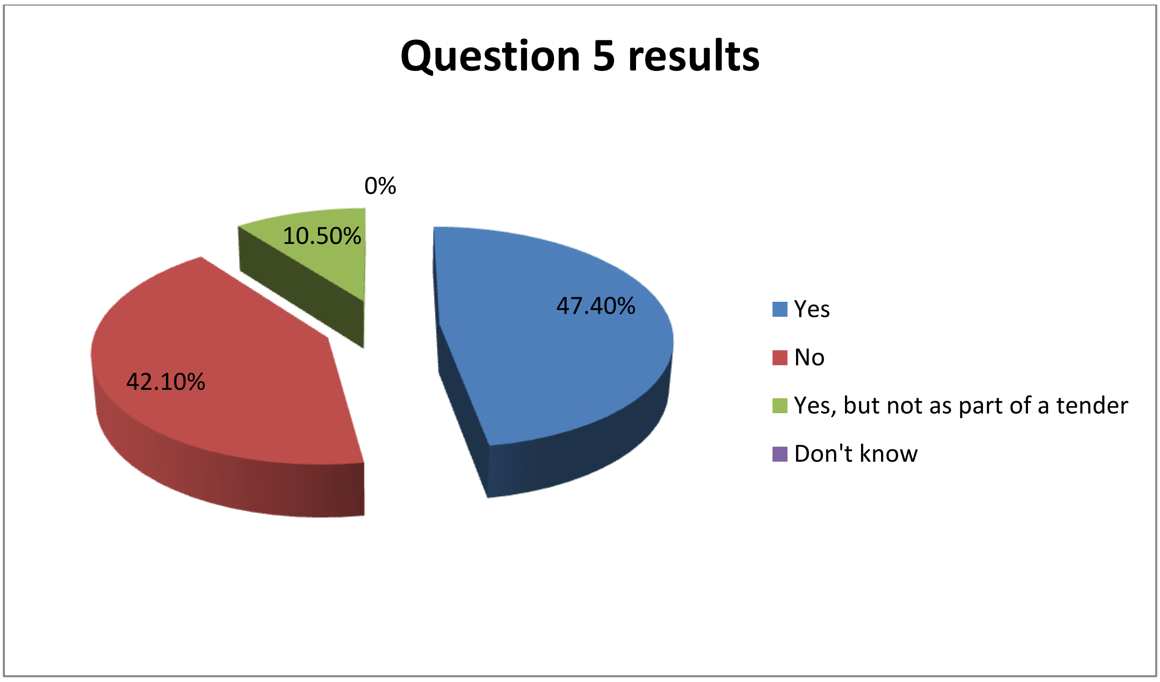


Figure 5.8 Question five results

Analysis

This question sets out to establish whether the companies surveyed have ever been required to prepare a waste management plan. The results are mixed as 47.4 per cent of the companies surveyed have been required to prepare a plan while 42.1 per cent have never been required to prepare a plan. A further 10.5 per cent of companies have been required to prepare a plan but not as part of the tendering process. It was anticipated that the majority of the companies surveyed would have had experience in producing waste management plans due to their size and the legislative requirements to produce waste management plans in Ireland when a project exceeds certain thresholds; however this does not seem to be the case. It is important that a company prepares a waste management plan even when it is not required to as this will save the contractor money as well as the other benefits outlined in this study.

Question 6

Have you ever asked subcontractors or site operatives to provide feedback to site management in the development and implementation of waste management initiatives on site?

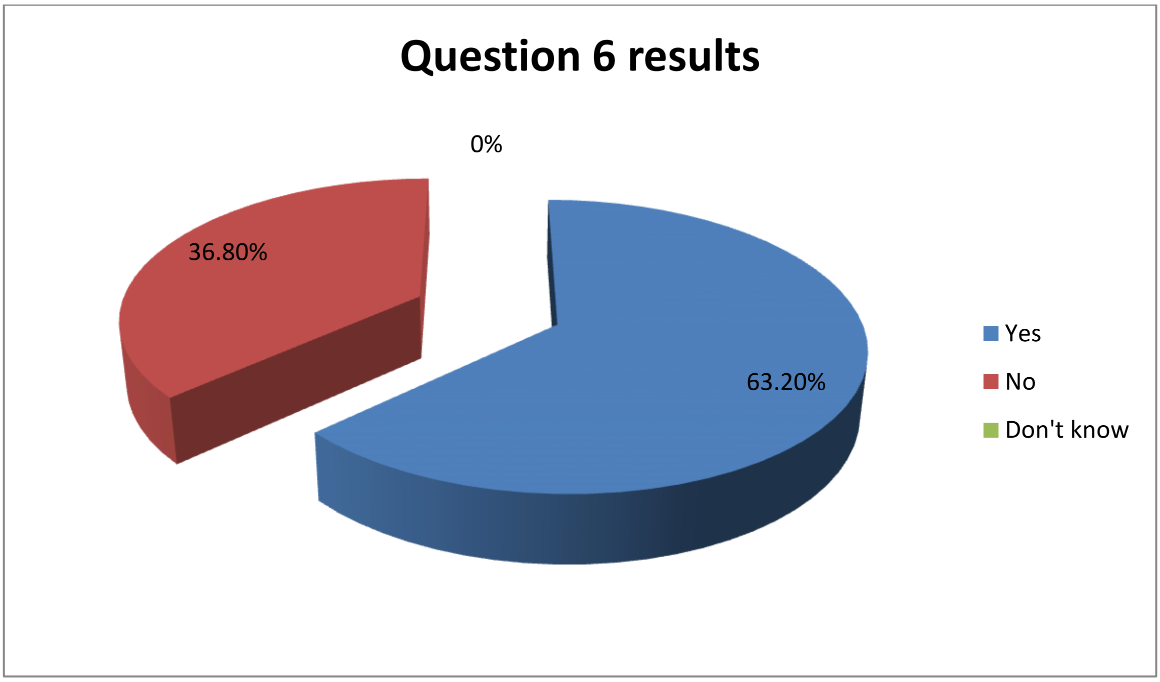


Figure 5.9 Question six results

Analysis

The results from this question are somewhat positive as 63.3 per cent of the companies surveyed have asked sub-contractors or site operatives for feedback in relation to waste management initiatives on site while 36.8 per cent had not asked for any feedback. It is important that feedback is obtained from those working on site as these are the workers who have the day to day experience of implementing the waste management initiatives set out by the company's management staff. This feedback can provide valuable information during the development and subsequent updating of the company's waste management initiatives.

Question 7

In your experience on construction projects, what percentage of waste is allowed for at the tender stage?

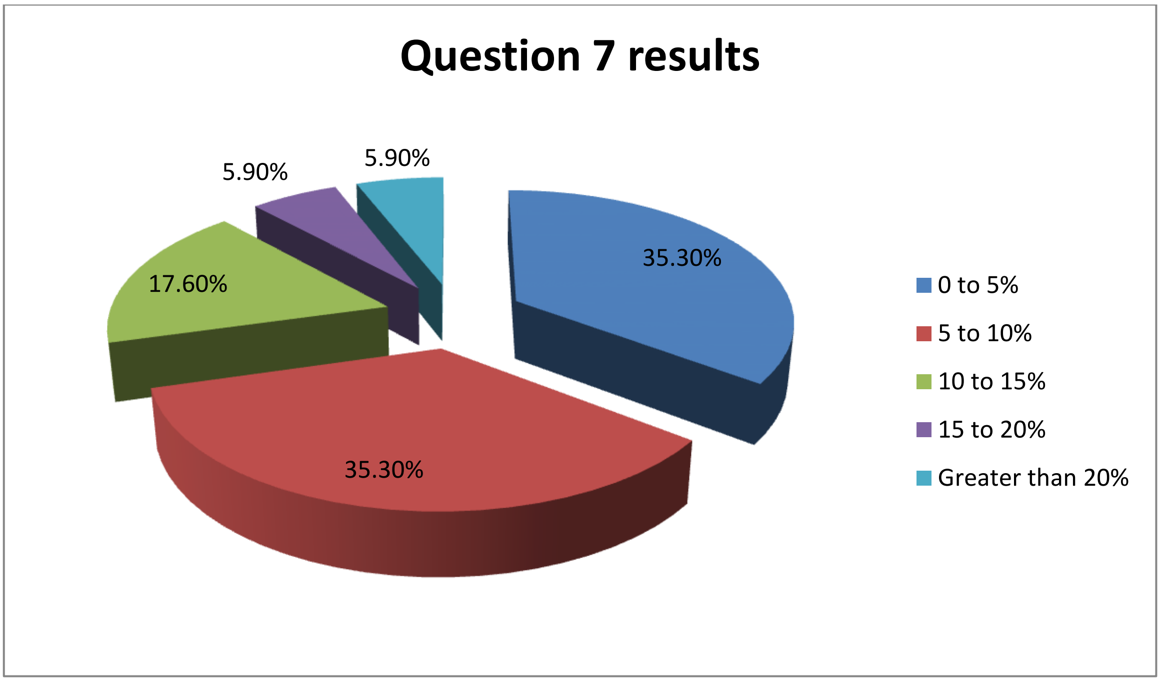


Figure 5.10 Question seven results

Analysis

The aim of this question was to establish the acceptable levels of wastage allowance within the surveyed companies during the tender stage. The results are mixed with 35.3 per cent stating that the wastage rates were between zero and five per cent, 35.3 per cent stating that it was between five to ten per cent and 17.6 per cent stating that it was between ten and fifteen per cent. A further 5.9 per cent of respondents stated that the wastage rate was between fifteen and twenty per cent and the same percentage stated that it was greater than twenty per cent. A total of two respondents skipped this question.

The results show that 70.6 per cent of the companies surveyed allow for wastage rates of below ten per cent. Any of the companies that stated that their wastage rate allowance was higher than this need to revaluate and consider there allowance on future projects. The allowance of a twenty per cent wastage rate is not acceptable for good practice waste management and this policy should be changed within that company.

Question 8

In your experience on construction projects, what percentage of materials waste occurs on site?

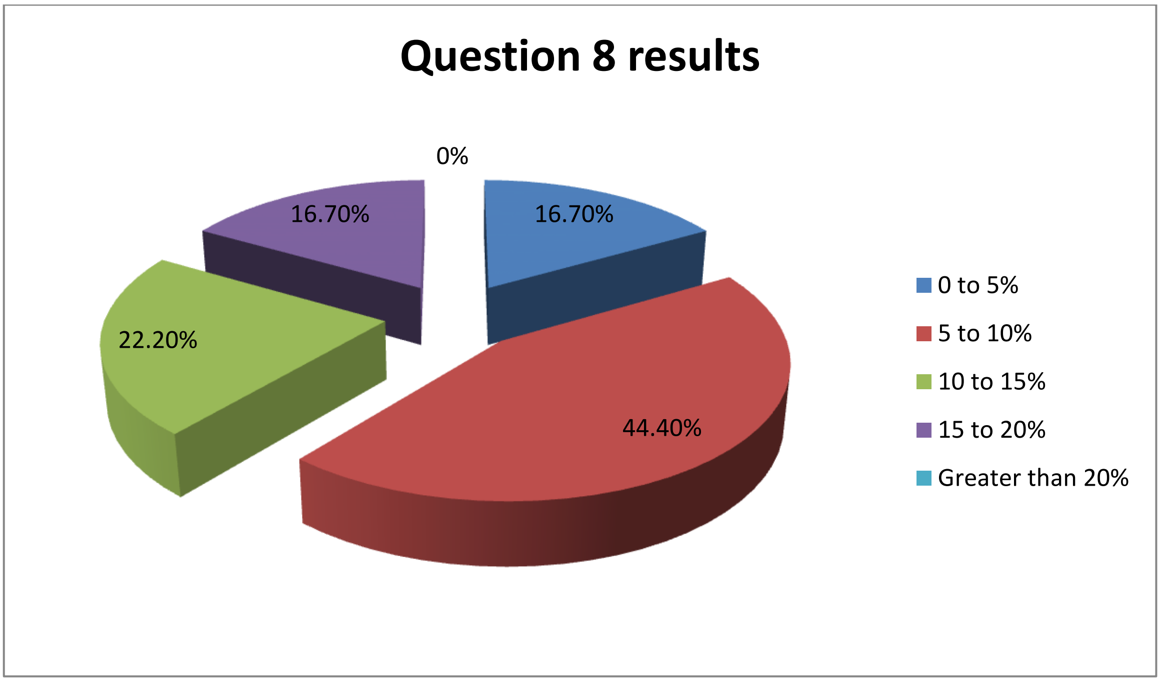


Figure 5.11 Question eight results

Analysis

The answers provided to this question are interesting as they can be compared against the previous questions answers. The results are that 16.7 per cent of respondents believe that materials wastage is between zero and five per cent, this is a drop of 18.6 per cent when compared to the allowance given during the tender stage. 44.4 per cent of respondents believe that wastage rates are between five and ten per cent which shows an increase from the previous question of 9.1 per cent. The wastage bracket from ten to fifteen per cent has increased by 22.2 per cent and the wastage rates between fifteen and twenty per cent have also increased by 16.7 per cent. In this question no respondents believe that current wastage rates are greater than twenty per cent. It is clear from these results and the results from the previous question that there are large differences between the wastage rates allowed for during the tender stage and the respondents' experience of wastage rates on site.

Question 9

How would you describe your experience of waste reduction policies on Irish construction projects?

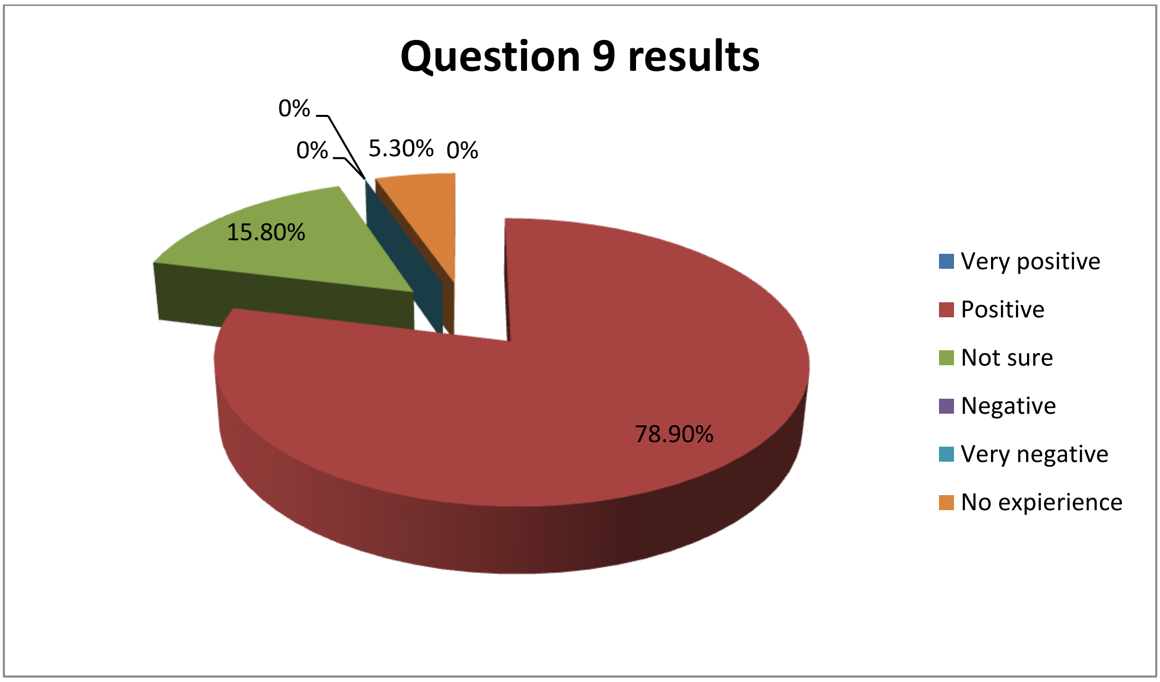


Figure 5.12 Question nine results

Analysis

The results of this question were that 78.9 per cent of the respondents rated their experience of waste reduction policies as positive. Only 5.3 per cent or one respondent stated that they had no experience of waste reduction policies while 15.8 per cent of respondents were unsure of their previous experiences. The results show that attitudes towards waste reduction policies are by and large positive within the surveyed companies. This positive attitude now needs to be filtered right through each organisation to each operative working on site. During the literature review and the case study carried out as part of this thesis it was found that there was some negative perceptions of waste management within some parts of the workforce on site. It is positive to see the results of this question that the majority of experiences have been positive. The results are in line with Osmani et al. (2006) who found that contractors' attitudes were positive and proactive in relation to developing environmental and waste management policies. Teo et al (2000) found that operatives' attitudes towards waste were positive but that it was being impeded by a lack of managerial commitment. The results stated here would suggest that the management's positive experiences could now lead to a greater managerial commitment which will further increase the operatives' attitude towards waste management.

SECTION B

Question 10

Waste is accepted as an inevitable by-product of the construction process by industry stakeholders.

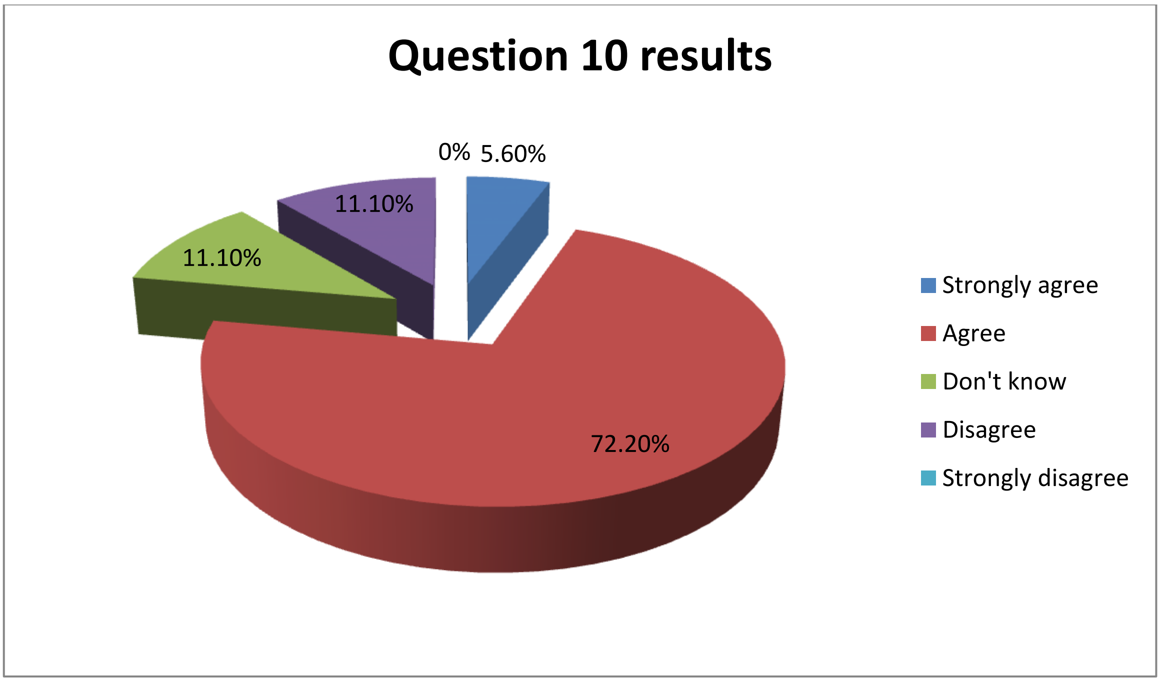


Figure 5.13 Question ten results

Analysis

The aim of this question was to establish whether or not a main contractor believed that waste was an inevitable by-product of the construction industry. The results show that 72.2 per cent of contractors agreed while 11.1 per cent disagreed and the same proportions did not know. One respondent skipped this question. The results indicate that waste is seen as something that will happen during construction rather than being something that should be eliminated. If waste was not considered an inevitable by-product then better waste management policies could help to achieve waste minimisation through each stage of the construction project. Osmani et al. (2006) also found that main contractors perceived waste to be inevitable on a construction project. This attitude needs to be changed in order to achieve good practice waste management and minimisation on site as waste must be considered as something that should not be occurring rather than being inevitable.

Question 11

Main contractors have an important role to play in the reduction of waste generation on site.

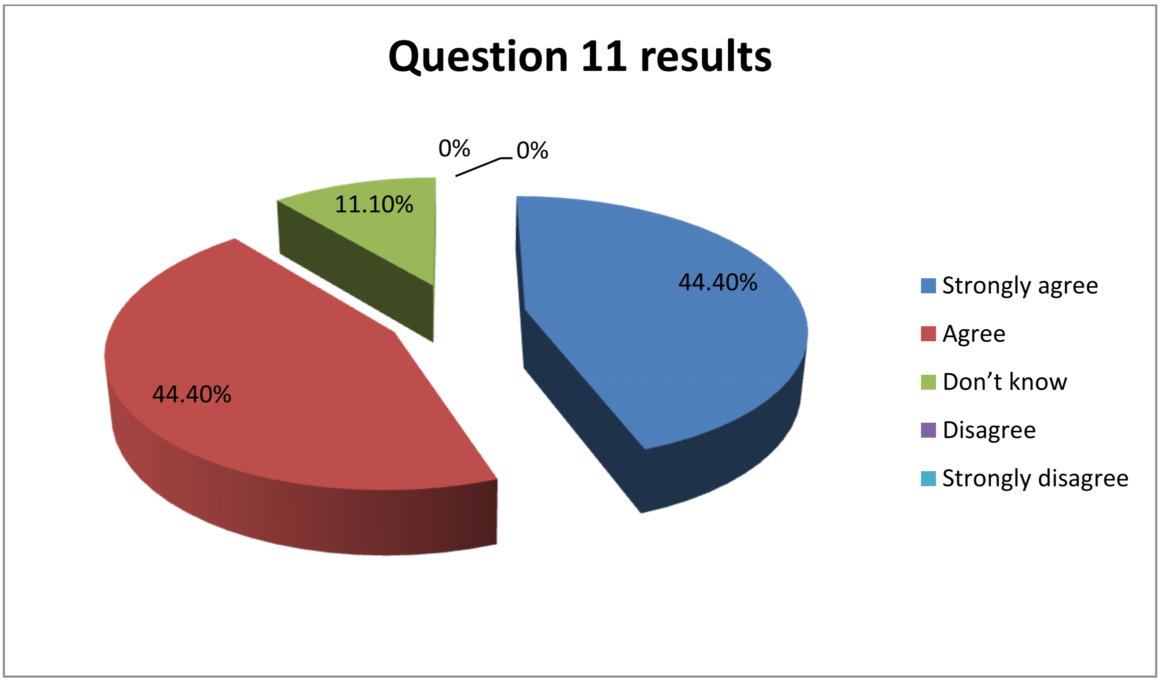


Figure 5.14 Question eleven results

Analysis

The aim of this question was to establish whether the main contractor surveyed believed that they had a responsibility in relation to reducing waste on site. The results show that 88.8 per cent of respondents agree with this statement and a further 11.1 per cent do not know. One respondent also skipped this question. This shows that main contractors are aware that they have a responsibility and an important role to play in minimising waste generation on site. Due to the fact that they have acknowledged their role in the process it should now be possible for them to implement good practice waste management techniques.

Question 12

The current level of construction and demolition waste production is a problem for the Irish construction sector.

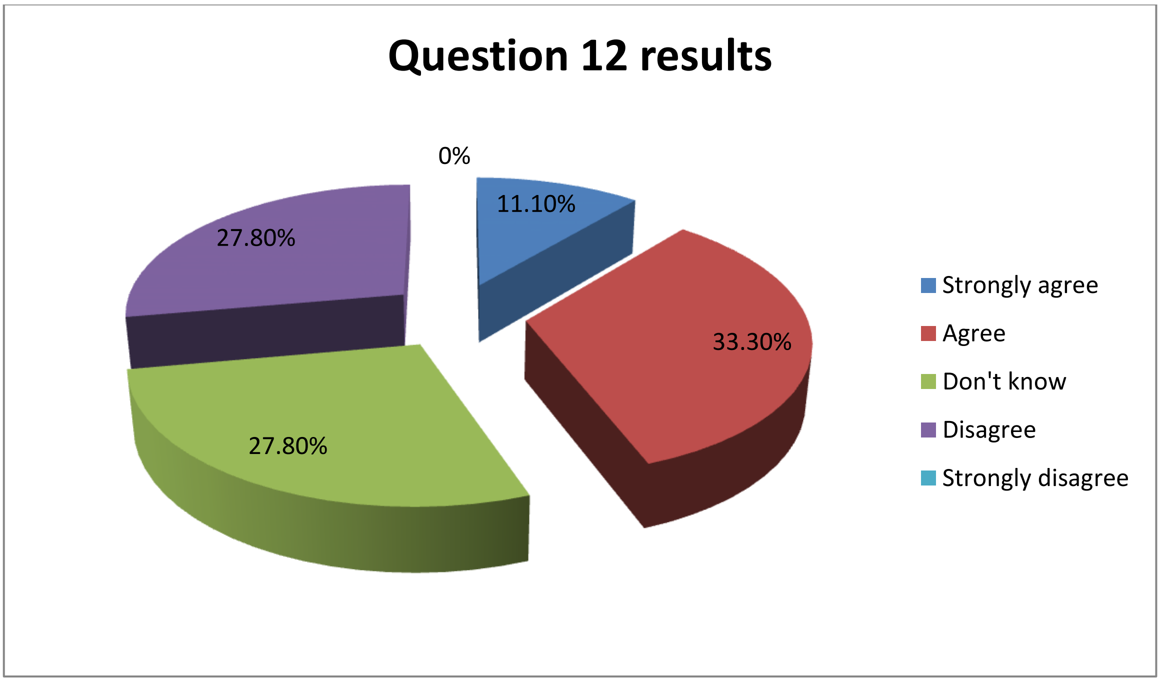


Figure 5.15 Question twelve results

Analysis

The aim of this question was to establish if the respondents believed that the current levels of construction and demolition waste production was a problem for the construction sector in Ireland. The results show that 11.1 per cent strongly agree, 33.3 per cent agree, 27.8 per cent disagree and 27.8 per cent do not know if it is a problem. One respondent also skipped this question. The results are mixed but the majority of respondents would agree with this statement. This is positive as almost half of the respondents believe that there is a problem; once this problem has been identified then it should be possible to provide suitable solutions within these companies.

Question 13

There is a lack of waste management training and knowledge in the Irish construction industry.

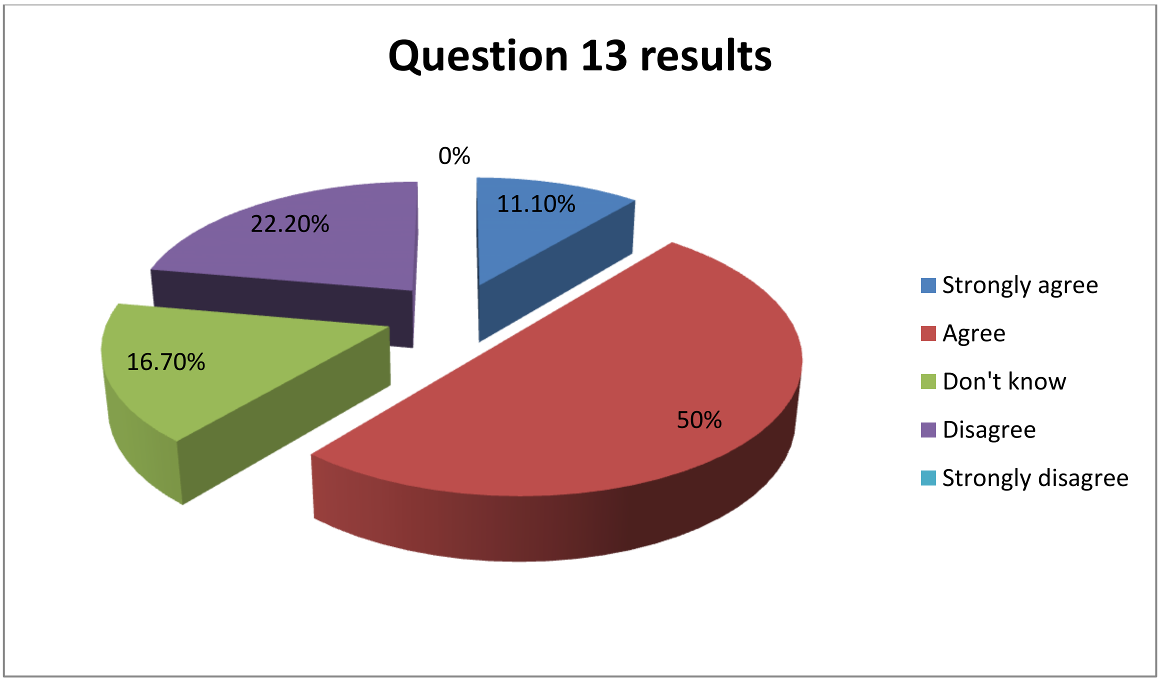


Figure 5.16 Question thirteen results

Analysis

The aim of this question was to gain the respondents opinion on the availability of suitable training and knowledge within the Irish construction industry. The results show that 61.1 per cent agree or strongly agree while 22.2 per cent disagree and 16.7 per cent are undecided. One respondent failed to answer this question. The results indicate that the majority of respondents believe that there is a lack of suitable training and knowledge within the Irish construction industry. If we look at the UK where organisations such as WRAP carry out extensive work in the area then it is clear that from an Irish perspective we are lacking in this knowledge. We are however able to use the knowledge provided by organisations such as WRAP and apply it to the Irish construction industry. It is important that the appropriate training and knowledge is provided to the industry so that waste management can become successful throughout every project taking place in this country.

Question 14

Poorly defined waste management responsibilities are a major cause of waste production on construction projects.

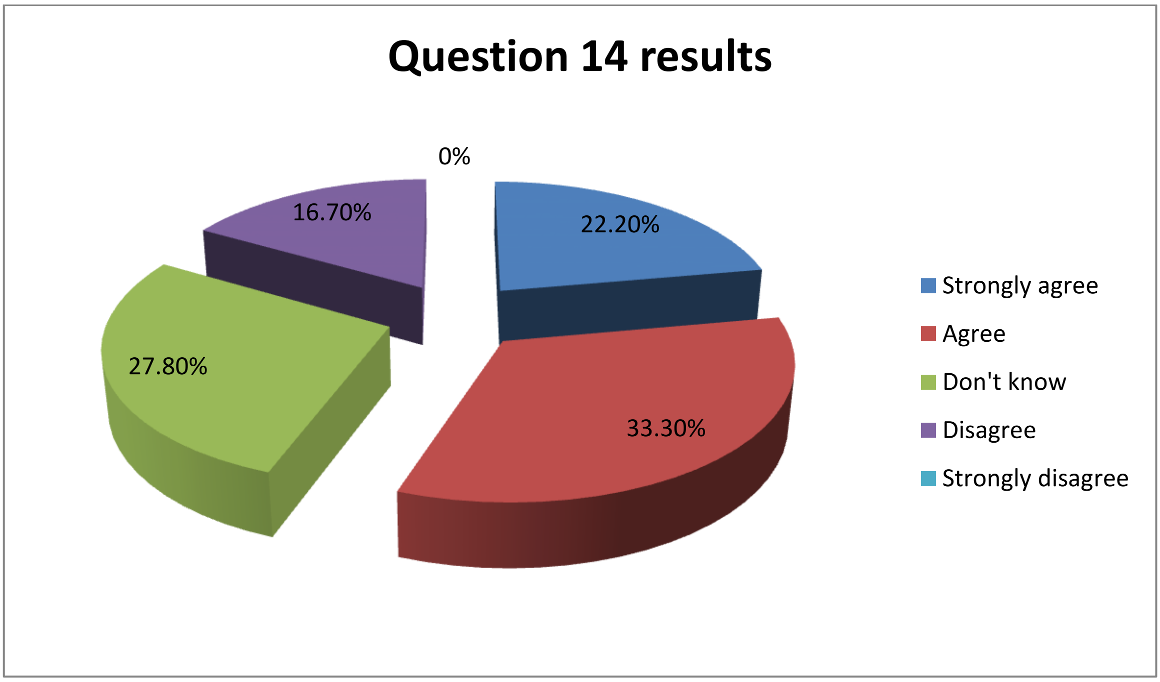


Figure 5.17 Question fourteen results

Analysis

This question seeks to identify if the respondent believes that poorly defined waste management responsibilities have an effect on waste production on site. The results are that 55.5 per cent either agree or strongly agree with the statement while 16.7 per cent disagree and a further 27.8 per cent do not know if poorly defined responsibilities lead to waste production. One respondent skipped this question. From the results it is evident that it is essential that the waste management responsibilities are clearly defined in order to avoid confusion. These responsibilities need to be relayed to all personnel working on site so that each operative is aware of their responsibility and also other operatives and managements responsibilities.

Question 15

Work processes on site are not designed to facilitate waste reduction strategies.

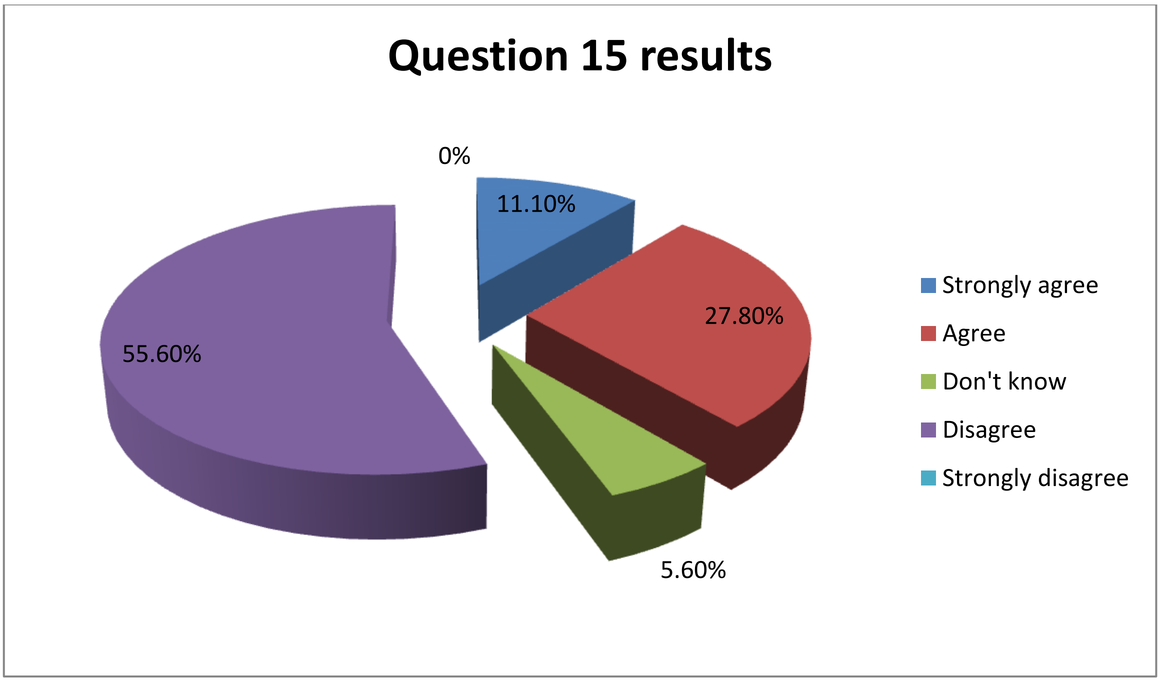


Figure 5.18 Question fifteen results

Analysis

The results from this question show that 55.6 per cent of respondents disagree with the statement that work process on site are not designed to facilitate waste reduction strategies. 38.9 per cent of respondents agree or strongly agree with the statement while 5.6 per cent do not know and one respondent skipped this question. The results show that the majority of main contractors believe that work processes are designed to facilitate waste reduction strategies but perhaps these answered may be biased as it is the main contractor answering questions about its own work processes. It is important that all work processes taking place on site are designed to facilitate waste reduction strategies and that at the early stages design decisions are made at an early stage so that waste production can be reduced or eliminated on all work processes.

Question 16

Waste prevention and minimisation will be major issues for main contractors to consider in the future.

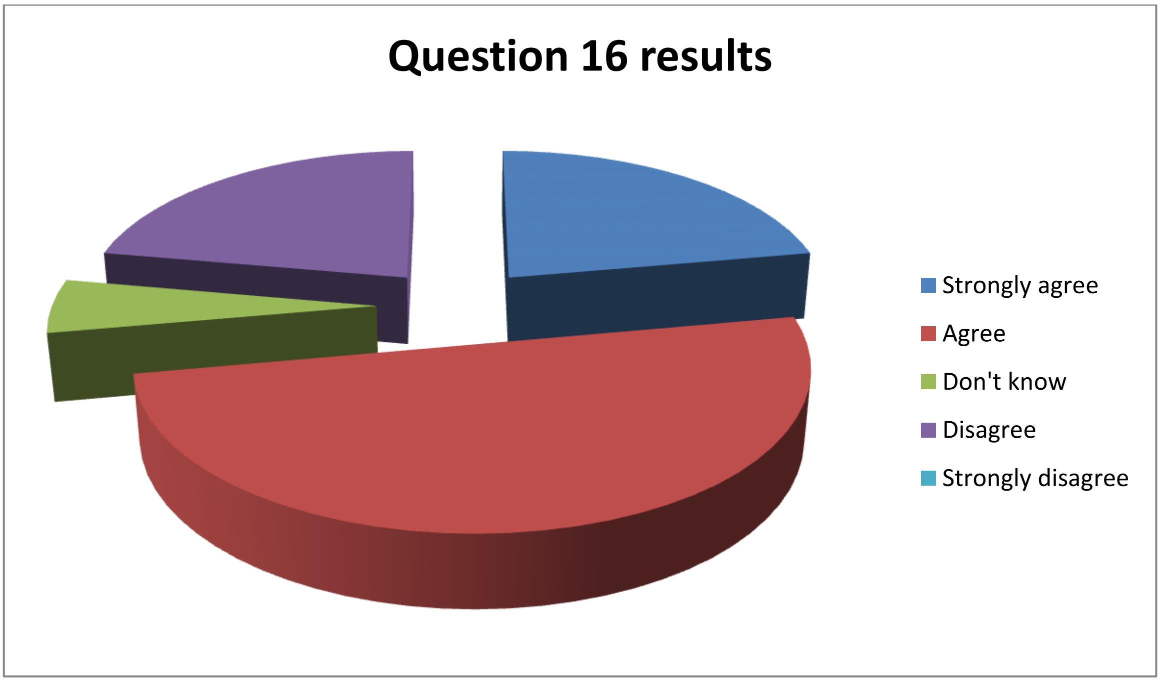


Figure 5.19 Question sixteen results

Analysis

This question is important as it seeks to investigate the main contractors' ability to look forward and consider future issues in relation to waste management. The results show that 72.2 per cent of respondents agree or strongly agree while 22.2 per cent disagree and a further 5.6 per cent do not know. One respondent failed to answer the question. It is possible that in the future legislative and policy changes by the government in Ireland will force contractors to become better at waste prevention and minimisation. As well as this, issues such as the increase in the landfill levy and the governments' targets for diverting waste from landfill will force contractors to revaluate their position in relation to waste management. It is positive to see that the majority see this as a future issue as now is the time when planning can start so that these issues can be dealt with successfully when they arise.

Question 17

There are no financial rewards or perceived benefits for main contractors to prevent, minimise, reuse or recycle waste on site.

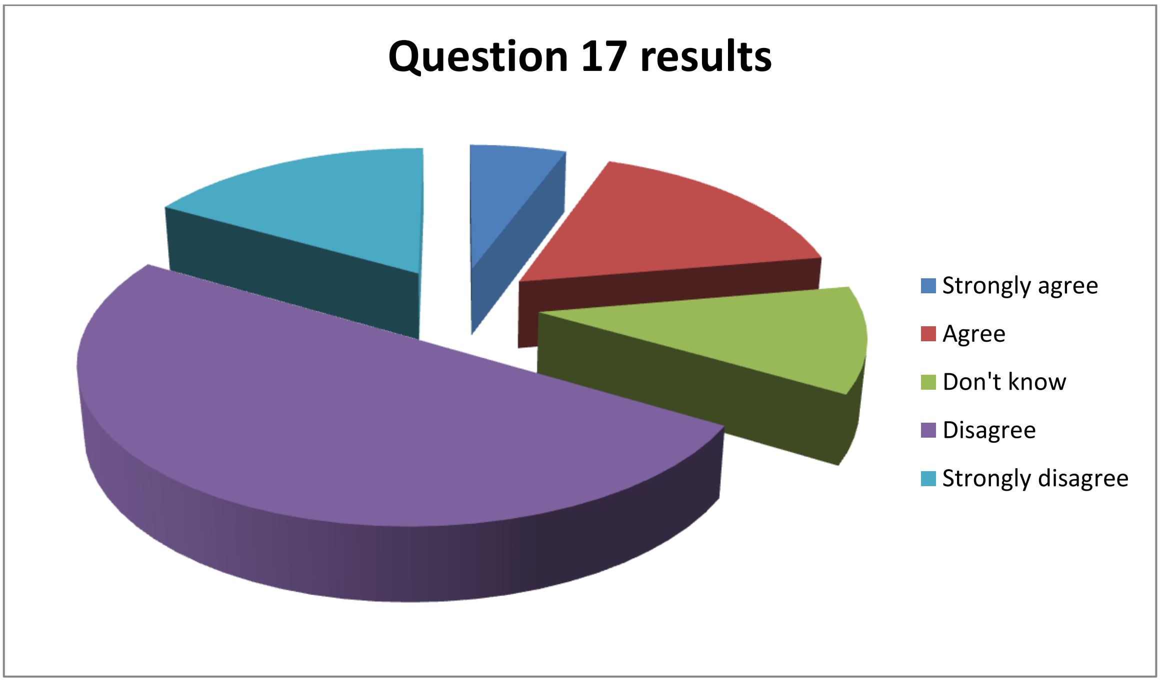


Figure 5.20 Question seventeen results

Analysis

The aim of this question was to see if the main contractors believed that there were financial rewards to be gained if waste was prevented, minimised, reused or recycled on site. The results show that 66.7 per cent disagree or strongly agree with this statement. 22.3 per cent agreed or strongly agreed with the statement with a further 11.1 per cent stating that they did not know. One respondent skipped the question. The results are positive because if a main contractor believes that there are financial rewards for good waste management practices then they will be more likely to implement good waste management practices on site. It is important that the belief that there are no financial rewards is changed as a main contractor can achieve a number of benefits including financial rewards when implementing good practice waste management as outlined in this thesis previously.

Question 18

Have you ever been involved in a project that implemented any of the following waste management strategies?

(A) Waste reduction targets.

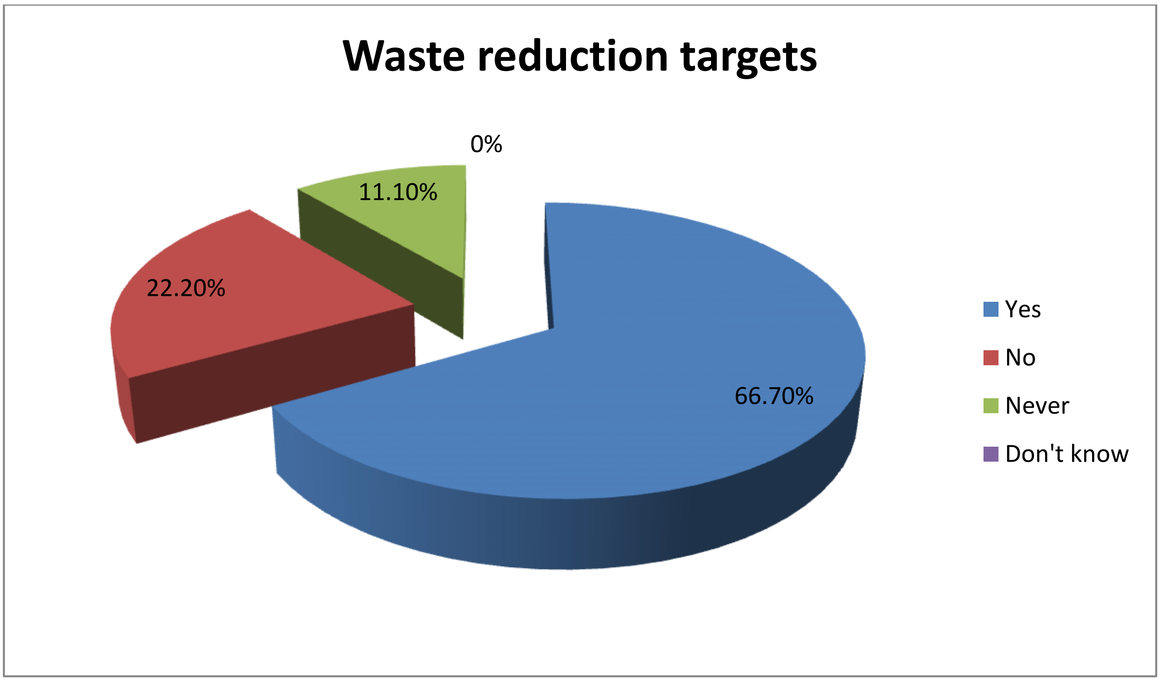


Figure 5.21 Question eighteen (A) results

(B) Non-hazardous waste segregation

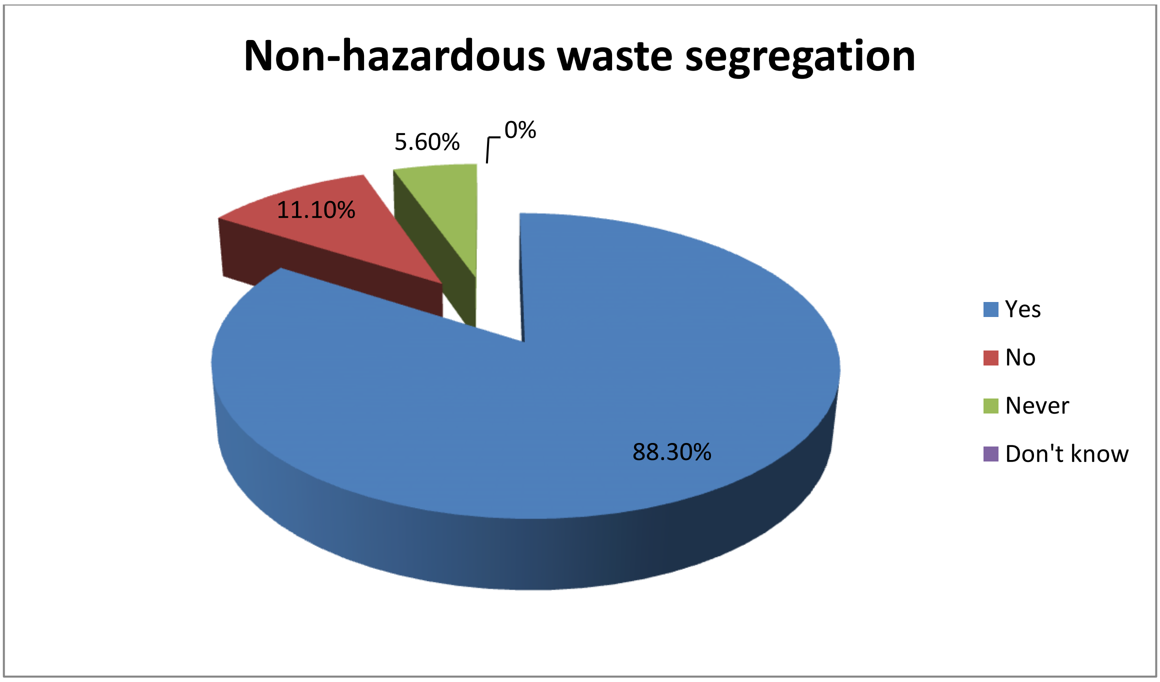


Figure 5.22 Question eighteen (B) results

(C) On site reuse of materials

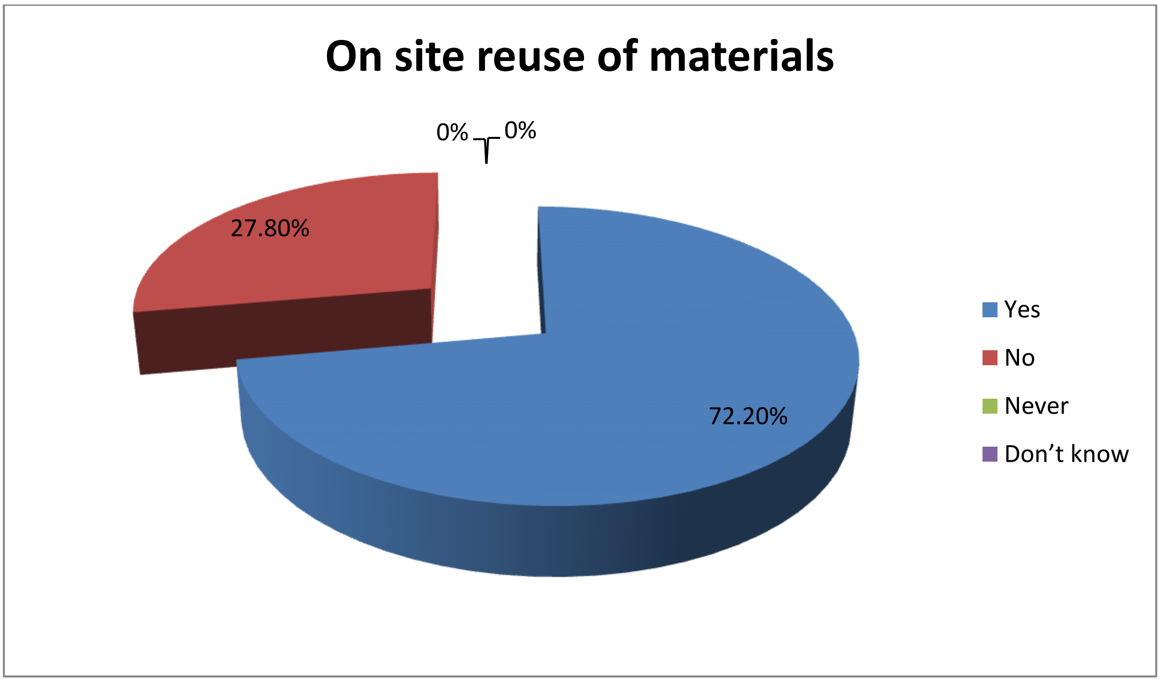


Figure 5.23 Question eighteen (C) results

(D) On site recycling of materials

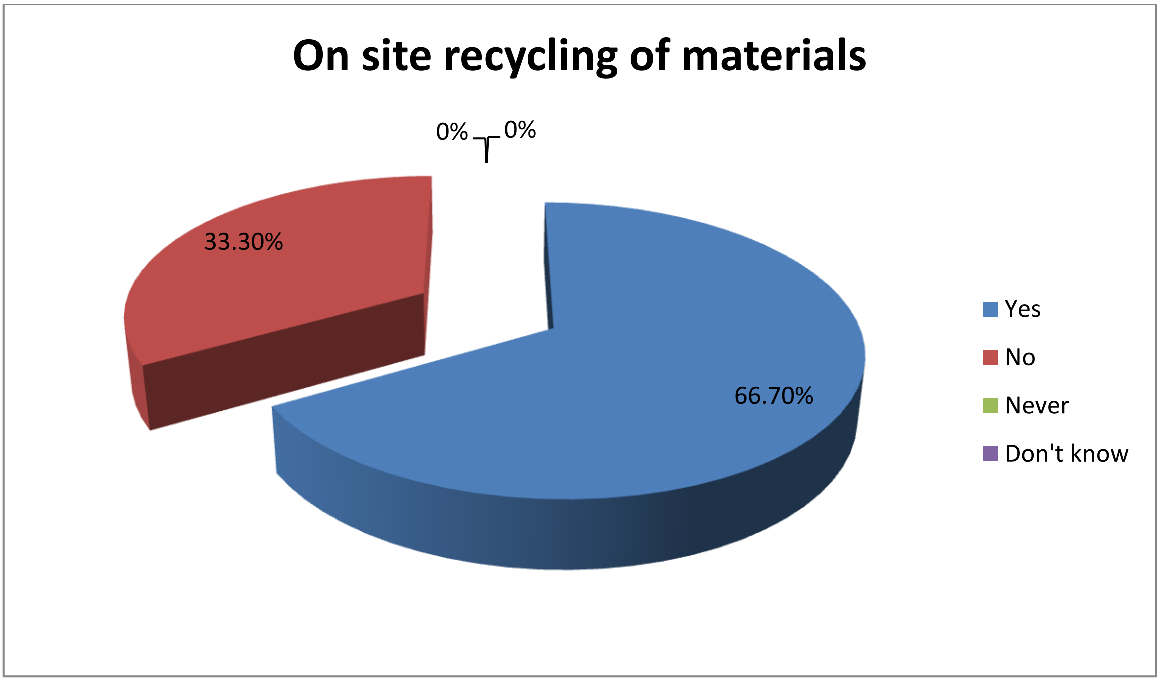


Figure 5.24 Question eighteen (D) results

Analysis

The main aim of this question was to establish what type of waste management strategies, if any, the main contractor had experience of.

(A) Waste reduction targets: The results of this question were that 66.7 per cent had been involved in a project that implemented waste reduction targets while 33.3 per cent had not. This is a good result as it shows that there are construction companies in Ireland that are currently or have in the past implemented waste reduction targets. The setting of these targets is seen as good practice waste management and minimisation. Waste reduction targets are an effective method in the minimisation of waste production and waste reduction targets should be embedded within company policy.

(B) Non-hazardous waste segregation: The results show that 83.3 per cent of respondents had been involved in a project that segregated non-hazardous waste while 16.7 per cent had not. The segregation of non-hazardous waste is one of the basic tasks required when trying to implement good practice waste management. On site segregation of waste should

be taking place so that the waste can be recycled effectively by the waste management contractor. The results are positive as the majority of contractors surveyed have been involved in waste segregation which shows that it is a common activity on construction sites in Ireland.

(C) On-site reuse of materials: The results of this section of the question shows that72.2 per cent of main contractors have been involved in a project that reused materials on site while 27.8 per cent had not been involved in such a project. The reuse of materials on site is an important and effective waste minimisation technique that should be implemented on all sites. Reusing materials reduces the need to rely on virgin materials and this reduces the environmental impact of the construction project.

(D) On-site recycling of materials: The results of this question were that 66.7 per cent had been involved in a project that implemented on-site recycling of materials as a waste management strategy while 33.3 per cent had not had any experience of this. Again the results are positive as the majority of respondents stated that they had experience with the on-site recycling of materials. On site recycling of materials such as concrete and rubble waste can reduce a company's reliance on virgin quarried materials. Off-site recycling is very common on construction sites whereas on site recycling normally only takes place on larger sites.

SECTION C

Question 19

What are the main causes of waste on site? [Ranking 1 indicates the biggest cause and ranking 5 indicates the lowest cause. Each option listed can be ranked 1 to 5].

(A) Waste from the application process e.g. offcuts.

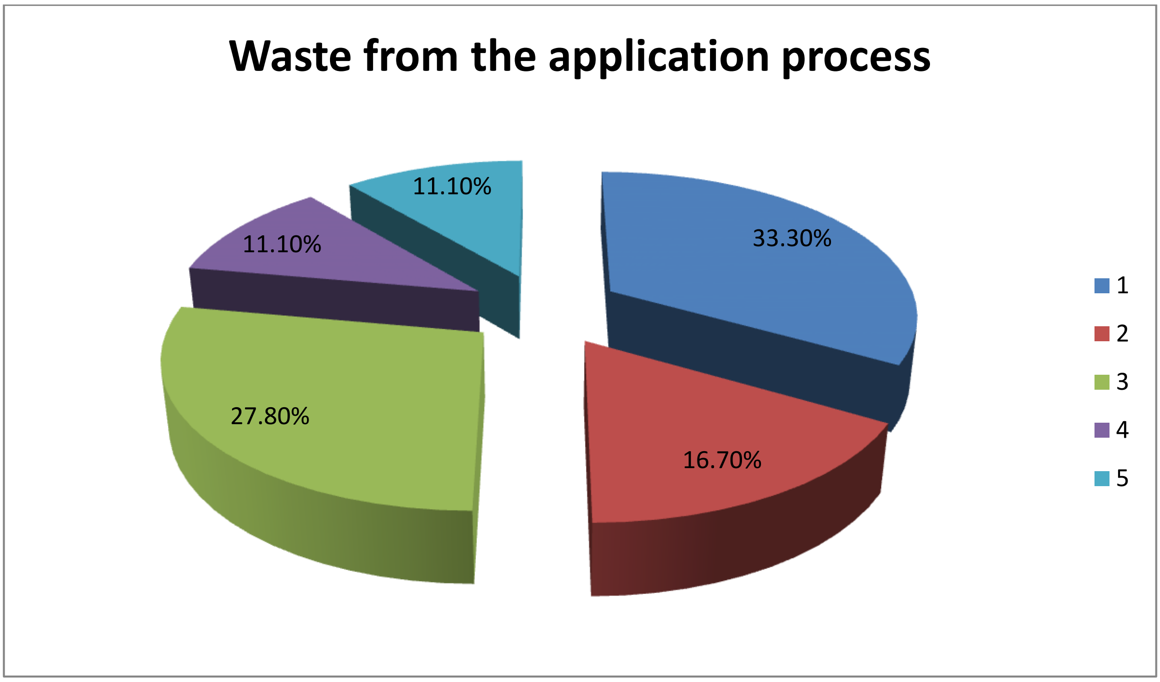


Figure 5.25 Question nineteen (A) results

(B) Improper storage space and methods.

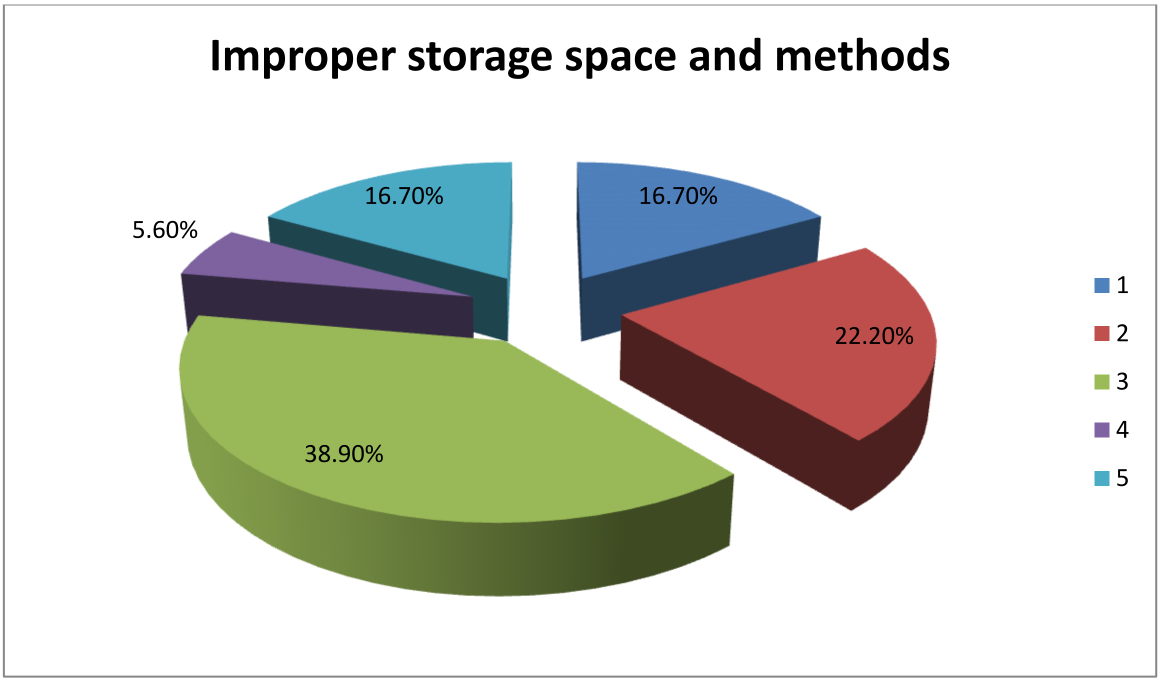


Figure 5.26 Question nineteen (B) results

(C) Poor site management.

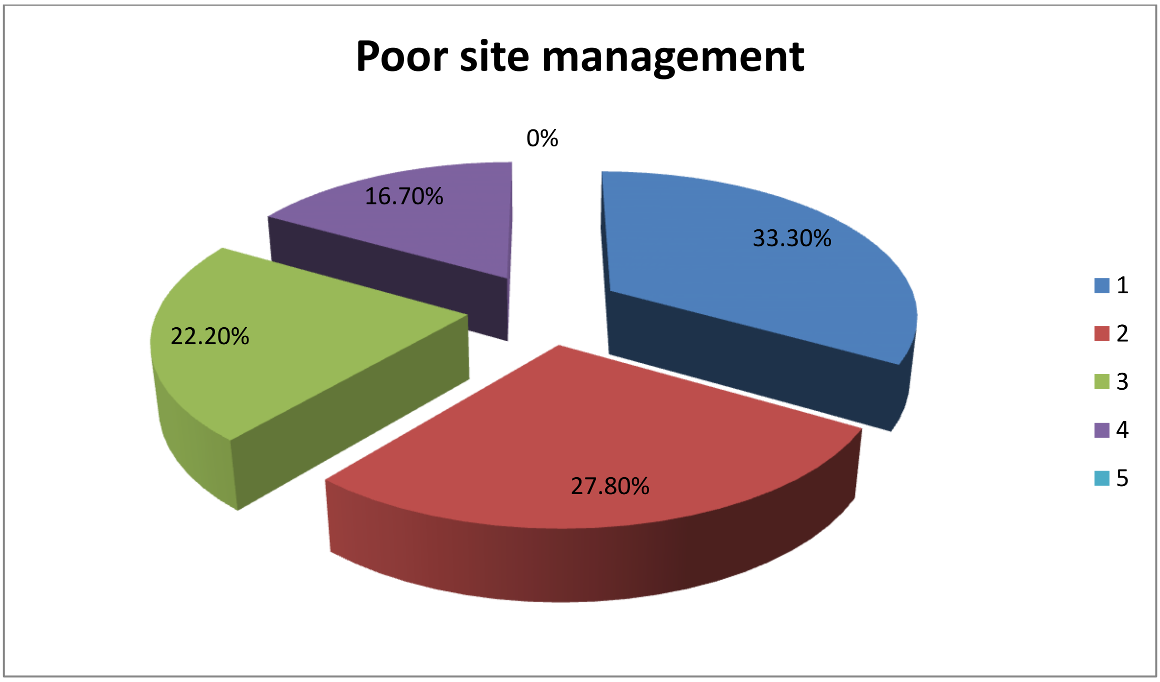


Figure 5.27 Question nineteen (C) results

(D) Poor specification and drawings.

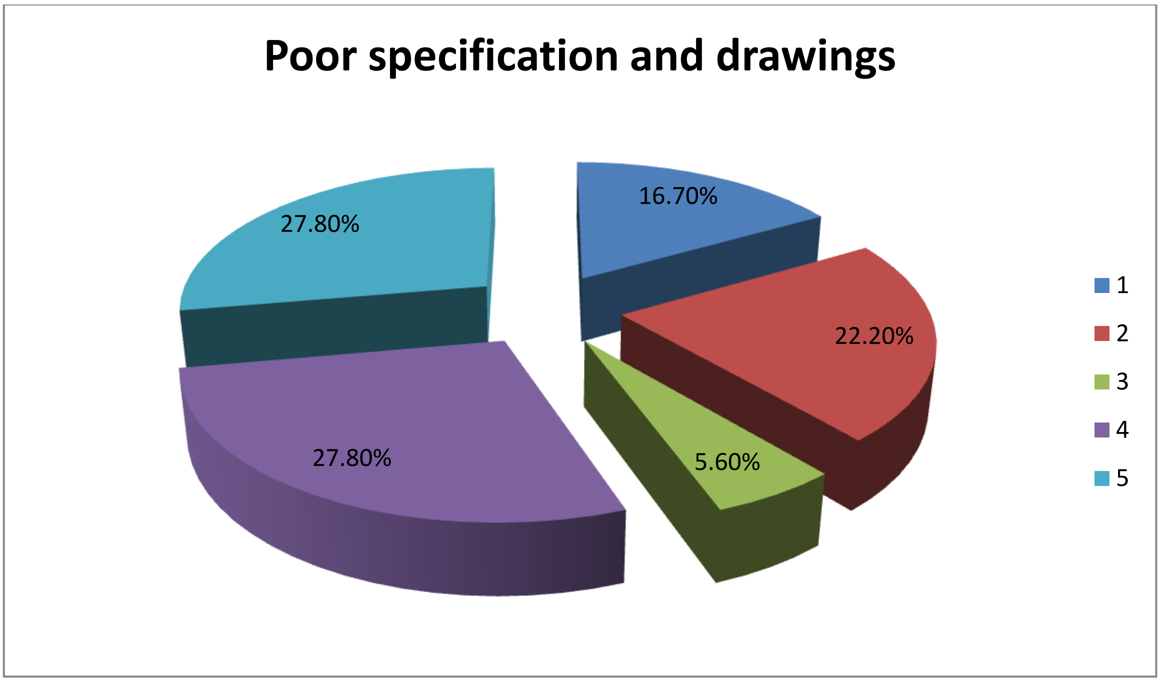


Figure 5.28 Question nineteen (D) results

(E) Inappropriate design.

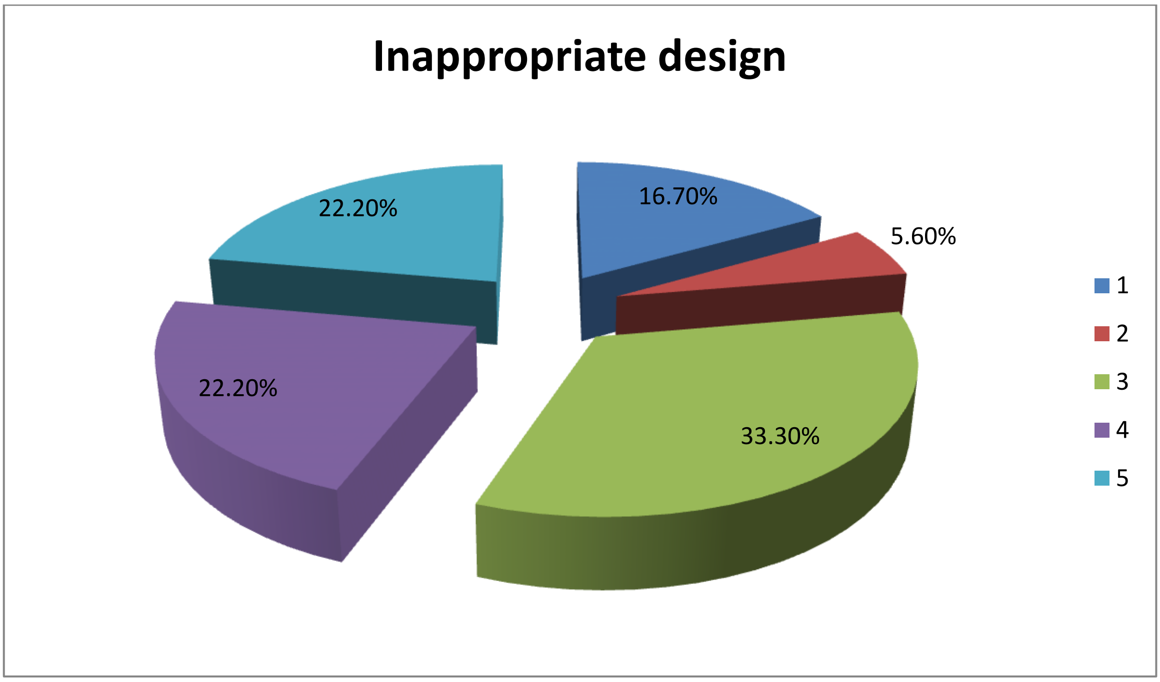


Figure 5.29 Question nineteen (E) results

Analysis

The aim of this question was to establish the contractors' opinion of what they believed to be the biggest causes of waste on site. The results show that waste from the application process and poor site management were the main causes of waste on site.

(A) Waste from the application process: The majority of respondents believed that waste resulting from offcuts was one of the main causes on site. 33.3 per cent of respondents rated it as the biggest cause of waste production on site while 11.2 per cent of respondents believed that it was not a cause of waste production. This is in line with work processes monitored on site during the observation of the case study site.

(B) Improper storage space and methods: Again in this instance 77.8 per cent of respondents rated improper storage above 3 on the scale which shows that they believe that improper storage contributes to waste production on site while 22.3 per cent rated it as a low cause of waste production. This is also in line with what has been observed on the case study site as poor storage often lead to materials being damaged on site.

(C) Poor site management: In this instance all of the respondents believed that poor site management had some impact on the production of waste on site with no respondent rating this question as 5. This may be slightly unfair as the management within the company is placing all the responsibility of reducing waste on the site manager. While the site manager has a crucial role to play it is important that management support the on-site management so the good practice waste management can be implemented. It is crucial that the blame culture is removed and that everyone accepts their responsibilities for waste management both on and off the site.

(D) Poor specification and drawings: In this question the majority of respondents rated this issue as quite low as one of the causes of waste on site. This may be somewhat untrue as during the research for this thesis it was found that one of the best possibilities for waste minimisation was during the design stage. It is important that waste minimisation is considered from the outset as it is during the design stage that major decisions are made that can contribute to waste generation on site.

(E) Inappropriate design: The results of this question show that the majority of respondents list this as a neutral cause or a low cause of waste production on site. Again this may be untrue as the design of the building is important in the generation of waste. It is important that waste is considered during the design stage so that waste production is minimised on the project.

Question 20

Who is responsible for waste management during site operations? [Ranking 1 indicates the 'most responsible' and ranking 5 indicates the 'least responsible'. Each option can be ranked from 1 to 5].

(A) Supplier.

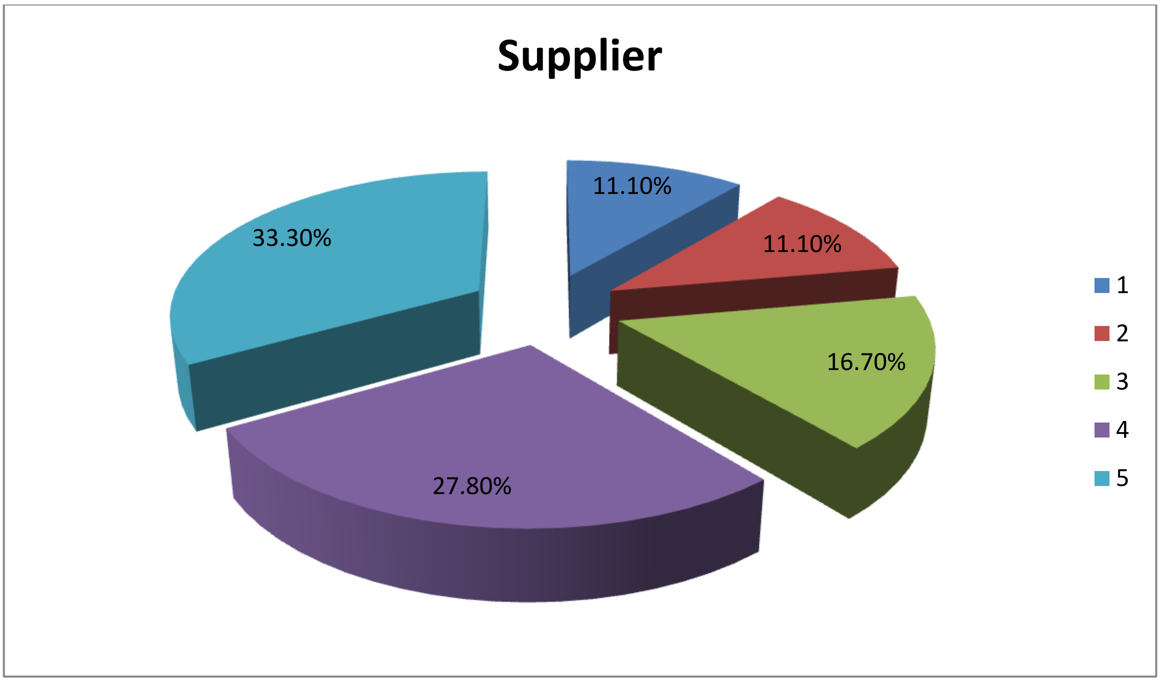


Figure 5.30 Question twenty (A) results

(B) Main contractor.

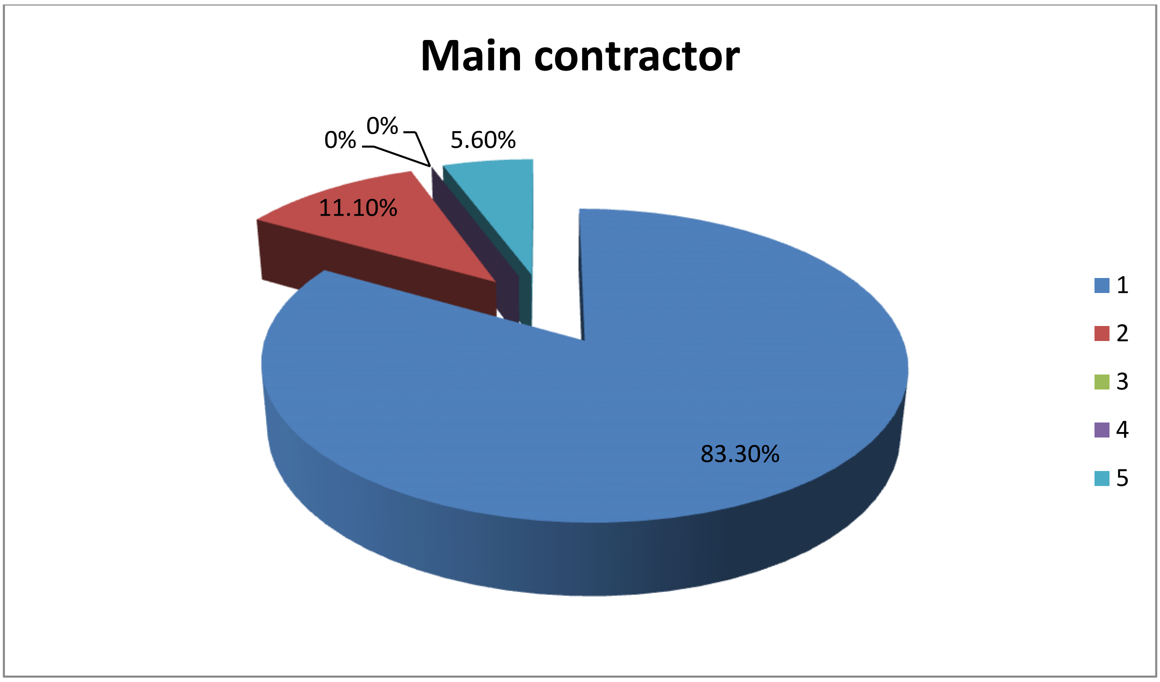


Figure 5.31 Question twenty (B) results

(C) Sub-contractor.

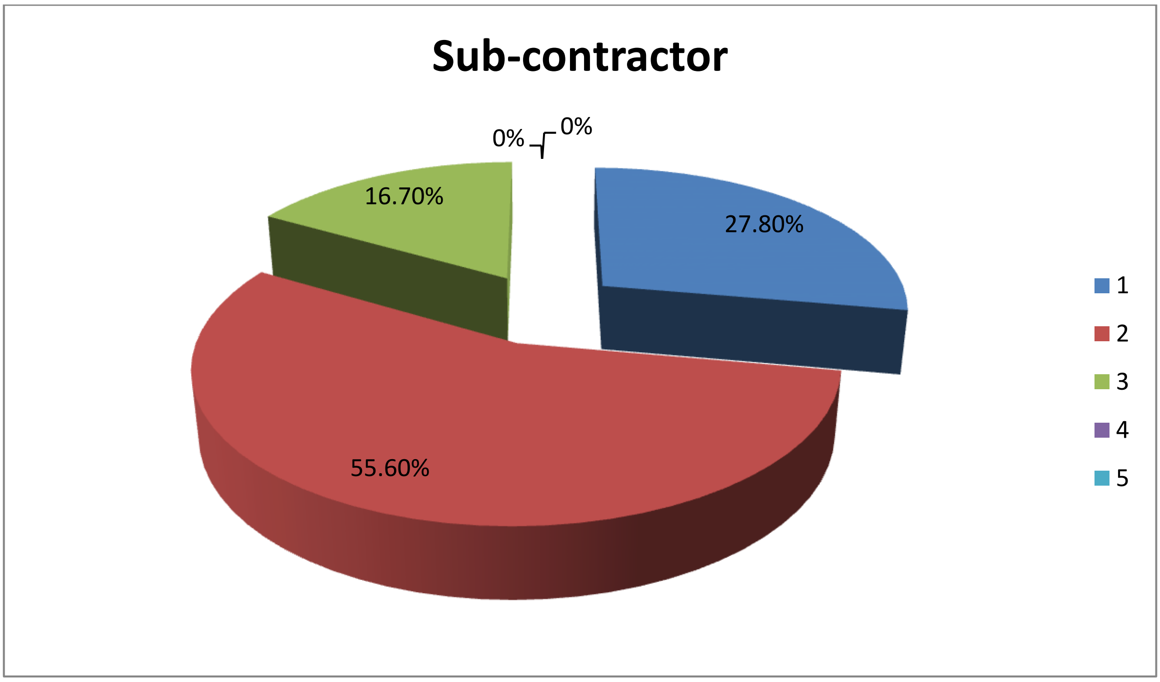


Figure 5.32 Question twenty (C) results

(D) *Designer/ Architect.*

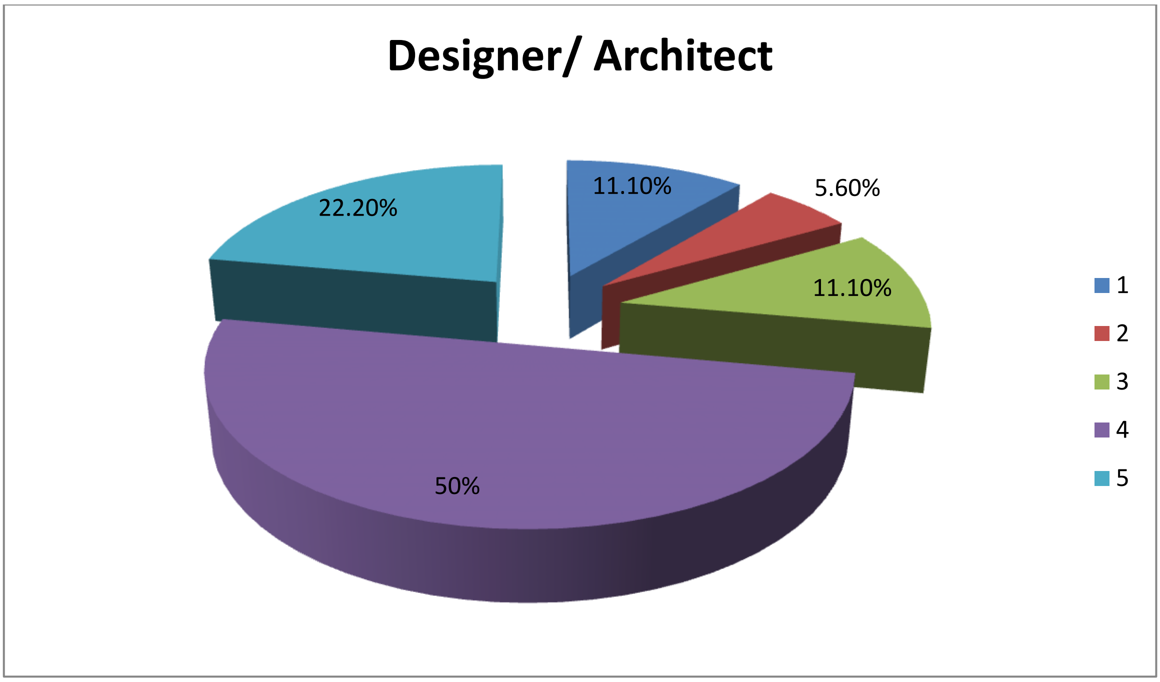


Figure 5.33 Question twenty (D) results

(E) Client.

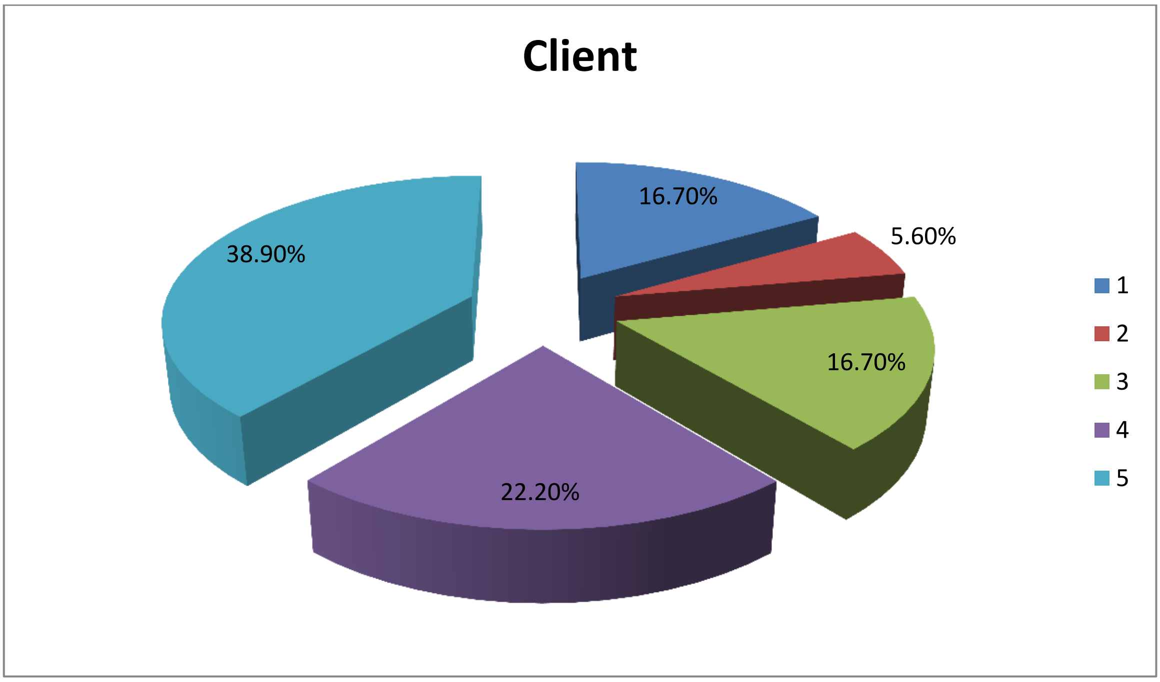


Figure 5.34 Question twenty (E) results

Analysis

The aim of this question was to ascertain who the respondents believed was responsible for waste management during site operations. The results of this question show that the majority of the main contractors surveyed believe that either the main contractor or the sub-contractor is responsible for waste management during the site operations. The rest of the answers are mixed but the reality is that each party should play a role within the waste management process but overall the main contractor will be responsible during site operations.

Question 21

What is the main goal of stakeholders on a construction project? [Ranking 1 indicates the 'most important' and ranking 5 indicates the 'least important'. Each option can be ranked from 1 to 5].

(A) Time.

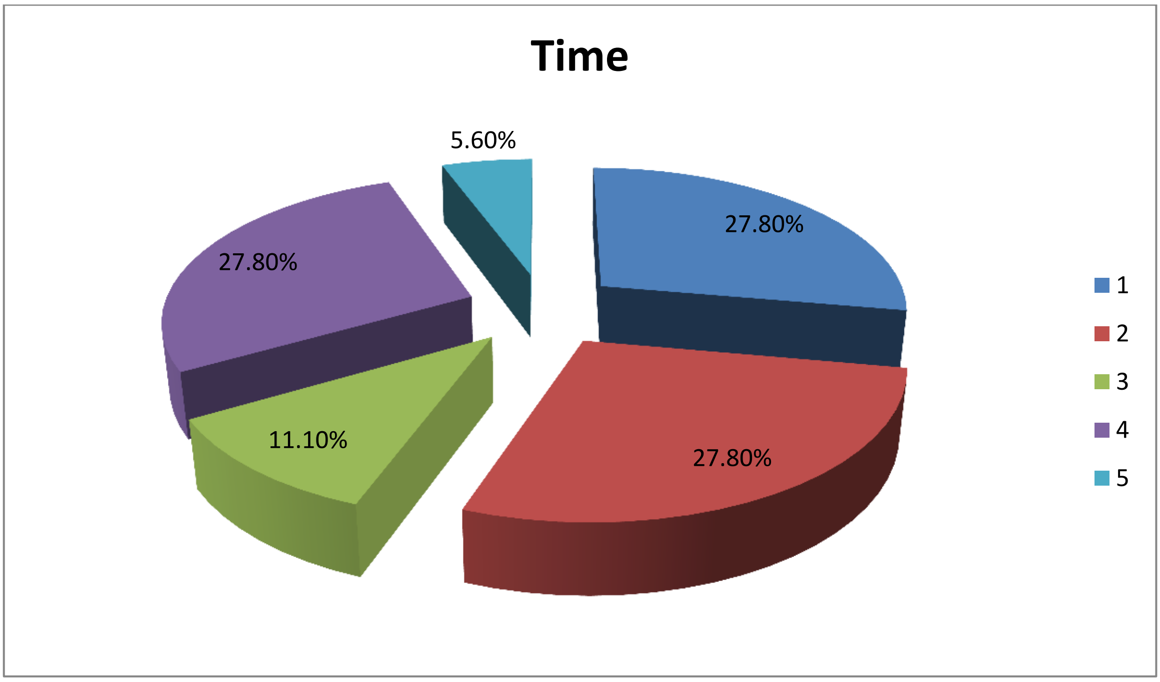


Figure 5.35 Question twenty one (A) results

(B) Cost.

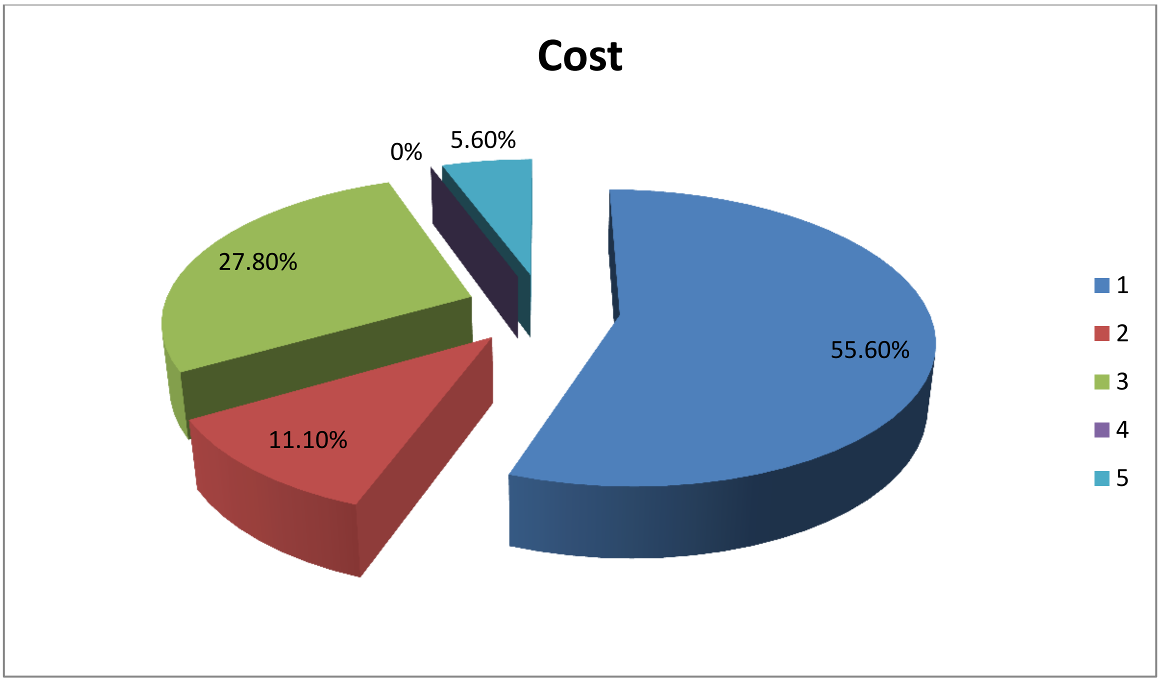


Figure 5.36 Question twenty one (B) results

(C) Quality.

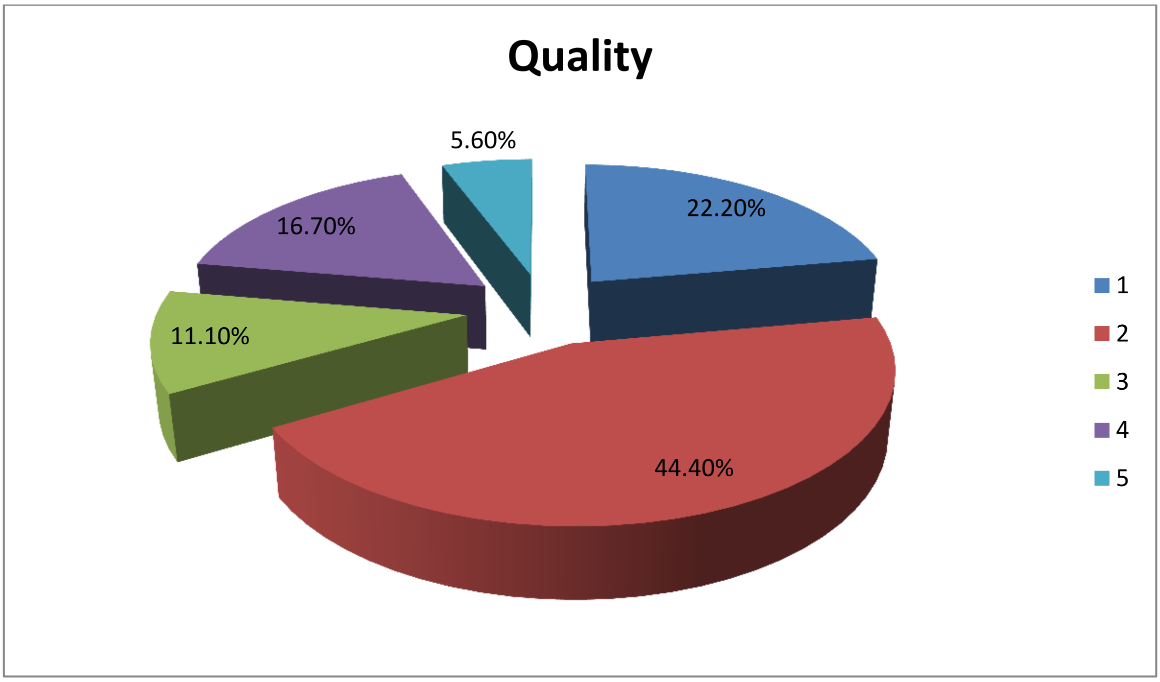


Figure 5.37 Question twenty one (C) results

(D) Safety.

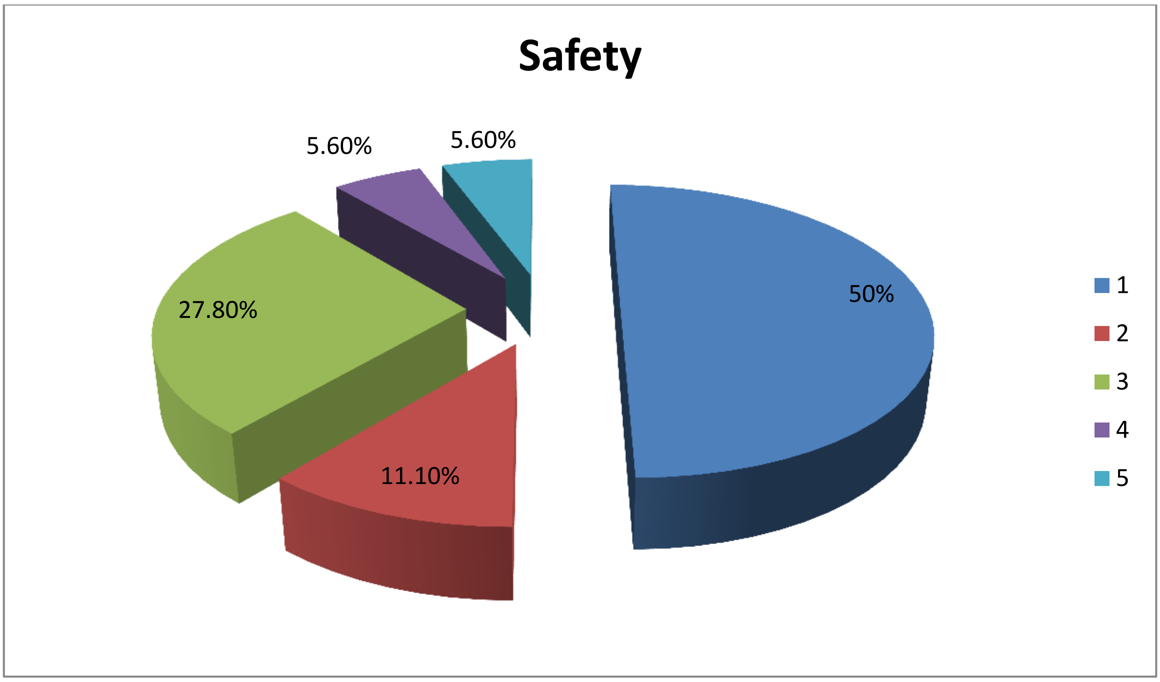


Figure 5.38 Question twenty one (D) results

(E) Waste management.

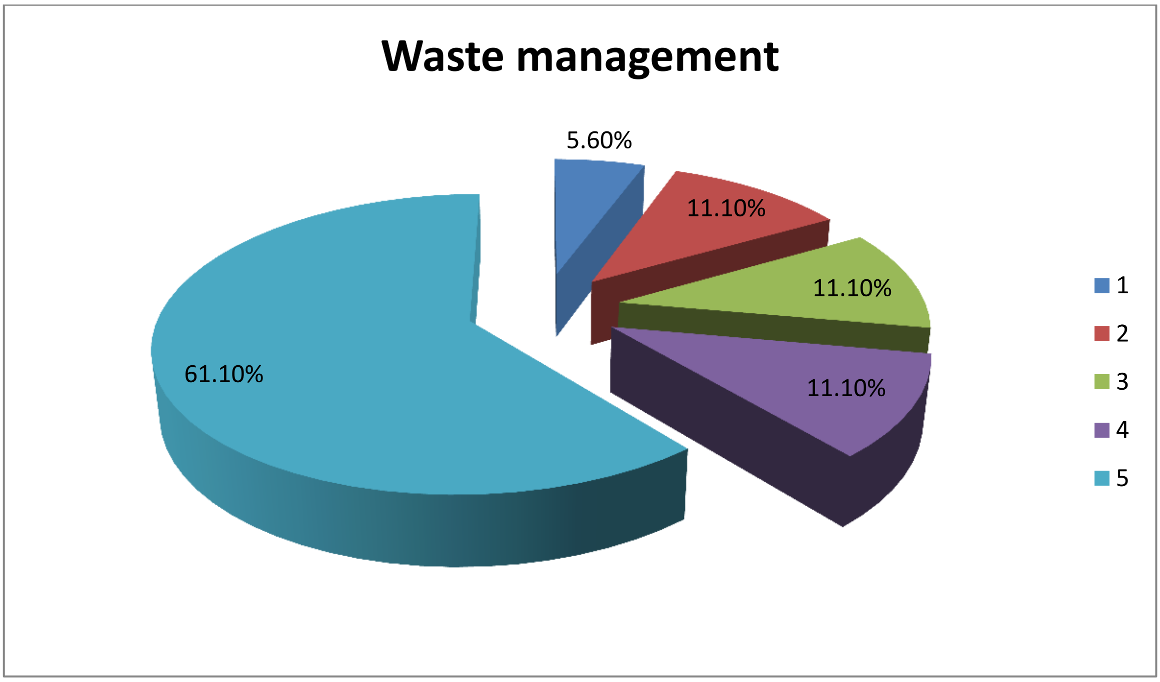


Figure 5.39 Question twenty one (E) results

Analysis

The aim of this question was to establish what the contractor believed was the stakeholders' main goal on a construction project. The results show that the contractor believes that waste management is a very minor goal of the stakeholders while time, cost, quality and safety all rank highly on the list of stakeholders goals. While waste management is not currently a goal of the stakeholders it should be considered in line with the other objectives as the implementation of good practice waste management could also impact positively on time, cost, quality and safety.

Question 22

What are the main incentives to reduce waste on site? [Ranking 1 indicates the 'biggest incentive' and ranking 4 indicates the 'smallest incentive'. Each option can be ranked from 1 to 5].

(A) Financial rewards for site personnel.

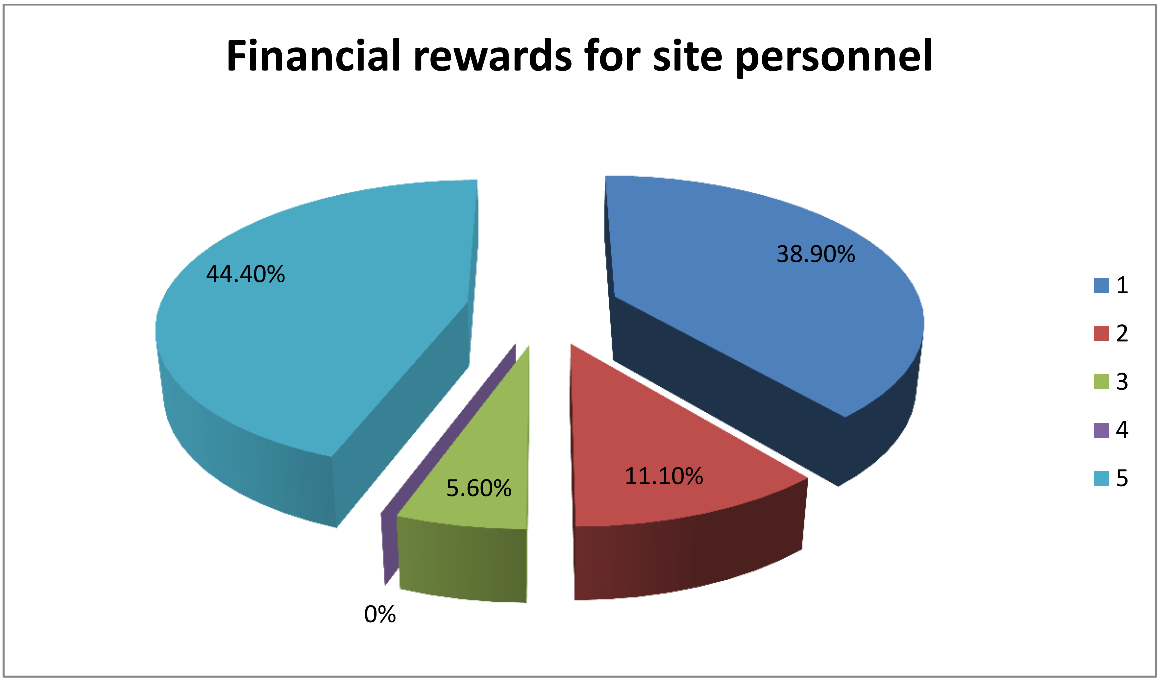


Figure 5.40 Question twenty two (A) results

(B) Waste management policy/ strategy on site.

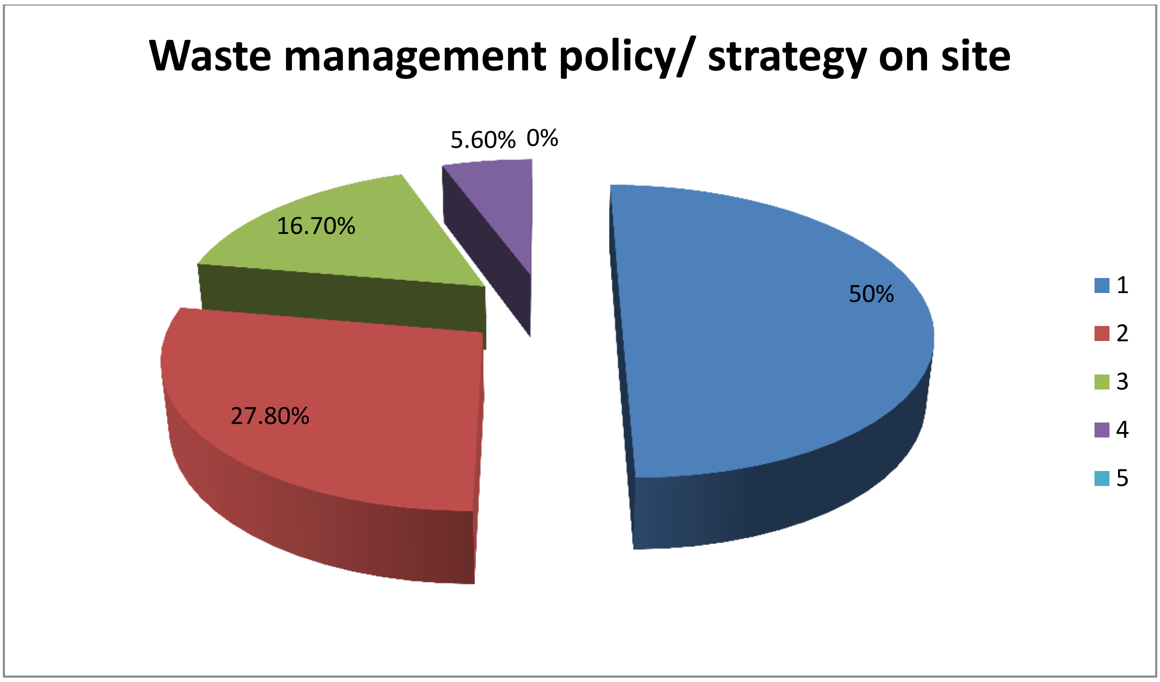


Figure 5.41 Question twenty two (B) results

(C) Clear waste management responsibilities on site.

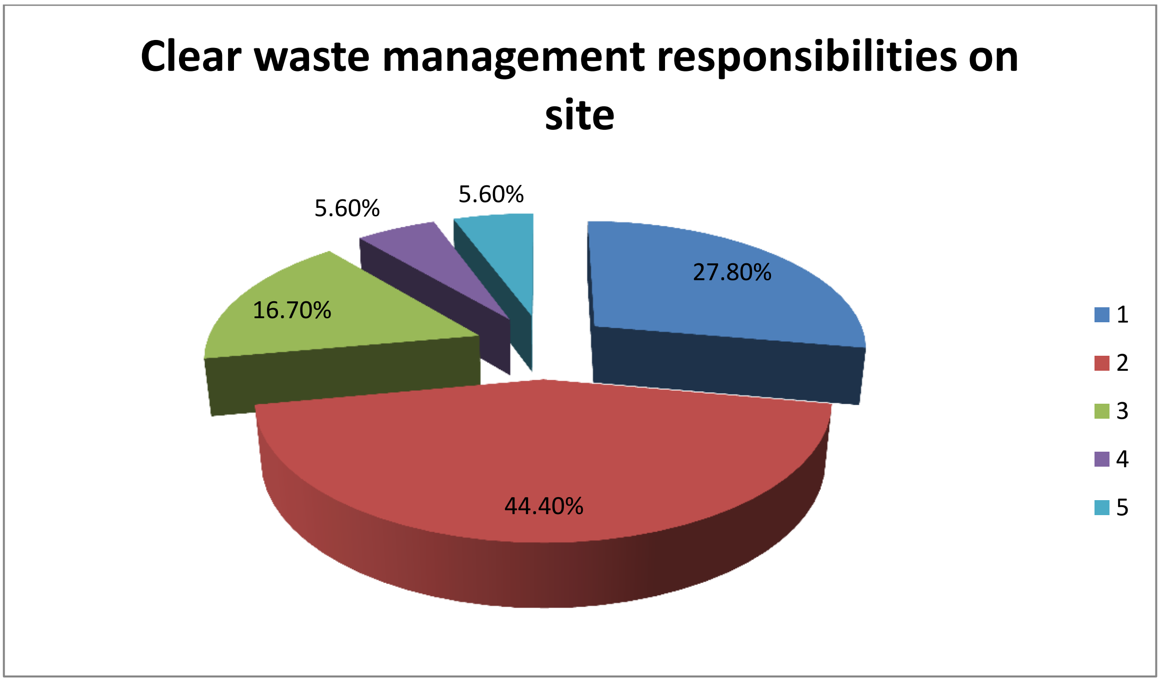


Figure 5.42 Question twenty two (C) results

(D) Training for site personnel.

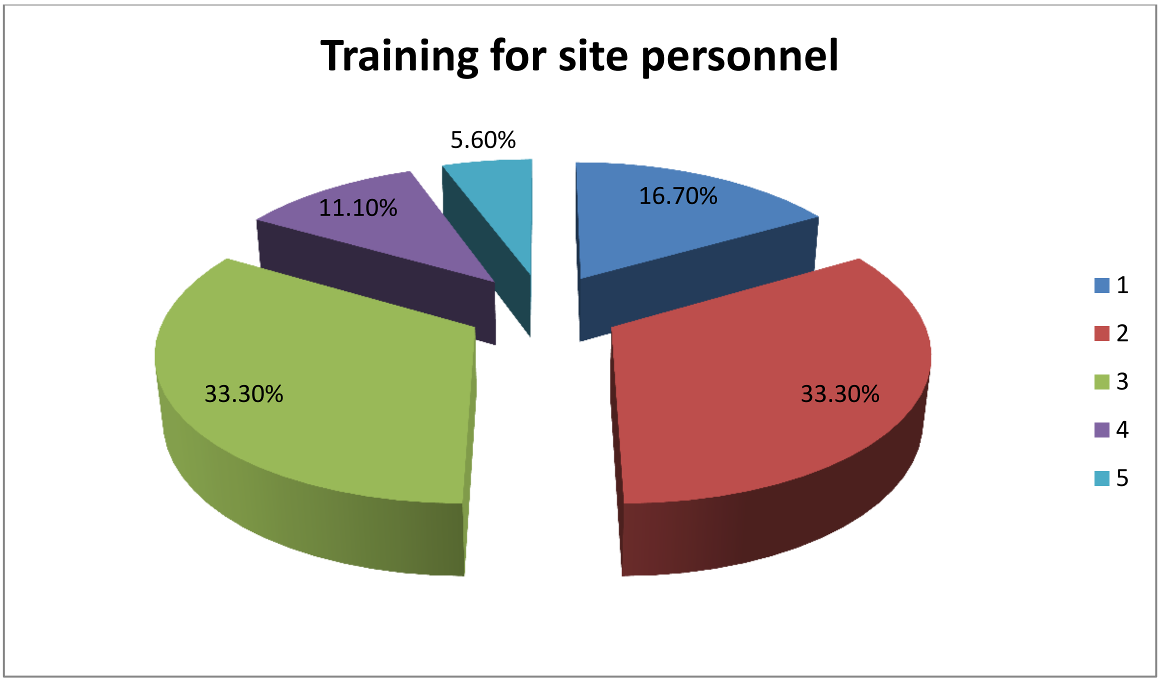


Figure 5.43 Question twenty two (D) results

(E) Materials purchasing by sub-contractors.

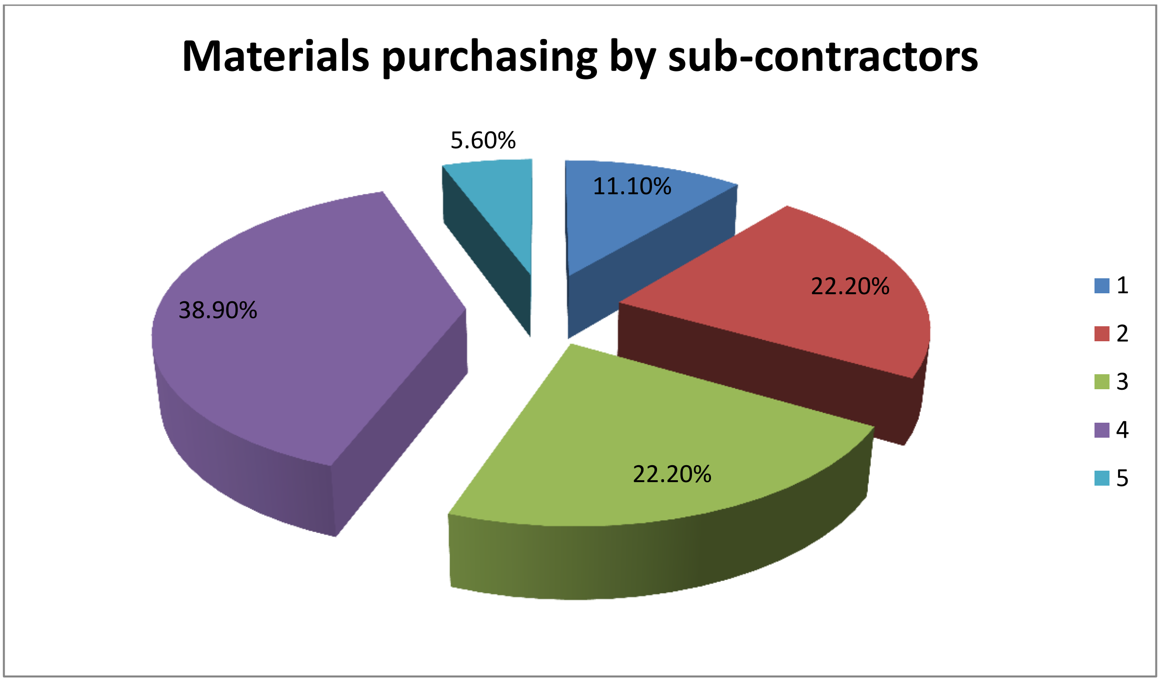


Figure 5.44 Question twenty two (E) results

Analysis

The aim of this question is to establish what the main incentives are to reduce waste on site for main contractors.

(A) Financial rewards for site personnel: The results of this question rate this as both the biggest incentive and the smallest incentive. The results show that some companies have financial rewards or incentives in place while others don't. The use of financial rewards can be used as a positive incentive to get site personnel to develop better waste management and minimisation habits.

(B) Waste management policy/ strategy on site: The results show that all the respondents believe that a waste management policy/ strategy on site are an incentive to reduce waste on site. One of the first steps of implementing good practice waste management is to put a waste management strategy in place on site. Once this strategy is in place it can be used as a reference point in relation to all waste management activities on site. Without a waste management strategy there may not be as big an incentive to reduce waste on site as there are no targets to be met or procedures to be followed.

(C) Clear waste management responsibilities on site: Similar to the previous question the majority of the respondents believe that clear waste management responsibilities act as an incentive to reduce waste on site. Once clear responsibilities have been outlined then it is possible for leadership to be taken in relation to waste management. Setting out responsibilities is seen as a good practice waste management task and should take place on each project. These responsibilities should also be outlined in the waste management plan.

(D) Training for site personnel: The results from this question again show that the majority of respondents believe that the training of site personnel can act as an incentive to reduce waste on site. Training and communication are seen as crucial to the implementation of a successful waste management plan. Training can take place through site inductions and also tool box talks and staff should be constantly updated on the progress of achieving good practice waste management on site.

(E) Materials purchasing by sub-contractors: The answers to this question were fairly neutral with the majority rating the question as 4. This shows that the main contractors believe that if a sub-contractor purchases his own materials that it is not a big incentive to reduce waste on site. However if a sub-contractor does purchase their own materials then they may be more likely to minimise the waste produced.

Question 23

What are the main barriers to reducing waste on site? [Ranking 1 indicates the 'biggest barrier' and ranking 5 indicates the 'smallest barrier'. Each option can be ranked from 1 to 5].

(A) No financial incentives for site personnel.

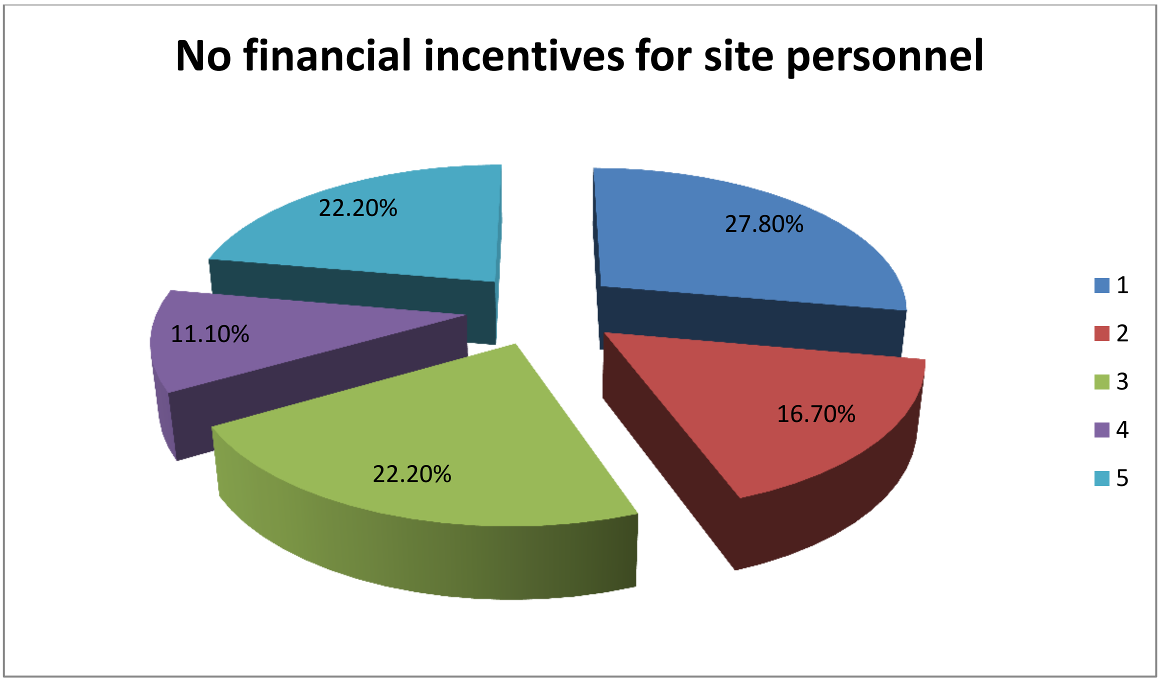


Figure 5.45 Question twenty three (A) results

(B) Waste accepted as inevitable on site.

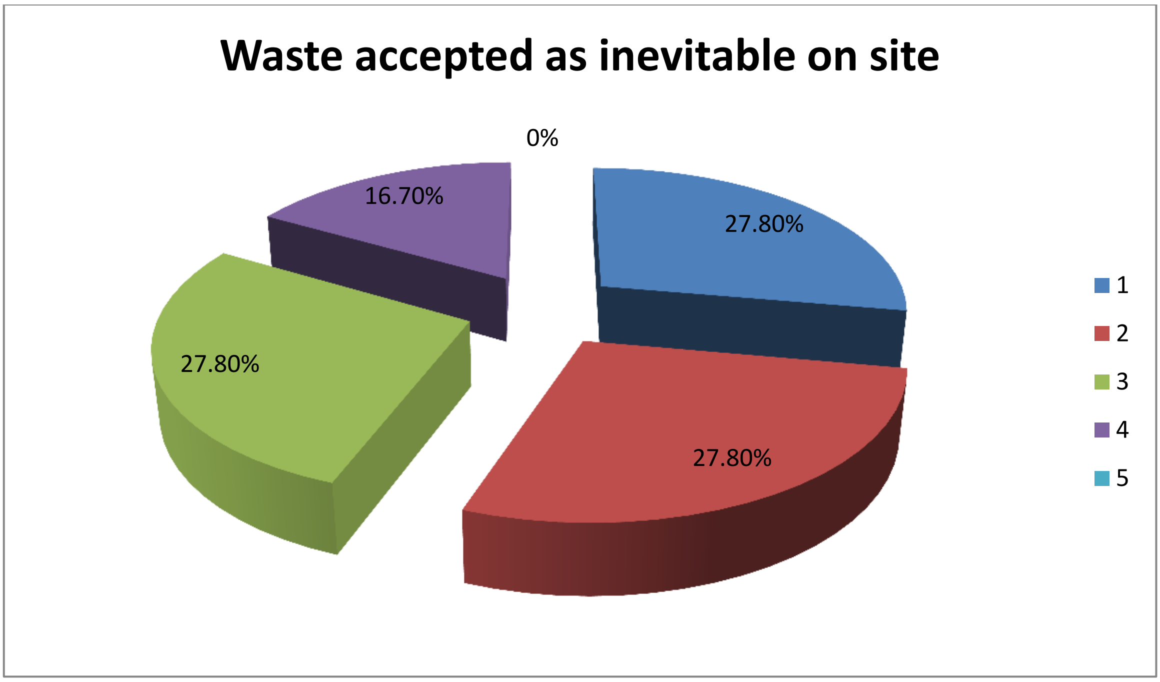


Figure 5.46 Question twenty three (B) results

(C) No waste management policy/ strategy on site.

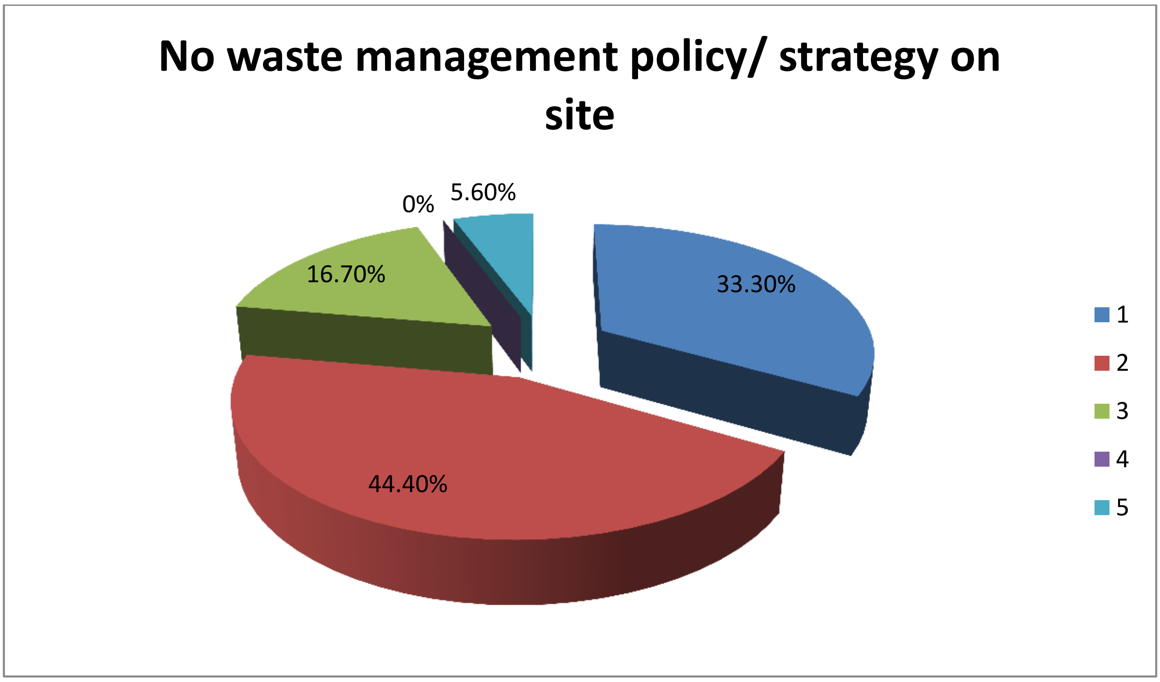


Figure 5.47 Question twenty three (C) results

(D) No commitment/ direction from site management.

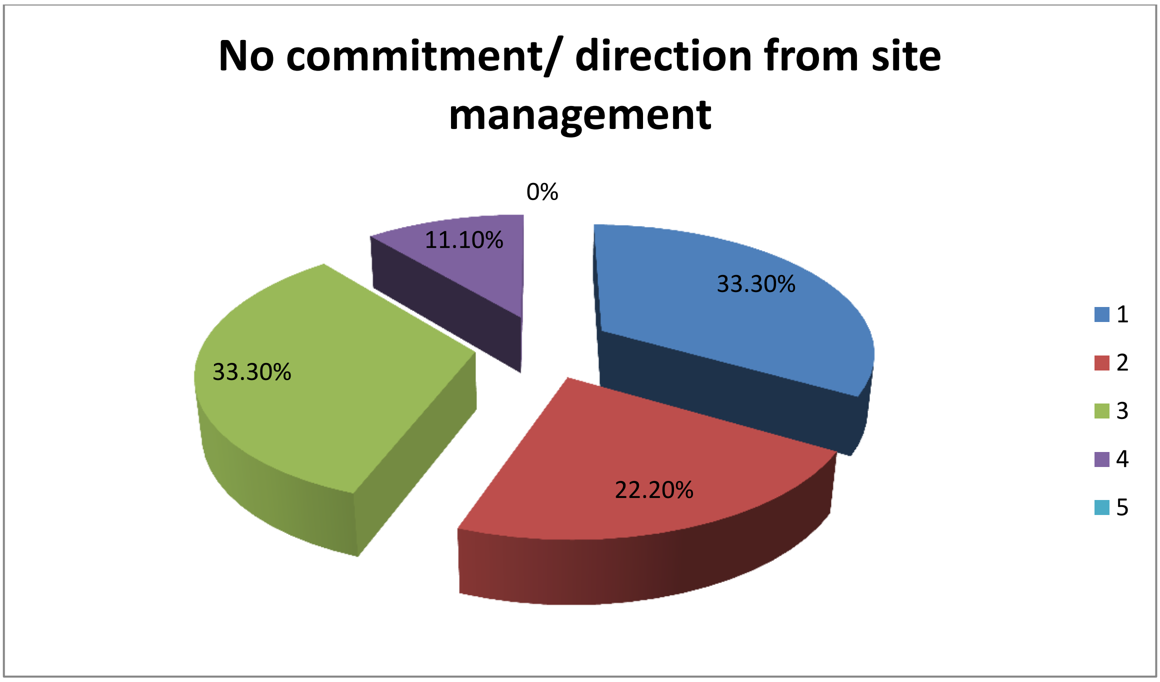


Figure 5.48 Question twenty three (D) results

(E) Design considerations and specifications.

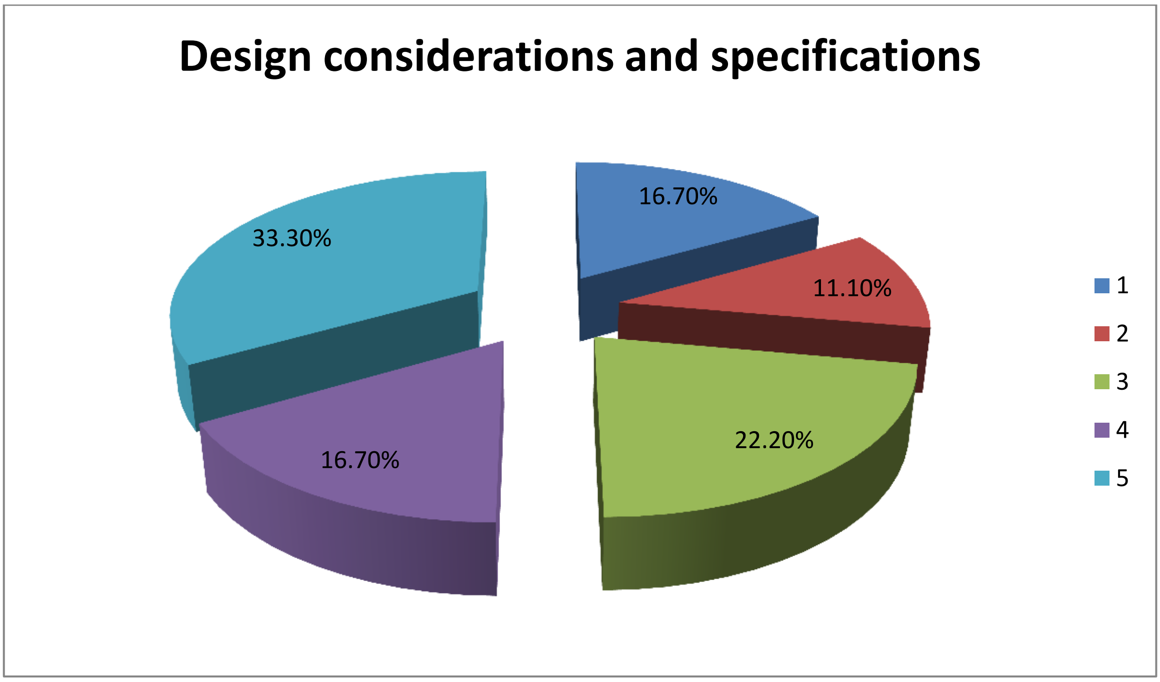


Figure 5.49 Question twenty three (E) results

Analysis

It is clear from the results of this question that the main barriers to reducing waste on site are the lack of a waste management policy and a lack of direction from site management. This highlights that there is a need for management to implement waste management strategies and it is also important that top level management guide the waste reduction process from the upper levels of management. Without this management support it will prove extremely difficult to implement good practice waste management. The next two biggest barriers are that there are no financial incentives and that waste is accepted as inevitable. These barriers can also be overcome by providing financial incentives and promoting the minimisation of waste through training and communication so that waste is no longer considered as inevitable. The design considerations and specifications were considered as the smallest barrier to reducing waste on site. However it is in this area that some of the biggest waste minimisation changes can be made. It is important that the design team consider waste minimisation from the outset so that the design does not impact negatively on waste production.

5.11 Conclusions

After analysing the information gathered during the survey it was possible to draw some conclusions about main contractors' attitudes towards waste management on Irish construction site;

- The environmental awareness of the respondents and the companies that they work for is quite high. All of the respondents recycle at home and all are motivated to reduce waste as part of their job. As well as this the majority of the companies have a waste management strategy in place. The majority of respondents also felt that their previous experience of waste management have been positive. This provides a good basis for the implementation of good practice waste management and minimisation.

- The majority of the respondents had received no training in relation to waste management. It is important that even at management level the correct training is provided so that management can pass their knowledge of waste management onto the site operatives. Regular training should be provided to all personnel involved with waste management. The majority also believe that a lack of training and knowledge of waste management is a problem within the industry.

- Only around half of the respondents have been asked to produce a waste management plan at the tender stage. However the majority have been involved in a project where waste management strategies were used.

- Not all of the respondents have asked sub-contractors and workers for feedback in relation to waste management. It is important that the workers are asked for feedback regularly as changes may need to be made to the waste management process.

- The majority of respondents state that their waste allowance at tender stage is zero to ten per cent while at construction stage the majority believe that the actual waste occurrence is between five and fifteen per cent. There is a clear difference here and any allowance for waste at the tender stage should be set as a target for the construction stage to achieve. Unfortunately the majority of respondents also consider waste as an inevitable by-product of the construction sector.

- Almost all of that respondents agreed that the main contractor plays an important role in reducing waste and in another question it was found that the majority believed that waste management was the responsibility of the main contractor or the sub-contractor.

- The barriers to waste management were found to be; poorly defined responsibilities, waste management is not a goal of the main stakeholders and the lack of waste management policy was preventing companies from implementing waste reduction measures.

- The majority of respondents believe that waste prevention and minimisation will be a major issue for the construction industry in the future and that there are currently financial rewards to be gained from minimising, preventing and recycling waste.

The survey has provided a good insight into the current attitudes of main contractors towards waste management in Ireland. The answers have given the author a snap shot of the industry and the information gathered has also been integrated into the text of this thesis. Through the use of the questionnaire and the case study an insight into the current practices and attitudes within the industry has been gained.

5.12 Summary

This chapter has outlined a brief analysis of the survey questionnaire used as part of the research methods for this thesis. The next chapter contains information on the case study used for this thesis and outlines the observations made on the visits to the site as well as the lessons learnt.

6.0 Chapter six – Study of a main building contractor in Ireland

6.1 Aims and objectives

The previous chapter outlined a brief analysis of the survey questionnaire used as part of the research methods for this thesis. This chapter contains information on the case study used for this thesis and outlines the observations made on the visits to the site as well as the lessons learnt.

This chapter will give an insight into the:

- The observations made and the possible solutions.
- Current and future recommendations for improvement.
- Desktop study of the drawings and specifications.
- Lessons learned as a result of the observations made.

6.2 Introduction

There have been numerous case studies carried out by WRAP in the UK on waste management practices on site but these only give an insight into good practice and not into current practices that may be causing damage to the environment. The case study for this thesis is seen as a good opportunity to develop an insight into the realities of the treatment of construction waste on a construction site in Ireland. The issue of waste management and the generation of waste is now becoming a more prevalent topic within construction companies and some companies are now developing waste management policies and plans in order to minimise the amount of waste being produced. Contractors are now beginning to see the benefits of waste management and are now setting targets for a reduction in waste. This shift in attitudes is occurring mainly in large companies and it is now going to be necessary for small to medium sized companies in Ireland to develop similar policies in order to comply with future legislative requirements and avoid the rising costs of landfill and waste management. It is now becoming necessary for construction companies to develop some form of environmental management system.

Previous studies in this field have suggested that a high rate of success can be obtained by implementing waste management strategies and this is one of the aims of the case study. It is anticipated that through the observations made during the site visits that Carey Developments can be advised on their future waste management requirements. This case study will report on the investigations carried out during the course of this thesis and will determine the lessons learnt and evaluate their practicality for their future.

6.3 Scope of the project

A partnership was developed with Carey Developments Ltd., based in Co. Galway and an analysis of their waste management practices was undertaken. The primary case study site was the development of a new convent in Lenaboy – Taylors Hill, Co. Galway where work commenced in March 2012. The case study allows the author to gain an insight into the realities of waste management on site and to gain a practical experience of the changes that could be made in such a company. As part of the study site visits were carried out regularly in order to make observations of current practice and to then report back to the main contractor on what possible changes could be made on and off site in order to implement good practice waste management and minimisation. This chapter outlines the observations made during a four month period and discusses the lessons learnt as well as the future waste management possibilities.

6.4 Methodology

A case study was used in order to apply the educational side of the thesis to a practical example. The case study assisted in gaining a better insight into the waste generation behaviours on site by both the main contractor and the sub-contractors. The case study provided a substantial quantity of information to this thesis. The case study allowed the author to gain real world practical experience on site, monitoring the generation of waste and providing solutions to the contractor. The aim of the case study is to help Carey Developments develop their waste management strategies and help them achieve their goal of producing a waste management plan in line with industry good practice standards.

6.5 The contractor

Carey Developments Ltd is a building contracting company which was established in 1998 by Paul Carey. The company's projects range from small renovations to multi-million euro projects. Carey Developments specialise in healthcare & industrial facilities, commercial, retail, institutional and educational developments spanning a diverse geographical area. The company prides itself in providing innovative project management techniques and solutions to complex construction projects.

6.6 The project

The project for the case study consists of the clearing of a site in Lenaboy – Taylors Hill, Co. Galway and the subsequent development of a new convent with 42 hotel type accommodation rooms, communal living and eating areas, an oratory and recreational rooms. The development also includes the construction of a car park, all ancillary works and site landscaping.

Picture 6.1 Overview of case study site

6.7 Review of site visits

During the course of the research for this thesis, seventeen site visits were made to the Carey Developments site in Taylors hill and during these visits observations and the general behaviour of the staff towards waste management was noted. Some of the more important observations involved; the type of waste being produced, the waste handling methods, the influence of construction programming on waste, the cost implications, the existence of training and communication methods and the human influence on waste management. Observations were made in relation to the waste management procedures, the contents of the skip and general waste handling procedures.

6.8 Current waste streams

Currently all the waste on site is disposed of into one mixed construction skip and sent for segregation and recycling off site by the waste management contractor. There is also a timber skip being used but this is not belonging to Barna Waste. From an early stage this timber skip was full and overflowing and timber waste was being discarded into the mixed waste skip. The main waste streams identified on the site that would be suitable for segregation are; timber, cardboard, plastic and metal. These four main disposed materials are the areas where segregation and waste management could be improved, the details of which are outlined below. Other current waste streams include insulation and concrete/ rubble waste.

6.8.1 Timber

The timber waste generated during the observation carried out for this thesis was generated from the formwork process and also pallet waste. Further timber waste occurred from packaging and work undertaken to make materials fit the required shape and size for use. Good planning by the formwork and carpentry subcontractor to make products fit with minimal modification and better care would have contributed to reducing waste. Waste timber generated on site was deposited in a mini skip (3 cubic yards) belonging to Careys that rapidly filled up. Once this skip was full it was not emptied and subsequently timber waste was deposited in the general waste skip. Problems with waste timber include the lack of segregation and the careless contamination of timber with foreign substances such as masonry or other waste as well as timber being left on the ground and subsequently being rendered useless and non-recyclable.

6.8.2 Packaging waste (Cardboard and plastic)

To date there has been some packaging waste and in the future during fit out packaging waste will increase. All packaging waste was disposed of in the general waste skip and it was generally intended for disposal once it had finished acting as the protection to goods during delivery and handling. Again, the lack of segregation meant that very little packaging was recycled and was mainly disposed of as general waste. Following the visit to Barna Waste it was found that some of this waste is recycled but a lot of it becomes unsuitable once it has been mixed with the general waste. In order for cardboard to be recyclable it must be clean and dry and plastic waste must be free from contaminants.

6.8.3 Metal

To date metal waste has been minimal but it is expected to increase as the project progresses. The metal waste to date has been made up of metal from reinforcement, steel off cuts from the installation of the drop ceilings and roofing off cuts. The metal waste was mainly derived from miscellaneous reinforcement off cuts and left over after the completion of the work. There was no metal scrap bin and any left-over reinforcement was disposed of along with the general waste. Metal waste from the roofing was due to off cuts and modifications made to metal roofing materials and flashings. Metal waste from the drop ceilings was due to the requirement to cut some metal lengths to fit the required modification. Valuable metal waste such as lead is retrieved by the roofing sub-contractor and does not contribute significantly to metal waste. Any remaining metal waste is disposed of in the general waste skip. It is anticipated that metal waste will increase due to the fit out of the mechanical and electrical fittings as well as from the final site clean-up.

6.8.4 Insulation

During stages of the observations made, a large portion of the waste in the skip was insulation waste. Some of this waste was of large sizes that could have been suitable for reuse. Insulation waste was also generated when the insulation materials were left behind once the job had moved onto a different area, this resulted in the materials being forgotten and over time they were damaged. A solution would be to gather the materials when the job is moving on or else to set up a central storage area for the material. During the visit to Barna Waste it was established that this insulation waste is currently not recyclable and is either sent to landfill or incineration. The manufacturer was also contacted in order to establish whether any take back schemes were available in Ireland but unfortunately there are none set up at present.

6.8.5 Concrete, blocks, rubble etc.

Currently on site the majority of this waste stream is used as fill on site which is good as long as no other waste is mixed in which contaminates it. The fill is being used to raise a low area of the site but unfortunately other waste is also being dumped here. Some concrete block waste and mortar waste is being produced through bad handling and poor storage. On one visit the mortar was going off quite quickly due to the warm weather but despite this full mortar bins were still being used. A solution would have been to use half bins so that the mortar would not go off. Concrete block waste was being caused by useable and sometimes full blocks being discarded during clean up as well as reworking and breaking out blocks to allow for the installation of building services.

6.9 Future waste streams

6.9.1 Plasterboard

Plasterboard is susceptible to damage during delivery, handling, storage and also once in place on site. If the sheet sizes are planned to minimise the number of off cuts then waste could be minimised. This could be carried out by the design team in conjunction with the plasterboard manufacturer and the plasterboard sub-contractor. Plasterboard waste should be collected from the work areas and deposited into segregated bins. Due to the size of the project there may be quite a large volume of plasterboard waste produced and it is important that this waste is segregated so that it does not contaminate other waste in the skip. As well as this Barna Waste only allow for up to 10 per cent of gypsum waste in a general waste skip so it is important to comply with this. Unfortunately no recycling facilities exist in Ireland for gypsum waste but Barna Waste can process and transfer the materials to the UK for reprocessing.

It is anticipated that as the Taylors Hill project progresses that packaging, metal and timber waste will increase and concrete/ rubble waste will decrease. It is important that forward planning is implemented in order to deal with these waste streams.

6.10 Waste recovery quick wins

The waste recovery quick wins for the case study site have been identified as; metal, plastic, cardboard, and timber. These four waste streams can be easily segregated on site and can save the contractor money; for example the metal skip will actually provide revenue for the contractor. The costs are outlined below;

- Cost of mixed C&D skip; €158/ tonne. (including the service charge)
- Cost of segregated timber skip; only charged a service charge @ €95 for the Taylors hill site* plus €50/tonne.
- Cost of segregated cardboard skip; only charged a service charge @ €95 for the Taylors hill site plus €32/tonne.
- Cost of segregated plastic skip; only charged a service charge@ €95 for the Taylors hill site plus €80/ tonne.
- Cost of metal skip; provided free of charge and revenue generated from sale of metal to recycling company.

*The service charge varies depending on the distance from the recycling facility.

If we take a simplistic example of a skip weighing four tonnes the cost savings are outlined below;

4 tonne mixed C&D skip cost = €158/ tonne plus service charge = €632 + €95 = €727

If we break this example down into, for example, four waste streams then the costs for segregating the waste is the following;

1 tonne timber skip cost = €50/ tonne plus service charge = €50 + €95 = €145

1 tonne cardboard skip cost = €32/ tonne plus service charge = €32 + €95 = €127

1 tonne plastic skip cost = €80/ tonne plus service charge = €80 + €95 = €175

1 tonne metal skip cost = Free of charge and may generate revenue.

Total cost of segregated skips = €447

Total cost saving versus mixed skip = €280

6.11 Site visit observations and solutions

The following are pictures taken on site which show the observations made during the site visits. Due to the large volume of pictures taken it is not possible to include all pictures but the most important aspects are outlined below. It is important to note that these issues were recurring issues throughout the observation period and a number of pictures are available to show each problem but some have been omitted for clarity.

It would be unfair to just focus on the negative aspects of site operations so the current good practice activities are shown first;

Picture 6.2 On-site crusher

Observation (Picture 6.2): An on-site mobile crusher was used to process rock on site. The material was then used as fill and also as sub-base material. Good practice ☑

Picture 6.3 Delivery of blocks

Observation (Picture 6.3): This is an example of good practice where the blocks are being delivered onto pallets or onto a dry stone sub-base. If blocks are delivered and set down on wet mucky ground, capillary action will cause the blocks to soak up moisture and upon installation cause the release of efflorescence on the blocks. The delivery driver is also not wearing a high visibility jacket or a hard hat. All persons entering the site must be instructed to wear a high visibility jacket and hard hat as well as safety boots. Good practice ☑

Picture 6.4 Mortar mixing silos

Observation (Picture 6.4): The use of these mortar mixing silos is good as it could reduce mortar waste on site. On one visit however the generator was running despite no concrete being mixed. The generator must be switched off when not in use. Good practice ☑

Picture 6.5 Importing fill material

Observation (Picture 6.5): Fill material was removed from another Carey Developments site and used on the Taylors Hill site. It is important that the fill material is clean material that is not contaminated with other waste. Good practice ☑

Picture 6.6 Window and door delivery

Observation (Picture 6.6): The window and door delivery and installation is taking place and the installers are taking back the bubble wrapping for reuse. This is good but is largely down to the choice of the installer on whether they want to reuse the packaging materials or not. Good practice ☑

Picture 6.7 Timber roof trusses

Observation (Picture 6.7): Timber roof trusses are being used on this project. The use of these trusses could speed up the installation process and reduces waste. Good practice ☑

Picture 6.8 Precast concrete stairs

Observation (Picture 6.8): The use of these precast stairs could save time, money and waste. Good practice ☑

Picture 6.9 Hollowcore installation

Observation (Picture 6.9): The use of hollowcore can be considered to be implementing off site construction. Good practice ☑

6.11.1 Practices that require improvement

According to previous studies carried out by WRAP the main causes of waste on site are;

- Over-ordering of materials and inaccurate estimates of the materials required.
- Damage caused to materials through incorrect storage or bad delivery practices.
- Off cuts produced because of bad construction practices and inefficient design.
- Change of design causing reworking of materials and waste.
- Temporary works such as formwork or site hoarding.
- Demolition materials.
- Contamination of clean waste.
- Packaging.

The practices that require improvement have been outlined below and grouped into waste streams;

Packaging Waste

Picture 6.10 Bitumen packaging

Observation (Picture 6.10): Beside the mobile generator is a pallet with rolls of bitumen on it. This is an example of packaging that has been over engineered. The cardboard boxes around the bitumen are unnecessary.

Solution (Picture 6.10): Consult with the supplier and manufacturer regarding take back schemes for the cardboard. Failing this the cardboard should be recycled.

* Please note that it is expected that packaging waste will increase during the fit out stages of the project.

Timber waste

Picture 6.11 Leftover pallets 1

Picture 6.12 Leftover pallets 2

Observation (Picture 6.11 & 6.12): There are numerous pallets left over after deliveries and sometimes when left lying around they became damaged and subsequently unusable.

Solution (Picture 6.11 & 6.12): Store pallets that are being unused and then return to supplier that supplied that pallet during delivery.

Picture 6.13 Roofing battens overruns

Observation (Picture 6.13): The roofing battens have very long overruns which were cut off and remained unused and consequently ended up as waste.

Solution (Picture 6.13): Use up cut lengths first before new lengths are used. Reuse off cuts wherever possible.

Picture 6.14 Slate crates and slate waste

Observation (Picture 6.14): The crates that the slates come in are wasted after one use and slate off cuts ending up as waste.

Solution (Picture 6.14): The crates that the slates come in should be 100 per cent reusable as long as they are carefully opened. The supplier should be contacted with relation to providing a take back scheme for these. Innovative solutions could also be made to use them for storing materials or for use as mini skips at the work face. The final option for these should be recycling. The slate off cuts can be used as fill material or saved up and broken into pieces for use during the landscaping phase in flower beds.

Poor storage of materials

Picture 6.15 Inadequate storage of sand

Observation (Picture 6.15): Piles of sand dumped on the ground will inevitably lead to the bottom foot of the sand pile becoming unusable through contamination and treading into the ground. Also in this photo the radon barrier is being improperly used to cover some cement bags.

Solution (Picture 6.15): Sand should be delivered onto either steel plates or a plywood base so that all of the sand remains usable and there will be no waste. The cement bags should be covered by the polythene bag supplied during the delivery.

Picture 6.16 Inadequate storage of stone

Observation (Picture 6.16): Piles of small stone such as this 804 sub base stone dumped on the ground will inevitably lead to the bottom foot of the stone pile becoming unusable through contamination and treading into the ground.

Solution (Picture 6.16): As the last point explained deliveries of sand and in this instance some 804 sub base should be delivered onto steels plates or a plywood base.

Picture 6.17 Poor storage of protection barrier

Observation (Picture 6.17): Poor storage of protection barrier leading to damage.

Solution (Picture 6.17): Correct storage is required. In this instance simply placing the sheet on the pile of sheets next to it would have saved it from damage.

Picture 6.18 Incorrect storage of topsoil

Observation (Picture 6.18): The storage of topsoil is far too high.

Solution (Picture 6.18): Topsoil should be stored at a maximum of two meters high in order to prevent damage to the cell structure of the topsoil.

Picture 6.19 Poor storage of materials 1

Picture 6.20 Poor storage of materials 2

Observation (Picture 6.19 & 6.20): The storage of materials in this container is inappropriate and should not be this untidy. Through bad storage valuable materials can end up being damaged and being rendered useless. An example from this picture is the toilet which is being stored on top of a plastic bucket; if this toilet falls it will break or chip and become unusable.

Solution (Picture 6.19 & 6.20): Keep all storage areas clean and tidy at all times.

Picture 6.21 Protection barrier damage 1

Picture 6.22 Protection barrier damage 2

Observation (Picture 6.21 & 6.22): Protection barrier left behind and subsequently damaged beyond use. As well as these two pictures there are five other pictures from around the site showing the same type of wastage.

Solution (Picture 6.21 & 6.22): Once work moves on from one area it is important that materials are gathered up and brought to the next area or stored for reuse.

Picture 6.23 DPC waste 1

Picture 6.24 DPC waste 2

Observation (Picture 6.23 & 6.24): Similar to the previous problem the DPC material was left behind as work moved on and was subsequently damaged and contaminated with mortar waste. It is unlikely that this material was reused.

Solution (Picture 6.23 & 6.24): Once work moves on from one area it is important that materials are gathered up and brought to the next area or stored for reuse.

Picture 6.25 Poor storage of concrete bags

Picture 6.26 Poor storage of concrete bags

Observation (Picture 6.25 & 6.26): Concrete bags left exposed to the elements and subsequently hardening and becoming unusable.

Solution (Picture 6.25 & 6.26): Store bags in a dry secure area at all times in order to prevent unnecessary waste.

Picture 6.27 Insulation materials damaged

Observation (Picture 6.27): Similar to the previous problems with the DPC and the protection barrier insulation was left behind as work moved on and was subsequently damaged and contaminated with mortar waste. There are numerous photos detailing this type of waste gathered during the observation period.

Solution (Picture 6.27): Once work moves on from one area it is important that materials are gathered up and brought to the next area or stored for reuse.

Picture 6.28 Equipment damage

Observation (Picture 6.28): Equipment left outside and stored incorrectly resulting in the subsequent damage to the lighting equipment.

Solution (Picture 6.28): Store all equipment in the storage containers or other secure areas when not in use.

Picture 6.29 Poor storage of protection barrier

Observation (Picture 6.29): There has been an attempt to protect the barrier from the elements but unfortunately it was not done correctly. The material has subsequently become wet and will require drying out before use.

Solution (Picture 6.29): The simple solution would have been to cover the material completely to prevent this from happening.

Picture 6.30 Poor storage of windows and doors

Observation (Picture 6.30): As can be seen in the picture; windows and doors are being stored beneath a loading bay on the scaffolding. In the event that blocks etc. are being loaded and something falls the glass will be broken and result in waste.

Solution (Picture 6.30): Store windows and doors in a secure location prior to installation.

Picture 6.31 Incorrect use of materials 1

Picture 6.32 Incorrect use of materials 2

Observation (Picture 6.31 & 6.32): Radon barrier being used to cover cement bags. While no a huge issue the radon barrier is now susceptible to damage.

Solution (Picture 6.31 & 6.32): Use polythene in place of the radon barrier.

Concrete/ blocks etc. waste

Picture 6.33 Material wastage 1

Picture 6.34 Material wastage 2

Picture 6.35 Material wastage 3

Observation (Picture 6.33, 6.34 & 6.35): There are a number of problems occurring in this picture. When this picture was taken it was quite a hot and humid day and the mortar was going off quite quickly. Despite the waste occurring full buckets of mortar was still being produced and subsequently wasted. The concrete blocks etc. seen in the photo are being used as fill which is fine; as long as they are unusable pieces, but it is important to avoid other waste materials being mixed with the fill as is happening here. Some of the blocks being discarded are also of sizes that could be reused and in some instances are full unused blocks. If the blocks are reusable then the fill being used here is going to be very expensive.

Solution (Picture 6.33, 6.34 & 6.35): During warm weather use half bins of mortar to prevent it from going off, avoid the mixing of other wastes with the fill and reuse all concrete blocks if they are still useable.

Picture 6.36 Concrete block waste

Observation (Picture 6.36): Some useable blocks being discarded with other concrete block waste.

Solution (Picture 6.36): Reuse blocks whenever possible and avoid discarding blocks that are over a half size.

Picture 6.37 Overfilling mortar bins 1

Picture 6.38 Overfilling mortar bins 2

Observation (Picture 6.37 & 6.38): Mortar bins are being overfilled and as a result waste is occurring due to overflow. Note also the insulation damaged as a result of inappropriate storage.

Solution (Picture 6.37 & 6.38): Ensure that bins are moved from under the silo before they overflow and ensure the correct storage of materials. There is no reason why that stack of insulation is in the place that it’s in.

Picture 6.39 Wastage of concrete 1

Picture 6.40 Wastage of concrete 2

Observation (Picture 6.40): Concrete delivered to site and dumped on the ground resulting in part of the delivery becoming unusable.

Solution (Picture 6.40): Place metal sheets or plywood on the ground so that all of the delivery becomes useable.

Picture 6.41 Wastage of concrete during delivery 1

Picture 6.42 Wastage of concrete during delivery 2

Observation (Picture 6.41 & 6.42): This problem took place a number of times and it happens during the delivery of concrete in between the buckets etc. being filled with concrete.

Solution (Picture 6.41 & 6.42): A simple solution is to place a plastic sheet on the ground so that the waste can be scooped up and used.

Picture 6.43 Concrete waste after delivery 1

Picture 6.44 Concrete waste after delivery 2

Picture 6.45 Concrete waste after delivery 3

Observation (Picture 6.43, 6.44 & 6.45): On a number of occasions concrete was left over after a delivery that could have been used in different applications.

Solution (Picture 6.43, 6.44 & 6.45): The concrete could be used to make manhole covers or other small concrete items that will be required later on in the project.

Picture 6.46 Hollowcore waste 1

Picture 6.47 Hollowcore waste 2

Observation (Picture 6.46 & 6.47): Hollowcore waste produced by the need to cut the hollowcore to fit.

Solution (Picture 6.46 & 6.47): Ensure that the correct sizes are ordered so that waste like this does not occur.

Picture 6.48 Cut window sill.

Observation (Picture 6.48): A number of pieces of cut window sill were observed during some of the site visits.

Solution (Picture 6.48): This type of waste is avoidable through the correct ordering of window sill sizes. Window sills should arrive on site made to the correct size so that cutting is avoided.

Metal waste

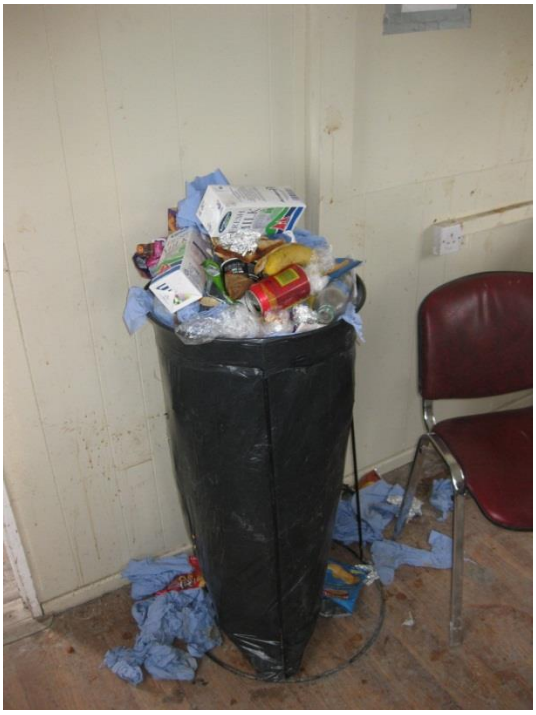
Picture 6.49 Metal waste 1

Picture 6.50 Metal waste 2

Observation (Picture 6.49 & 6.50): Metal waste made up of leftover reinforcement and metal ties used during the delivery of the reinforcement bars. Note also in the background the escalation of the dumping of waste in the ground.

Solution (Picture 6.49 & 6.50): A metal skip should be provided on site so that valuable metal waste can be segregated. A full size skip may not be needed but smaller skips are also available for this purpose. The waste being dumped in the background is unacceptable and unfortunately became a very common occurrence throughout the project.

Canteen waste



Picture 6.51 Canteen bin 1

Picture 6.52 Canteen bin 2

Observation (Picture 6.51 & 6.52): Canteen bins overflowing and the area is generally untidy.

Solution (Picture 6.51 & 6.52): Implement a clean as you go policy and empty the bins once full. Organise the cleaning of the canteen once a week.

Fly tipping of waste

Picture 6.53 Fly tipping of waste on site

Picture 6.54 Fly tipping of waste 2

Picture 6.55 Fly tipping of waste 3

Picture 6.56 Fly tipping of waste 4

Observation (Picture 6.53 – 6.56): In one of the more serious issues, waste is being fly-tipped on site. This was witnessed on a number of occasions and in once instance was being carried out by the site quantity surveyor. As well as fly tipping from the small skips on occasion waste was actually being taken out of the large skip and being placed in the ground.

Solution (Picture 6.53 – 6.56): This should be avoided at all costs and is a clear breach of the law.

Re-working

Picture 6.57 Walls built incorrectly

Observation (Picture 6.57): In the hallways of both the ground floor and the upper floor every door jamb required moving. This is a large amount of reworking and should have been avoided. The reworking leads to material wastage and also time delays as the work is revisited.

Solution (Picture 6.57): Ensure that walls are set out correctly prior to construction.

Picture 6.58 Breaking out to accommodate future work

Observation (Picture 6.58): Concrete broken out to allow for the installation of the precast concrete stairs. This may seem like a small problem but if all costs are considered it adds up. The costs involved here is the cost of installing the concrete initially, the cost of breaking out the material and the time lost through reworking.

Solution (Picture 6.58): Plan ahead so that issues such as this can be avoided.

Picture 6.59 Breaking out for services

Picture 6.60 Breaking out for services

Observation (Picture 6.59 & 6.60): In a number of areas throughout the building there was breaking out of block work occurring to allow for the installation of mechanical and electrical services.

Solutions (Picture 6.59 & 6.60): Forward planning could help avoid this situation and the use of a programme such as BIM could also contribute positively.

Waste caused by electricians

Picture 6.61 Electrical wire tails

Picture 6.62 Electrical wire tails

Observation (Picture 6.61 & 6.62): The tails left by the electricians were quite long and on a project of this size the waste produced can add up to a significant amount and due to the cost of electrical wire cost benefits can be achieved by minimising these tails.

Solution (Picture 6.60 & 6.62): Provide the electricians with training and communicate to them that tails must be kept to a minimum.

Carbon emissions

Picture 6.63 Mobile generator

Observation (Picture 6.63): When the generator requires refuelling it is important that it is done in a secure bunded area with a spill kit available if required. The generator was also sometimes running when not needed.

Solution (Picture 6.63): The area should be bunded and a spill kit should be available on site at all times. Ensure that the generator is switched off when not in use.

Picture 6.64 Volvo dump truck

Observation (Picture 6.64): On this site visit it was observed that this vehicle stood in the same position for well over ten minutes idling and not in use. This idle period burns valuable diesel and means that the diesel is essentially being wasted.

Solution (Picture 6.64): An idle reduction policy should be put in place whereby any vehicle that is idling for over three minutes should be turned off. This will save on diesel and other running costs.

Water wastage

Picture 6.65 Mobile water butt

Observation (Picture 6.65): Rather than filling the water butt from the mains water it may be possible to fill the butt with the use of rainwater harvesting from the site offices and stores.

Solution (Picture 6.65): A second water butt could be installed alongside the site office or other site building and could be used to gather rainwater. The water butts can then be swapped with each other when required.

Picture 6.66 Leaking water pipe

Observation (Picture 6.66): On a number of site visits this pipe was leaking water. While there is currently no financial cost incurred because metering of water has not started yet, in the future there may be a cost incurred because of wastage like this. There is also the environmental cost of wasting clean water needlessly.

Solution (Picture 6.66): Ensure fittings are secure and that the water pipes do not contain any holes.

Miscellaneous waste

Picture 6.67 Early stages of waste production

Observation (Picture 6.67): Despite the belief on site that no waste was occurring at the early stages of the project it can be seen here that even at the beginning waste is being produced. Waste in this picture includes; cardboard, plastic, timber and metal.

Solution (Picture 6.67): The segregation of waste must begin from the outset. Despite its small quantity it is still important to encourage on site segregation early on in the project.

Picture 6.68 Inappropriate use of materials

Observation (Picture 6.68): The use of pieces of the bituthene to hold up the protection board is an inappropriate use of materials unless the material used is an off cut.

Solution (Picture 6.68): The use of duct tape would provide a suitable solution to this problem.

Picture 6.69 Illegal dumping by sub-contractor

Observation (Picture 6.69): A sub-contractor decided to empty his car of unwanted documents onto the ground of the car park.

Solution (Picture 6.69): Monitor illegal dumping and if possible look through the documents for a reference name so that the person responsible can be reprimanded.

Picture 4.70 Untidy site entrance

Observation (Picture 6.70): The entrance to the site looks quite untidy and the footpath is being blocked by bollards and cones. The building adjacent to the site houses retired priests some of whom require the use of walking aids and wheelchairs to get around. Blocking the footpath like this impedes their ability to get around.

Solution (Picture 6.70): The entrance to the site is the first thing people see on arrival to the site and in order to provide a good first impression it should be kept neat and tidy. The footpath should not be blocked for any reason so as to allow free access to other users. Please note that this was subsequently fixed and in general the entrance to the site remained quite tidy.

Picture 6.71 Cleaning out waste 1

Picture 6.72 Cleaning out waste 2

Observation (Picture 6.71 & 6.72): This type of waste is inevitable but the issue here is the location of the waste piles. Throwing the waste just outside the door creates an uneven access area and when installing windows and doors for example the walking surface becomes unstable for those trying to negotiate it.

Solution (Picture 6.71 & 6.72): When cleaning out the building place waste into small bins and remove the waste from the vicinity.

Picture 6.73 Poor installation of materials 1

Picture 6.74 Poor installation of materials 2

Observation (Picture 6.73 & 6.74): The protection barrier has been installed but remains unsecure leading to waste and future rework.

Solution (Picture 6.73 & 6.74): Secure the protection barrier to the wall so that it is less susceptible to damage.

Picture 6.75 Drying room

Observation (Picture 6.75): The drying room is untidy and the dryer is on despite all the clothes being dry, the weather outside being good and the door has been left wide open.

Solution (Picture 6.75): Only have the dryer running when needed, keep the door closed and ensure that the area is kept neat and tidy.

Picture 6.76 Overflowing skips

Observation (Picture 6.76): The skips are overflowing leading to wind-blown litter around the site. Overflowing skips also lead to reduced disposal of waste and instead the waste ends up being fly tipped on the ground.

Solution (Picture 6.76): Ensure that waste containers are regularly emptied so that these problems are avoided.

Picture 6.77 Material wastage

Observation (Picture 6.77): Even though the wastage appears minimal it is still an instance of materials being wasted unnecessarily. The nails are left behind as work moved on and ended up getting wet and rusted. The nails were subsequently removed during a clean-up and discarded.

Solution (Picture 6.77): As work moves on, gather up all the materials and take them to the next stage or store them for reuse.

Picture 6.78 Insulation damage

Observation (Picture 6.78): Damage to insulation that was caused by poor striping of the formwork.

Solution (Picture 6.78): Formwork should be striped carefully so that damage such as this does not occur.

Picture 6.79 Efflorescence on block work

Observation (Picture 6.79): Efflorescence visible on some block work within the building. This is caused by the poor storage of blocks leading to water building up within the blocks caused by capillary action.

Solution (Picture 6.79): Blocks should be stored on pallets or on clean stones where possible. It is important to avoid areas such as muddy ground for the storage of blocks.

Picture 6.80 Plastic piping waste

Observation (Picture 6.80): The plastic piping waste on the left is ideal waste suitable for segregation because of its high recycling value. Also all the off cut lengths appear to be the same size so perhaps a different pipe length may be available from the manufacturer.

Solution (Picture 6.80): Order more suitable lengths if available and segregate plastic waste from the general waste in order to aid recycling.

Picture 6.81 Holes in the roofing membrane

Observation (Picture 6.81): Holes are visible in the roofing membrane due to careless walking on the roof surface. These holes can affect the air tightness of the building and contribute to heat loss. While this build is not to a passive standard, on a passive house build this would be a big issue.

Solution (Picture 6.81): More care should be taken by the roofers when traversing the roof. Any holes made should be patched up with air tightness tape.

6.12 Waste auditing

A skip audit book was used to access the quantities and types of waste entering the general waste skip on site. The dockets were filled in on each visit to the site and they give a good indication of the percentages of waste present in each skip. The audit dockets are attached in the Appendices of this document.

The following set of pictures shows the build-up of waste in each skip that has been transferred off site to date.

4th of April (Picture 6.82)

Picture 6.82 Mini skip 4th of April

Currently there is no large skip on site from Barna Waste so the moveable mini skip is being used. Even at this early stage waste is being produced and needs to be managed effectively. A skip should be on site from the outset of the project.

22nd of May (Picture 6.83, 6.84 & 6.85)

Picture 6.83 General waste skip 22nd of May

At this stage a waste skip has been placed on site by Barna Waste. To date the skip contains insulation, plastic packaging, paper packaging, plastic bands from blockwork, a small amount of timber and other miscellaneous waste. The large jump between dates is because there was no Barna Waste skip on site so it was not assessed.

Picture 6.84 Mini skip 22nd of May

The mini skip at the work face contains similar materials as the main skip. There is some concrete blocks in this skip which should be removed as they add a large amount of weight to the waste and can be used as fill on site rather than being sent to the recycling facility.

Picture 6.85 Mini skip with timber waste 22nd of May

This mini skip is being used to segregate waste timber which is good; however it is important that the plastic bands are removed from the skip to maintain the segregation taking place.

Summary of skip one *

Material	EWC Code	Percentage full
Insulation	17 06 04	50 per cent
Plastic packaging	17 02 03	16 per cent
Cardboard packaging	17 09 04	17 per cent
Plastic bands	17 02 03	21 per cent
Miscellaneous waste	17 09 04	15 per cent

Table 6.1 Waste in skip one summary

* Please refer to Audit sheet 0002 in the appendices for more details.

29th of May (Picture 6.86)

The general waste skip has been removed off the site today and a new skip has been left in its place. The skip does not contain any waste.

Picture 6.86 Mini skip 29th of May

As before the waste build up is familiar. The waste consists mainly of insulation, plastic packaging and the plastic bands from the concrete blocks.

1st of June (Picture 6.87 & 6.88)

Picture 6.87 General waste skip 1st of June

Within three days the skip has become over half full. The skip contains waste that is made up of mainly insulation followed by plastic packaging, some cardboard waste, DPC waste, plastic bands from the concrete blocks deliveries and metal bands from the delivery of lintels.

Picture 6.88 Mini skip 1st of June

The mini skip today contains waste such as DPC, timber and a piece of fire proof insulation. The DPC is a large piece that could easily be reused. There are also two pieces of protection barrier which have ended up in the skip because of poor storage.

5th of June (Picture 6.89 & 6.90)

Picture 6.89 General waste skip 5th of June

Very little waste has been added to the skip since the last visit. The pieces of insulation in the fore ground of the picture are all the exact same size. Perhaps it would have been possible to buy the insulation to the size required to prevent these off cuts.

Picture 6.90 Mini skip with timber waste 5th of June

The mini skip that contains the timber is now full and beginning to overflow. Of the three pallets in the skip two are easily repairable and thus reusable. The plastic bands have still not been removed from the skip.

8th of June

No pictures were taken today on account of extremely heavy rain. There was however no additional waste in the general waste skip.

13th of June (Picture 6.91 & 6.92)

Picture 6.91 General waste skip 13th of June

Since the last visit there has not been a lot of waste added to the skip. Waste added included more insulation, plastic packaging and a small amount of timber waste.

Picture 6.92 Mini skip 13th of June

The mini skip now contains additional waste such as insulation, plastic packaging and plastic bands from the concrete blocks. There is also some canteen and office waste in the skip.

19th of June (Picture 6.93 & 6.94)

Picture 6.93 General waste skip 19th of June

On today's visit there still has not been much waste added to the general waste skip. The clear bag contains mainly waste for the electricians. There are a number of large pieces of DPC in the skip that could be reused. The large piece of plywood at the rear of the photo should definitely not be in the skip as parts of it are still useable. Also due to the mini timber skip overflowing timber waste is being placed into the general waste skip.

Picture 6.94 Mini skip 19th of June

The mini skip has been emptied since the previous visit and it now contains mainly plastic packaging waste along with some plastic bands, insulation and DPC off cuts.

26th of June (Picture 6.95)

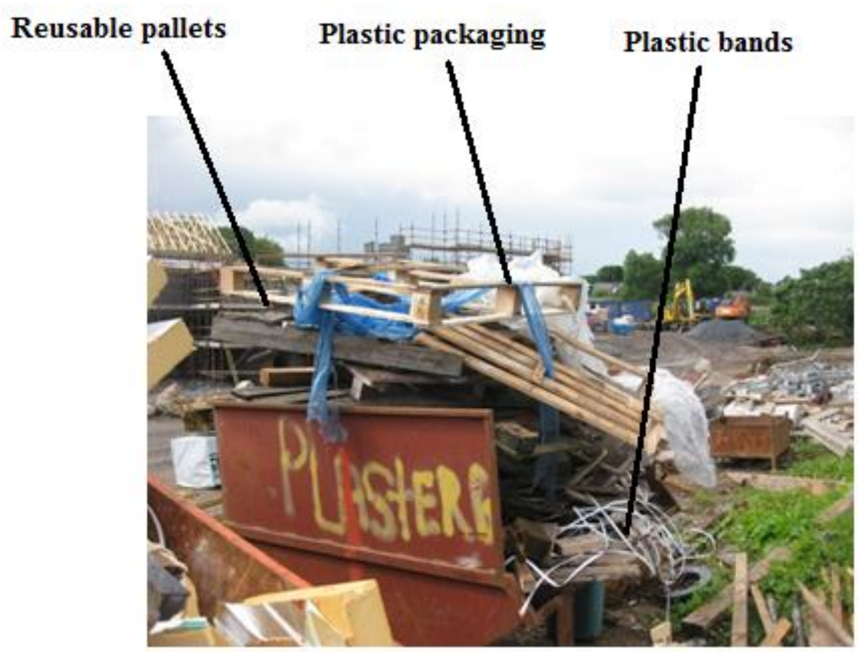
Picture 6.95 General waste skip 26th of June

The general waste skip on this visit was now full and overflowing. The majority if the waste added since the last visit has been insulation waste. Some of the pieces are of a size that they could be reused while others have ended up in the skip because they have been carelessly damaged. The mini skip was empty on this visit and the mini skip containing timber is also overflowing.

4th of July (Picture 6.96, 6.97 & 6.98)

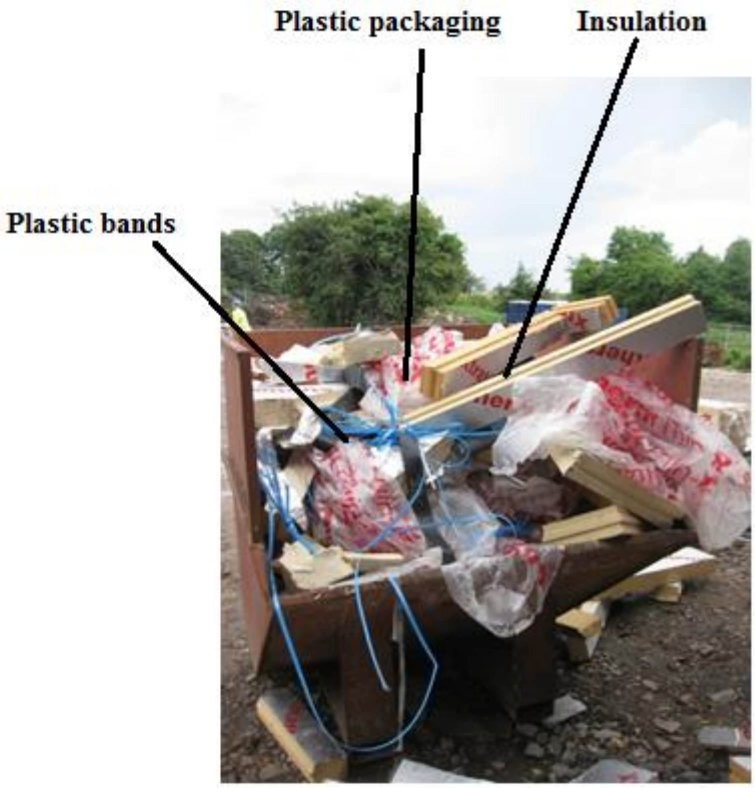
Picture 6.96 General waste skip 4th of July

Waste added to the skip since the previous visit includes insulation, cardboard, timber and plastic. The skip also appears to have been compacted which is good. All skips on site are now full and this has led to illegal fly tipping of waste taking place on site.



Picture 6.97 Mini skip with timber waste 4th of July

The timber mini skip is now very full and overflowing. There are a number of timber pallets being placed in the skip also. The plastic waste and plastic bands should be removed from the skip.



Picture 6.98 Mini skip 4th of July

The mini skip at the workface is also full and overflowing the skip contains mostly insulation waste along with plastic packaging and some plastic bands.

Summary of skip two *

Material	EWC Code	Percentage full
Insulation	17 06 04	60 per cent
Plastic bands	17 02 03	2 per cent
Plastic packaging	17 02 03	17 per cent
Cardboard	17 09 04	7 per cent
DPC	17 02 03	2 per cent
Timber	17 02 01	5 per cent
Canteen waste	17 09 04	4 per cent
Electrical wire waste	17 04 11	3 per cent

Table 6.2 Waste in skip two summary

* Please refer to Audit sheet 0003 in the appendices for more details.

12^{th} of July (Picture 6.99)

Picture 6.99 General waste skip 12^{th} of July

The waste skip today contains mostly insulation and plastic packaging. There is also some cardboard present and a filter of some kind from a machine. The fly tipping problem is escalating on the site. The mini skip on site is empty.

18th of July (Picture 6.100)

Picture 6.100 General waste skip 18th of July

Since the last visit the waste has been compacted and some waste has been added. Of note is the large sheet of insulation in the centre of the skip which could be reused. There is also a long length of gas pipe (yellow) that is reusable. There has also been more timber waste added to the general waste skip. The mini skip on site is still empty.

26th of July (Picture 6.101 & 6.102)

Picture 6.101 General waste skip 26th of July

Since the previous visit there has not been much waste added to the general waste skip. Waste added includes two bags of rubbish from the site canteen along with cardboard and plastic packaging. The pieces of insulation to the front of the skip are all the same size and are caused by off cuts. It may have been possible to order these materials to a different size in order to avoid these off cuts. The fly tipping of waste has continued on site and the majority of waste being dumped since the previous visit has been timber waste.

Picture 6.102 Mini skip 26th of July

The mini skip contains cardboard packaging produced by fit out work taking place in the sample apartment.

Summary of skip three *

Material	**EWC Code**	**Percentage full**
Insulation	17 06 04	63 per cent
Cardboard	17 09 04	20 per cent
Plastic packaging	17 02 03	6 per cent
Timber	17 02 01	5 per cent
Plastic piping	17 02 03	2 per cent
Canteen waste	17 09 04	4 per cent

Table 6.3 Waste in skip three summary

* Please refer to Audit sheet 0004 in the appendices for more details.

3rd of August

This visit was carried out by Dr. Mark Kelly in the absence of the author. The skip has just been emptied so it contains no waste.

10th of August

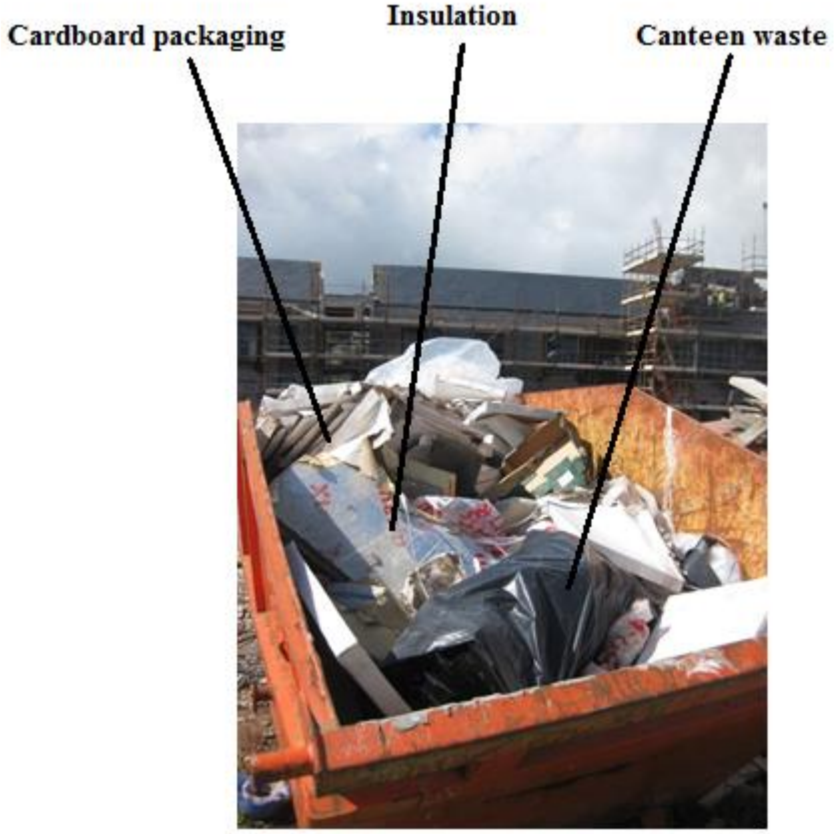
Site closed.

14th of August (Picture 6.103)

Picture 6.103 General waste skip 14th of August

This is a new skip and the waste trends seem to be changing. There is now not as much insulation waste and the predominant waste is plastic and cardboard packaging. Unfortunately the on-site fly tipping of waste has increased dramatically and this is contributing to the reduced amount of waste build up in the skip. The mini skip on site was empty and the mini skip containing timber waste remains in the same condition; overflowing.

22nd of August (Picture 6.104)



Picture 6.104 General waste skip 22nd of August

The waste added to the skip since the previous visit is mainly cardboard and plastic waste. As well as this some canteen waste has also been added. There are some large pieces of insulation in the skip which have been damaged due to poor storage and consequently have been thrown into the skip. This could have been avoided by storing the materials correctly. The mini skip used for waste was empty.

Summary of skip four *

Material	EWC Code	Percentage full
Insulation	17 06 04	52 per cent
Cardboard packaging	17 09 04	15 per cent
Plastic packaging	17 02 03	30 per cent
Canteen waste	17 09 04	3 per cent

Table 6.4 Waste in skip four summary

* Please refer to Audit sheet 0005 in the appendices for more details.

6.13 Comments

Waste streams vary depending on the type of construction and the construction phase but the main causes of waste identified during the visits were the following;

- Damage or wastage of materials by mishandling, weather and inadequate storage.
- Materials being left behind at the workface despite not being required and then subsequently getting damaged.
- Reworking due to incorrect setting out and allowing for building services.
- Lack of thought given to reusing off cuts in place of cutting new materials.
- No segregation of waste streams.
- Illegal fly tipping by the main contractor.
- Lack of training and communication with regards to waste management.

Although some workers seem to realise the benefits of reuse and waste minimisation there are no specific guidelines established within the work process, material planning, onsite training and methods of the effective reporting of waste quantities. The handling of materials and their storage is seen as crucial to the effective implementation of a waste management plan and the future aim of maximising recycling to benefit the environment and reduce disposal costs.

6.14 Current recommendations for improvement

The first step required is to eliminate all illegal fly tipping on site. This problem needs to be addressed immediately and this needs to come from top level management in order to ensure that this practice is stopped. This type of waste management is completely unacceptable and needs to be discouraged and prevented on this and future projects. Once this has been done it should be possible to start implementing the waste management plan and the solutions outlined in Chapter three of this thesis.

The current recommendations are to start to segregate waste and promote waste minimisation through better communication and training. The skip signage needs to be clear so that the user can identify the correct skip and more effort is required by all workers on site in order to achieve good practice waste management and minimisation. Currently it is difficult for the site foreman to implement waste management on his own due to his other duties on site so what is now needed is a waste champion on site that could visit the site once or twice a week in order to ensure compliance with the companies waste management policy. If this waste champion is somebody from the upper levels of management from the head office, for example, they may have more authority and influence on the construction workers compared to the site foreman.

Table 6.5 Initial commitment, targets and company policy

Task	**Current practice on case study site**	**Future possibility – on case study site**
Set a target for reducing waste to landfill and assign a team member with responsibility for delivery.	No	Set a waste reduction target and set out responsibilities.
Embed the target within corporate policy and processes.	No	Yes
Set requirements in project procurement processes and engage with its supply chain.	No	Consult with manufactures and suppliers re take back schemes.
Measure performance at a project level relative to a corporate baseline.	No	Set baseline levels to measure performance against.
Report annually on overall corporate performance.	No	Compile and publish annual reports within the company.
The overall objective should be to reduce the waste the company generates and manage waste as a resource.	Currently an objective of the company to develop waste management techniques and achieve ISO 14001.	Ensure that waste is treated as a resource and not as something that requires disposal.
Develop a waste minimisation policy.	As part of this thesis a waste minimisation policy will be developed.	Ensure the waste minimisation policy is implemented.
Allocate additional resources to bolster the environmental team.	No	Additional resources will be required both on and

		off site.
Carry out management training in order to instil the ideology of waste minimisation throughout the company.	No	Training and communication must become a cornerstone of the waste minimisation objectives.

Table 6.6 Construction stage good practice

Task	**Current practice on case study site**	**Future possibility on case study site**
Monitor and programme the construction activities.	Yes	Keep an accurate account of the construction programme.
Set up a performance based incentive scheme with rewards if targets are met.	No	Provide rewards to employees and contractors when targets are achieved.
In order to minimise the space taken up by compactible waste the use of space saving equipment such as balers could be used on site.	No	Yes. Barna Waste will collect these bales free of charge.
Use of good materials resource planning in order to minimise on site storage of materials.	Current system of Just in time ordering minimises storage of materials.	Storage of materials needs to be improved.
Place a ‘waste champion’ on site; this is a person who will deal solely with the waste management on site.	No.	Yes. This person needs to have authority to implement practices on site.
Engage with the suppliers to supply products and materials that use minimal or reusable packaging.	No.	Contact suppliers to determine the level of packaging used.
Hold regular meetings on site waste management.	Meetings are held but not on waste management.	Yes.
Ensure all necessary staff read and understand the waste management plan.	No.	All staff must understand their roles and responsibilities within the plan.
Place signage around the site to ensure locations of waste specific collection points are clearly marked for site operatives.	No.	Yes.
Consider a number of waste options for the waste that may be generated on site. These options should adhere to the waste hierarchy and consider minimisation, reuse, recycling,	Waste is currently taken away by Barna Waste.	Waste disposal should be the last option and other options should be considered first.

recovery and the final option of landfill disposal.		
Take back schemes should be established wherever feasible. Take back schemes are normally cost neutral or result in some cost savings. Take back schemes could be established for plasterboard, bricks/blocks, insulation and packaging.	No take back schemes in place.	Some suppliers were contacted as part of this thesis but the majority did not offer such a scheme. A secondary option would be waste recovery quick wins.
Any waste produced on site should be segregated into individual waste skips. This will produce a cost saving as the price for a skip with segregated waste is usually lower than if the skip contains mixed waste.	Waste is unsegregated.	A number of skips should be placed on site where feasible in order to segregate the waste. Use information posters to create awareness of waste segregation among the workers on site.
All waste containers should be clearly labelled and the appropriate signage should be put in place. Ensure that the distance from the workplace to the skip is not too great a distance.	No signage in place and skips are located a long distance from the workplace.	Yes.
Once the appropriate skips have been put in place it will be necessary to enforce the segregation of the waste. This should be done through the monitoring and auditing of the skips and other waste containers regularly to ensure that segregation of waste is occurring and will help the main contractor identify whether there is adequate compliance on site.	No.	Auditing and monitoring must be carried out be someone from head office in order to ensure impartiality.
It is important that the skips are regularly picked up and replaced by the waste contractor. An empty skip will encourage waste segregation, whereas if a timber skip, for example, is over flowing the subcontractor may revert to using the closest skip with space in it regardless of its contents.	Skips are regularly overflowing with waste.	Skips must be picked up and replaced regularly otherwise waste segregation becomes very difficult.
Carry out a periodic audit of the waste contractor to establish the movement of the waste once it has left the site.	No.	An audit of the waste contractor was carried out as part of this thesis.

The use of balers or shredders on site should also be considered. Materials such as cardboard or plastic could be compressed in order to save space. Theses bales can then be sent to a recycling facility.	No.	These bales can be collected by Barna Waste free of charge.
Incentives and rewards schemes could be introduced for when targets and KPIs are met on site.	No.	Yes.
Monitoring and reporting of the waste generated on site is extremely important. Waste quantities which were forecast should be compared to the actual waste generated on site.	No reporting taking place.	Monitor and measure waste generation and compare it to the waste forecasts.
The waste management must be regularly audited on site by an appropriate person, for example someone from the environmental department of the company. Following audits it is important to remove the blame culture as this will discourage the workers from achieving good practice waste management on site.	No auditing taking place.	Audits must be carried out regularly as waste management on site currently is poor.
Freezing the design at critical milestones during the construction phase can ensure that work is not unnecessarily undone.	Reworking taking place due to errors.	Yes.
If the cut and fill required on the project of carefully analysed then excavated material from one part of the site can be used as fill elsewhere on the site. It is also possible to use any excess excavated material as fill on other projects.	Yes.	Yes.
As the construction project progresses reviews should be carried out on each individual trade following completion of their works package and feedback provided to each trade.	No currently taking place.	These reviews can be kept on file and used for future procurement of sub-contractors.
Train and educate people about waste management and minimisation.	No.	Training to site staff via toolbox talks and induction.
Use materials with a recycled content where possible. The following products have the	No.	Recycled materials should be used wherever possible.

opportunity to use recycled content as part of their make up; sub-base and capping, materials used for fill, concrete, fittings and fixtures, asphalt, drainage products and topsoil. The use of materials can be cost neutral up to the use of 50% of recycled content materials. (WRAP, 2011)		
If wetting is required to keep down dust, consider installing water butts and recycling rain water for this task.	No water butts installed.	Yes.
Audit the waste carriers and treatment facilities to ensure appropriate licenses and waste treatment is being carried out.	No.	Auditing carried out as part of this thesis.
Order goods in economical quantities. This will reduce the number of deliveries and maximise the sending back of packaging waste to the supplier. Avoid over-ordering.	Materials are ordered correctly. No packaging waste is being returned.	Set up take back schemes for packaging where possible.
If plant maintenance is carried out on site, used oil shall be stored in a bunded area for collection. Oil and fuel filters should also be stored in a designated bin in a bunded area for separate collection and recycling.	No.	Yes.
Recycle materials that are already on the site into the building and use products with a recycled content or use more recycled materials.	Recycling of materials and materials with a recycled content are currently not given any preference.	Yes.
Look for a supply chain commitment to deliver materials to site that make it easier and safer to off-load and therefore avoid damage.	Materials are off loaded correctly. Some storage and handling of materials is poor.	Yes.
General mixed waste is the most difficult to segregate at source and different options for dealing with it should be considered. One option could involve waste being graded, and shredded, then dried and composted to produce a clean solid fuel (Refuse Derived Fuel), used in kilns which produce cement in a nearby factory.	No.	Barna Waste are currently in the process of developing facilities to produce RDF for export.

Materials should be stored carefully on site and out of the way of site traffic.	Storage of some materials is poor resulting in material wastage. Materials are being wasted due to bad storage and wet weather.	Storage of materials needs to be improved.

Table 6.7 Logistics good practice

Task	**Current practice on case study site**	**Future possibility on case study site**
Develop a logistics plan at the start of the project to ensure that consideration is given to material requirements through the construction phase, enabling efficient management of the delivery and storage of materials and ensuring that effective logistic methods are adopted.	Currently no logistics plan in place. Some storage and handling of materials is poor.	A logistics plan should be developed in tandem with the waste management plan.
Logistics techniques employed on site could be; just in time delivery, consolidation centres, take back schemes, fourth party logistics, site demand smoothing, integrated communication technology and reducing packaging.	Currently the Just in time method of delivery is being used.	The logistical techniques are site dependent and each one must be given consideration when planning for a project.
The main contractor should develop a materials handling strategy.	None in place. Materials handling on site can be poor.	Yes.
Placing a logistics specialist on site can achieve an improvement in logistical techniques. This person can receive the deliveries and co-ordinate the distribution of the materials around the site.	No.	Yes.

6.15 Future recommendations for further improvement

As the project progresses it is anticipated that the waste quantities will start to rise significantly especially in the area of packaging waste during the fit out stage. It is suggested that waste is segregated into the main waste streams, identified as; timber, plastic, cardboard/ paper and smaller skips for the segregation of metal and plasterboard. The plastic and cardboard/ paper skips will be required to be the covered type skip in order to prevent the recyclable materials from getting wet. It is also suggested that segregating the waste at the point of creation may be advantageous. The project is ideal for this type of segregation as centrally on both levels there is a large open area where small bins could be located. These bins should be clearly labelled and available on both levels. In order to achieve successful segregation additional time should be allowed for clean-up and that the clean-up is monitored and supervised if required. One problem that is envisaged is the argument that segregating the waste at the point of creation will require a lot of space for the various bins. However this is not applicable to this project because of the previously mentioned open area where bins could be located. As well as this it is debatable that additional space is taken up as waste stockpiles around the work area consumes space requirements and the space required for the placement of a waste bin is less than the area required to stockpile rubbish of the same volume. Mobile waste bins also enable waste to be handled more efficiently and they can be moved if required whereas a stockpile of rubbish will require a greater effort to be moved. The future requirements are similar to the current requirements as what is needed is the segregation of waste with clear markings on each skip to allow the user to identify the correct bin as well as more effort and common sense shown by the workers towards waste management and minimisation which can be instilled by additional training. While the success of good practice waste management will be difficult to implement at first it should not be seen as an insurmountable task. The London Olympics project recently showed that waste minimisation is possible on a large scale with 90 per cent of waste being diverted from landfill from all the construction and demolition projects taking place.

It is important that a waste strategy is now developed for the Taylors Hill site so that when waste increases at the end of the project, there will be a better chance to successfully segregate it. The waste strategy should consider the project specific opportunities, any constraints, the objectives and targets and the way in which the waste will be managed. Materials are a valuable resource and their wastage needs to be avoided. A waste management strategy has been produced for Carey Developments in order to achieve good practice waste management. Currently on site it is good that the waste is being diverted from landfill through the actions of the waste management contractor but the aim now should be to put processes in place that deliver results from the highest level of the waste hierarchy. These processes will include reusing materials in the highest application possible and recycling all waste that occurs on site. This can be done by increasing material resource efficiency by minimising the arising of waste in the first place and subsequently maximising the opportunities to re-use this waste. If the waste still cannot be reused then it can be recycled; this recycling takes place off site by Barna Waste. The final option for waste should be energy recovery while the sending of waste to landfill should be avoided if at all possible. Methods for monitoring and reporting the waste arising on site should also be set up so that the company's performance can be analysed and improved on if necessary. The appropriate tables and waste recording methods have been provided to Carey Developments so that they can achieve this goal. Waste data should be disseminated at the end of each project in order to learn and then further develop as a result of the project; lessons learnt should then be analysed so that future projects can be more successful in relation to waste management.

6.16 Desktop study of the design drawings

As part of the investigation into the possible waste reduction measures that could be undertaken on site, an analysis of the drawings was undertaken. The aim of this task was to identify areas where waste could be reduced, recycled materials could be incorporated and where the use of non-toxic building materials could be substituted. Normally a desktop study should be undertaken prior to the project going to site but in this instance the project has already started so the aim is to investigate areas where waste could be reduced as well as identifying other environmental concerns. This desktop study covers the area of waste reduction and also issues such as logistics, building toxicity and environmental issues.

Drawing No. 6035 - Site location map

- There are two schools situated close to the site with one of the schools located on an approach road to the site. It is important that delivery times are scheduled so that they avoid the school rush hour. In this instance it also becomes difficult as there is both a primary and secondary school located nearby. This means that the school finishing times are different, further complicating the issue of delivery times.

- The approach road to the site also causes problems as on one approach from Taylors Hill along Rosary Lane there is a narrow section with a tree growing in the middle of the road. Large trucks may find this difficult to navigate and the approach from the Salthill area is through a built up area. These issues should be taken into account in the logistics plan.

- Adjoining the site is the “Croi Nua” care home for retired priests. It is important that noise disruption is kept to a minimum along the site boundary and that noise is restricted to the times set out at the planning stage.

- The site in question is quite large and may require a large amount of fencing or hoarding. Site security might also be an issue due to access being available from a number of different locations.

Drawing No. 6001 – Site layout plan

- The retention of the mature trees, the existing boundary wall, the existing hedge and the installation of a rain water harvesting system are all examples of good practice.
- The installation of permeable pavements should incorporate the use of SUDs.
- The construction of the timber fence could incorporate the use of reclaimed timber or the reuse of timber from the site.
- The concrete footpaths should contain a recycled aggregate content.
- The stone facing on the front facing boundary wall could be constructed from reclaimed stone or stone dug up on site.

Drawing No. 6000 - Existing site survey

- The cut and fill required on site should be carefully analysed so that there is no requirement to export or import materials off site. The site contours range from 16m at the northern end of the site to 9.75m at the southern end of the site. The site area is quite large so there is plenty of space for the storage of topsoil on site.

- Any excavated rock should be crushed on site for reuse as sub base etc.

- All existing mature trees, hedges and boundary walls should be retained wherever possible.

Drawing No. 6002 – Lower ground floor plan

- The building design itself could be changed in order to reduce the possibility of waste occurring. The bottom half of the building (from Bedroom 25 – 32) is offset at an angle from the rest of the building. There seems to be no apparent reason for this and if built straight down it would minimise waste and maximise the space available in the off square rooms at the centre of the bedroom wing. The area to the top left of the drawing is also off set for no apparent reason. This could also be squared in order to minimise waste.

- The building design lends itself to the use of bathroom pods and also bedroom pods as the rooms are replicated over and over. In total there are 42 bedrooms with en-suites that could be constructed using pods. This would greatly reduce the amount of waste produced on site and also speed up the construction process.

Drawing No. 6003 – Upper ground floor plan

- Again this drawing highlights the possibility of using bathroom or bedroom pods on this project.

- The bay windows on the external façade of the bedroom walls may be an unnecessary architectural feature. Their addition does not extend the floor area of the bedrooms by much and as such are perhaps unnecessary.

- The curved wall in the oratory should be reconsidered as the installation of curved walls produced more waste then a straight wall. This wall may however be necessary as an architectural feature.

Drawing No. 6005 – Roof plan

The waste from the installation of the natural slate roof should be stored on site, broken down and then used as cover in flower beds. Waste should also be minimised through the reuse of off cuts and the appropriate handling of materials. The stacking of slates on the roof during times of high winds should also be avoided.

Drawing No. 6006 – Elevations Sheet 1

- The use of pre-fabricated roof trusses is an example of good practice.

- The sandstone cladding for the window surrounds should be manufactured off site as well as the Brise Soleill. The Brise Soleill should be manufactured in sections off site and then installed on arrival on site.

- The use of UPVC facia, soffit and gutters should be reconsidered and alternative materials such as aluminium should be considered.

- Lime render should be considered in place of mortar render.

- The glass for the balustrade should be specified to contain recycled glass content if possible.

Drawing No. 6007 – Elevations Sheet 2

- The sandstone for the cladding should be locally sourced where possible.

- The installation of solar panels is an example of good design practice.

- The curtain walling for the main entrance should be manufactured in sections off site and then assembled on site.

- The velux windows should be made of pine rather than composite materials.

Drawing No. 6008 – Building sections B & C

- The roofing battens should be untreated larch battens rather than treated softwood battens.

- The stone cills should be sourced locally and cut off site.

- The screed should be installed using the ‘easy screed’ system. This system produces less waste than the conventional screeding system.

- The chippings to be installed on the flat roof should be made from recycled aggregate and could be sourced from the site itself.

- The aluminium window cills should be manufactured off site and should be a ‘mill finish’ and remain untreated.

- The use of the precast stairs is an example of good practice.

Drawing No. 6009 – Building sections D, E, F & G

- The cut and fill should be analysed so that no material is required to be imported or exported off site.

- When constructing the suspended oak ceilings off cuts should be minimised due to the value of the material being used.

- The footpaths should be constructed to incorporate the use of SUDs.

- The in-situ concrete slab over the oratory should be reconsidered so that hollowcore or a precast slab could be used instead.

Drawing No. 6010 – Sections H-H

- The plasterboard off cuts should be minimised through good design and the installation techniques. Good storage is also required to protect the materials from damage. Any waste should be segregated and sent for recycling.

- Waste should be minimised when installing the zinc canopy and off site construction should be considered for this.

- The cut stone required should be sourced locally or contain reclaimed stone.

Drawing No. 6011 – Sections J-J & K-K

- Care should be taken during the installation and the storage of the glass balustrade on site. It should not be installed until all the heavy work has been completed.

- The cut roof will produce more waste during its installation compared to the trussed roof. The cold water storage tank seems to impede the use of a timber roof truss in this location. However if the cold water tank was constructed with a modular system then it could be constructed in-situ around the roof truss.

- All timber should be sourced from responsible sources and should be FSC certified where possible.

- The installation of pre-cast concrete lintels is an example of good practice and should be continued.

Drawing No. 6014 – Boundary wall details

- The timber for the fencing should be sourced from responsible sources and the use of creosote should be avoided.

- The stone facing for the front boundary wall should be made up of reclaimed or reused stone if possible.

Drawing No. 6017 – Typical bedroom fit-out

- The use of bedroom and bathroom pods should be considered across the entire project.

- On the kitchen floor if the space for tiling was 10mm longer than a half tile would be the only off cut required. This would greatly cut down on tiling waste.

- Similarly if the ceiling height was increased by 20mm the only off cut required would be a half tile.

- The use of mosaic tiles on the floor if the en-suite is good as the use of mosaic tiles reduces waste.

- The holes for the sink in the worktop should be cut off site and the sinks can then be installed on site.

- The installer or supplier of all the units should par take in a take back scheme for all the packaging. If not take back scheme exists then packaging waste should be segregated on site so that it can be recycled.

Drawing No. 6019 – Upper ground floor ceiling plan

The use of suspended ceiling tiles should be reconsidered as any waste produced through their installation is difficult to recycle. The plasterboard waste should be minimised during the design stage by the design team minimising the need for off cuts through the specification of appropriate sheet sizes. Any off cuts produced should be reused and all plasterboard waste should be segregated so that it can be recycled off site.

Drawing No. 6023 – Wall details 1

- It is important that the SIGA window tape is installed correctly in order to maximise the air tightness of the building.

- The window boards could be cut off site and then installed. The board should be wax finished rather than painted.

- The hardcore used on site should be made up of recycled aggregate preferably reused from on site as should the gravel material required behind the retaining wall.

Drawing No. 6025 – Internal details, fitted furniture

- All packaging should be removed off site by the installer or supplier through a take back scheme.

- Any tiling off cuts should be gathered up on the completion of one room and brought to the next room for reuse.

Drawing No. 6026 – Roof details 1

- The roofing battens should be untreated larch battens in place of treated softwood battens.

- The lead waste produced from the roofing installation should be gathered by the main contractor as this waste can generate revenue. It should not be permitted for the sub-contractor to take this waste off site.

Drawing No. 6029 – Internal joinery details

- The box out detail could be manufactured off site and then installed on site wherever it is required.

- Any packaging produced through the installation of the reception furniture should be removed off site by the installer or supplier. Alternatively it should be segregated for recycling off site.

- The skirting and architrave off cuts should be minimised at all times. The length of the timber should be considered so that for example on length of architrave is sufficient for one side of the door.

Drawing No. 6031 – Bins store layout

- The installation of a ‘brown roof’ could be considered for the bin store.
- A lime based render would offer carbon sequestration in place of a mortar render.

Drawing No. 6043 – Pedestrian and vehicular access

- The use of creosote should be avoided and the timber should be reclaimed or sourced from responsible sources.
- The stone facing should be sourced locally if possible.
- The galvanised steel on the gates should remain unfinished.

Drawing No. 6037 – Lower ground floor internal finishes schedule

- The use of vinyl floor should be avoided so that the emission of phthalates into the building is minimised.

- The matting for the matt wells should be cut off site so that no waste is produced on site.

- The issue of carpet off cuts needs to be considered. Will this waste be removed by the installer or will the waste end up in the general waste skip on site?

- The skirting should be wax finished rather than requiring four coats of paint.

Drawing No. 6040 – Sanitary schedule

All sanitary ware should be stored appropriately to avoid breakages and damage to the materials. It should be investigated to see if a take back scheme could be set up with the supplier or failing this waste should be segregated on site for recycling.

6.17 Desktop study of the project specifications

The following is a desktop study of the architectural specification document detailing the areas where it may be possible to reduce waste, incorporate recycled products and also the reuse of materials. The study also incorporates some environmental impact issues that should also be considered.

Part C - Demolition/ Alteration/ Renovation

Section 130

"Old foundations, slabs and the like: Break out in locations and to the extents stated." - Any old foundations broken out can be crushed by the on-site crusher and the material can be reused as fill material.

Section 230

"Arrange with the appropriate authorities for disconnection of services and removal of fittings and equipment owned by those authorities prior to starting deconstruction/ demolition." – This is good practice because the equipment will be removed by the authority responsible for it. This reduces the cost of disposing this waste for the main contractor.

Section 330

"Reduce airborne dust by periodically spraying deconstruction/ demolition works with an appropriate wetting agent. Keep public roadways and footpaths clear of mud and debris." - A water butt could be installed alongside the temporary structures on site and this harvested rainwater could be used for this wetting down requirement. It is also important to keep the footpaths outside the site boundary clear as they are used by people living adjacent to the site.

Section 510

"Components and materials arising from the deconstruction/ demolition work: Property of the Contractor except where otherwise provided." – Any materials arising should be first considered for reuse or recycling on site. The removal off site should then be the secondary option. Section 520 goes on to state that; *"Materials arising from deconstruction/ demolition work can be recycled or reused elsewhere in the project, subject to compliance with the appropriate specification and in accordance with any site waste management plan."*

Part D – Groundwork

Section 170

This section covers the removal of small trees, shrubs, hedges and roots. It is important that any mature trees on site are left in place where possible or else dug up and planted in an area which will be unaffected by the works. Any animal habitats should be also protected from any environmental impacts.

Section 225

Section 225 deals with the handling of topsoil. It is important that topsoil is not stored at a height of over two meters as this damages the cell structure of the soil. Waste should also not be mixed with the soil so that it remains uncontaminated and can be reused during the landscaping phase.

Part E - In situ concrete/Large precast concrete

Section 101

The specification given for the concrete is BS 8500-2. This specification does not allow for the inclusion of any recycled aggregate into the process. Concrete should be specified so that it contains a recycled aggregate content and also so that it has a lower carbon footprint.

Ecocem concrete can be specified with a recycled content of between 30 – 85 per cent and the most typical blend having 50 per cent recycled content.

Section 670

This section covers the transporting of concrete on site. It is important that this is done in an appropriate way so that no waste occurs through this process. Any container used should be free from contaminants and be suitable for the job it is required for.

Section 680

Section 680 concerns the placement of the concrete. It is important that the formwork does not contain any gaps or holes where the concrete can flow out. This type of waste must be avoided.

Section 120

"Formwork - Submit details for approval." – Formwork should be reused whenever possible and ideally should be a reusable type system rather than being made out of timber and plywood.

Part F – Masonry

Section 500

During laying of concrete blocks it is important that all block off cuts are reused where possible. Any block over a half size should not be discarded. Also ensure that mortar is not wasted unnecessarily through 'going off' due to lack of use or hot weather conditions.

Section 595

Lintels should be purchased at the correct size and should not require cutting in order to make them fit.

Section 110A

The rubble stone walling consisting of limestone should use reclaimed stone if possible. The use of virgin materials should be avoided. The Ashlar walling system should produce no waste as it should be constructed to size prior to installation on site. The use of this system is good as it prevents waste that would occur if a traditional stone walling system was being used.

Section 120

"Cavity base and faces, ties, insulation and exposed dpcs: Free from mortar and debris." – This is an important point but unfortunately it is not being carried out on site. Mortar debris is currently present on all the items listed above.

Section 155C and 155D

Kingspan Thermawall is specified as the insulation but the insulation being used on site is Xtratherm insulation. This is not a big issue but a manufacturer that provides a take back scheme should be chosen over one that doesn't.

Section 330A

Any useable sections of DPC offcuts should be stored for reuse and should not be discarded.

Part H - Cladding/ Covering

Section 115A

This section covers glazing and it is important that all glazing is handled and stored correctly in order to avoid damage as it is easily breakable.

Section 440

Section 440 states that the *"Design life of the curtain walling system: Not less than 30 years."* This is the design life of this system and following this it will either require a large amount of maintenance or replacement. The design team should consider the use of designing for deconstruction so that in the event that this system is removed or replaced that it can be done in a way that minimises the effect on the rest of the building.

Section 105

Any offcuts generated during the fitting of the natural roof slates can be either used as fill or they can be stored, broken into pieces and used for cover in flower beds during the landscaping phase. Slate waste should not be disposed of in the general waste skip. Any offcuts from the placement of the battens should be reused where possible or segregated into a timber waste skip for recycling. Batten lengths are only required to span three supports so even small offcuts can be reused. Care should be taken to prevent holes being put in the Tyvek sheeting. This reduces the air tightness of the building and any holes made should be patched with air tightness tape.

Section 615

Any waste arising from the installation of metal valleys should be gathered up and stored in a separate area. Waste such as lead has a high value when it comes to recycling and this waste can generate revenue for the main contractor. This waste should not be authorised to be removed by the sub-contractor. This also applies to the installation of lead flashings and soakers.

Section 630

Any offcuts from the plywood underlay should be reused where possible or segregated for recycling.

Section 110

Zinc waste should be collected for recycling as it has a recycling value and may generate revenue for the main contractor. It can be placed in a segregated metal skip if available.

Part J – Waterproofing

Section 470

The paving tiles used on the warm deck could be reclaimed tiles obtained through architectural salvage.

Section 475

The chippings could be chippings made from recycled aggregate either sourced on site or off site.

Park K - Linings/ Sheathing/ dry partitioning

Section 125A, Section 165A and Section 220A

Any waste left over from the installation of metal stud partitions should be segregated into a metal waste skip. Full lengths should only be cut when there are no offcuts available to complete the required task.

Section 401 – 410

All applications of plasterboard should focus on minimising the waste being produced. The design team should examine whether full size boards are available that would not require any cutting to fit. All off cuts should be reused where possible and gypsum waste should be segregated from the general waste.

Section 435

As above.

Section 505

All waste from mineral wool should be avoided. Any offcuts can be reused and waste should be minimal.

Section 680

There should be no wastage of skim coat plaster. Prior to mixing it should be assessed how much is needed to complete the works at that stage. Mixing too much should also be avoided because of the plasters tendency to 'go off'. Offcuts of the metal stops for corners etc. should be reused and full lengths should only be cut when no off cuts are available. Any metal waste should be placed in the metal waste skip.

Section 960

Timber waste should be minimised during the laying of the floating timber floors. All off cuts should be reused where possible and a full length should only be cut when necessary. Timber waste produced should be segregated into the timber waste skip. The design team could look at buying lengths of timber to suit the application that would avoid the need to cut boards.

Section 370 and 145A

As above.

Section 115C

The use of mineral ceiling tiles should be avoided as the waste produced is very difficult to recycle. Failing this a mineral tile with a high recycled content should be specified.

Part L - Windows/ Doors and Stairs

Section 115

This section is an example of good practice, it states; *"Timber (including timber for wood based products): Obtained from well managed forests and/ or plantations in accordance with: - The laws governing forest management in the producer country or countries. - International agreements such as the Convention on International Trade in Endangered Species of wild fauna and flora (CITES)."* And *"Documentation: Provide either: - Documentary evidence (which has been or can be independently verified) regarding the provenance of all timber supplied. - Evidence that suppliers have adopted and are implementing a formal environmental purchasing policy for timber and wood based products."* This is good practice and it timber should be continued to be sourced from well managed forests. If possible FSC certified timber should be used.

Section 410A and 480A

The windows are made up of Aluminium and wood which is also a good combination for the prevention of building toxicity. PVC should be avoided if a suitable alternative is available.

Section 330

The door frames and architraves should also be sourced from a sustainable source. Off cuts should be reused where possible. The design team should investigate the possibility of buying one long length of architrave/ door frame that would be long enough to do one door frame or one side of the doors architrave. This would help reduce wastage through off cuts.

Section 850

Could hinges be installed on doors prior to delivery on site?

Section 550A and 550B

All balustrades should be manufactured off site so that no waste is produced on site through cutting and fitting.

Section 510

Fall arrest system should be constructed off site and then brought to site ready for installation.

Part M – Surface finishes

Section 115A

Consider the use of 'Easy Screed' in place of a traditional screed system. Easy screed requires less thickness during installation and waste is virtually eliminated as only the required amount is mixed on site.

Section 620

Pre planning to the correct quantities should ensure that there is no mastic asphalt waste produced during installation. Re heated asphalt should not be used.

Section 130

Waste produced during the external render application should be minimised by providing a surface where the render can fall and subsequently be reused. During hot weather small amounts should be mixed in order to prevent the mortar from going off.

Section 200 and 710

As above. Consider the use of thin coat plasters for the interior of the building.

Section 830

Any metal mesh waste produced should be segregated into the metal waste skip.

Section 265

Could building paper be specified with a recycled content?

Section 110A and 110B

The design team should consider constructing the en suite and bathroom walls so that they suit the size of the tile. This means that no cutting would be required to the tiles in order to make them fit. The use of mosaic tiles is also an appropriate waste minimisation technique. Adhesive and grout waste should also be minimised. Tile spacers should be reused. Bring off cuts from one bathroom to the next for possible reuse – ensure batch codes are the same.

Section 130A

Carpet tiles are ideal for reducing waste but the off cuts need to be managed properly. Similar to the mosaic tiles if the room dimensions can match the tile then very little waste should occur. Waste material from carpet tiles or vinyl flooring should be retained in order to facilitate any required patching in the future.

Section M60

All paints should be organic based paints where possible. An effort should be made to use up half tins of paint. Other solutions can involve donating half full paint tins to charities, schools or local community development initiatives. The quantity of pain stored on site should not exceed 200 litres. Any paint spills that could affect the environment should be cleaned up immediately. Empty paint tins are considered as a hazardous waste and the appropriate disposal methods should be used.

Section 280

Wet paint signs should be reusable.

Section 711

Following application brushes and rollers should be cleaned or a system such as 'brush mate' can be used so that brushes and rollers are used multiple times.

Part N – Furniture and equipment

Section 310A and 320A

There should be no waste produced from the installation of timber units except the production of packaging waste. It should be investigated to see whether the manufacturer will participate in a take back scheme for packaging. Any packaging waste remaining on site should be segregated into the appropriate skip.

Section 340A

Worktops and counters should be pre-cut off site so that no waste occurs on site. Holes and openings for taps and sinks should also be created off site.

Part P – Building fabric sundries

Section 750

The empty containers left over from the application of mastics and fillers are considered as hazardous waste and should be disposed as such.

Section 110

The skirtings and architraves should also be sourced from a sustainable source. Off cuts should be reused where possible. The design team should investigate the possibility of buying one long length of architrave that would be long enough to do one side of the doors architrave. This would help reduce wastage through off cuts.

Section 200

The timber for the window boards should be sustainably sourced. It is possible that window boards could be cut off site in order to reduce wastage through off cuts.

Part Q - Paving/ Planting/ Fencing and Site furniture

Section 210

The wooden post fencing could be partially constructed or reclaimed timber or timber reused from on site. Site furniture could also be constructed of reclaimed timber.

Part R – Disposal systems

Section 321A

Facia, soffit and gutter off cuts should be minimised and reused where possible. Any waste should be segregated into the plastic skip on site.

Part Z – Building fabric reference specification

Section 380, 400 and 410

All metal waste should be segregated and placed in the metal waste skip.

Section 160

Ensure cement bags are stored correctly in a dry location so that it does not ‘go off.’

Section 630

The empty containers left over from the application of sealants are considered as hazardous waste and should be disposed as such.

6.18 Lessons learned

Anything that has been learned from previous projects and current projects whether successful or failures can teach a project manager and the entire team important lessons for future projects. Realising and then analysing the lessons learned from a project is the key for any construction company. Unfortunately sometimes it does not happen as the project team moves onto the next project and lessons learned become less of a priority. In order to ensure efficiency and development of good practice over time it is important to capture lessons learned on all projects no matter how big or small. By capturing, through hindsight, the lessons learned and turning that hindsight into foresight in order to develop good practice will help the company to achieve far greater long term success compared to simply ignoring what happened once a project ends.

Lessons learned from the Taylors Hill case study site include;

- Set out waste management and minimisation strategies and targets early on in the project. This can be done by the use of standard industry KPIs or KPIs developed by the company based on previous projects.

- Embed company targets within briefs, procurement documents and contracts. These targets need to be agreed with sub-contractors prior to work beginning on site and at the end of the project it should be assessed if these targets have been met.

- Develop and implement a site wide waste management plan. This waste management plan has been developed for Carey Developments as part of this thesis.

- Provide guidance on the implementation of the plan through training, communication and the use of existing industry tools. Training and communication tools have also been provided to Carey Developments during the course of this thesis.

- Establish effective processes in order to meet legislative requirements. These processes are outlined in Chapter three of this thesis.

- Develop ways to improve standard practice up to the level of good practice.

- Report waste quantities and lessons learned at the end of each project. Tools for reporting and estimating waste quantities have been provided to Carey Developments.

- In the future target the highest levels of the waste hierarchy, namely minimisation rather than relying on the waste management contractor to recycle the waste.

- Implement waste management early on during the design stage.

- Regularly monitor and audit the waste management techniques on site. An audit sheet has been developed for use by Carey Developments.

- Report waste arisings so that performance can be benchmarked, analysed and improved.

- Implement a waste management plan at the early stages of a project as this will help identify key areas where waste reductions can be achieved through resource efficiency and good materials management.

- The use of a waste management plan could stimulate the use of innovative technologies in order to achieve real cost savings.

- Implementing a detailed waste management plan means that waste issues are not forgotten and that each individuals responsibilities for waste management are clear.

- Liaising with the waste management contractor may allow the contractor to develop better waste management techniques and ultimately save money on waste management costs.

- The importance of a management buy in cannot be overly stressed. Without the commitment of the top level of management the waste management plan will end up as a paper exercise and become redundant.

- Waste management should become a topic at all meetings, site inductions and tool box talks where required.

- A waste champion on site or regularly visiting the site could act as a focal point for waste management on site and could provide the inductions and training required to sub-contractors.

- Off-site construction and MMC could have been used on this project due to the repetitious nature of the room construction. Bathroom and bedroom pods could have been considered.

6.19 Site waste audit sheet

An audit of a project provides the contractor with an opportunity to view issues and challenges encountered during the projects lifecycle. Audits should be carried out regularly, for example once a month and will provide an insight into what waste management practices are working well and what needs to be improved upon to achieve good practice waste management. The audit can also be used to develop success criteria that can be used on future projects. As a result, the use of a site waste audit will allow the main contractor to identify what it needs to do so that the same mistakes are not repeated on future projects.

This site waste audit sheet can be used when auditing a site for its waste management and environmental performance. Sections 1-7 will be used as a once off audit and Sections 8-15 can be used multiple times if more than one visit is carried out on the site. This site audit was carried out on the 14th of August during a visit to the site;

1. Project Information

Site reference number: CD 001
Date of audit: 14/08/12
Location: Taylors Hill, Co. Galway.
Name of site manager: James Skehill (QS) responsible for waste.
Name of waste champion: None in place.
No of workers on site: 20
Type of Project: Construction of convent.
Current project phase: Project is currently at roofing level with one example of an apartment completed.
Space limitations on site: Large site with no space limitations.
Value of project: €12,000,000
Main contractor: Carey Developments Ltd., Co. Galway.
Expected duration of project: 10 months.
Specific planning requirements: No specific requirements.
Is there an environmental plan in place: No
Is this plan being implemented: N/A
Is the project located in an environmentally sensitive area: No

2. Site waste management plan

Is there a site waste management plan for this project: No
Where is the document held on site: N/A
Are all staff aware of their duties in accordance with this plan: N/A

Who is responsible for updating the waste management plan: N/A

3. Staff training and awareness

Is there an environmental / waste specific notice board on site: No
Is there an on-site environmental champion: No

4. Transport

How many site vehicles are on site: 14
Do site operatives live locally: Some live in Co. Galway with others coming from further afield such as Co. Mayo
Is there a car share scheme in place: No, however some sub-contractors travel to work together
Are the suppliers local: Yes the majority of the building suppliers are local including the window manufacturer
How is the mechanical plant refuelled: Refuelled on site by an external fuel supplier from a tanker

5. Utilities and energy

Could energy efficiency be improved on site: Yes
Are there any targets in place to reduce energy usage: No
How are the site offices heated: Storage heaters are used in the site offices. A blow heater is used in the drying room and is often in operation despite the clothes already being dry.
Is the site office lighting and heating controlled: No
Is energy consumption monitored on site: No

6. Employee engagement

Are all staff aware of the environmental issues: No
Are staff aware of their duty of care towards waste: No, waste management is poor on site with a lot of waste ending up being buried in the ground
Are the staff aware of the SWMP and its requirements: No SWMP in place
Are there any barriers to training the staff: No, staff are available for training if required
Are staff made aware of waste during the site induction: No

7. General

Do the employees understand the effects of their actions on site: Seemingly not as waste is being buried in the ground and materials are being wasted
Are there any staff awareness campaigns: No
Is there an environmental team responsible for these issues on the project: No
Are environmental issues raised in the site induction: No
Are there toolbox talks taking place that cover waste management and minimisation: No

8. Current waste management

Is waste segregated on or off site: Waste is segregated by the waste contractor off-site
Are waste bins clearly marked: No markings on waste skips

9. Site housekeeping

First impression on approaching and entering the site: First impressions are good with a neat and tidy entrance and parking areas for cars. A concrete footpath is in place outside the site offices and the offices themselves are located in a prominent position
Condition of the on-site facilities such as the canteen and the toilet: The canteen is very messy with bins overflowing and waste scattered around. The toilets are filthy with no toilets sets in place and a sink that doesn't work
Conditions of the roadways on site: The roadways are in good condition today as it is dry but on wet days they become quite muddy
Condition of the hoarding or fencing around the perimeter of the site: Fencing is chain link fencing in good condition but parts of the site are missing fencing
Is the equipment storage space adequate: Yes
Is there any sign of fly-tipping on site: There is no sign of external fly tipping but the main contractor is fly tipping waste into a large hole to be buried, this has been on-going for a number of weeks
Describe the general tidiness of the site: Overall the tidiness of the site is good. The interior of the buildings is almost always neat and tidy but the externals of the site are not treated with the same care. Some storage of materials are poor and there are often valuable materials lying around that could be suitable for reuse on this project or future projects

10. Materials

Are the materials inspected on arrival on site: Yes; materials are checked for damage and whether or not they are the correct quantity
Are the storage facilities adequate, are they locked at night: There is adequate storage space and all storage containers are locked at night
Are materials off cuts re-used on the site where possible: Some off cuts are reused but off cuts from insulation and timber are often discarded without proper consideration

Is poor handling of materials causing damage to the materials: Yes; this issue is prevalent throughout the site on numerous occasions; Cement, mortar, blocks, timber, insulation as well as other materials are being wasted in large quantities
What is the level of stock held: The level of stock held is adequate as a 'Just in time' delivery system is being used
Is there evidence of damaged materials: Yes; as the point above on poor handling describes, materials are constantly getting damaged
Is there evidence of surplus materials: There is a lot of surplus insulation that is left behind once work has been completed in that area and these materials often end up getting damaged as a result
Does spillage occur when transferring materials: Some spillage of mortar occurs but only in small amounts
Can damage be avoided by improving storage and handling of materials: Yes; both the storage and handling of materials can be improved in order to avoid damage to materials
What has caused the most damage to materials: Poor handling, storage and undue care for the reuse of offcuts
Are materials being re-processed: Some materials such as timber are reused for shuttering while other materials are reprocessed through recycling off-site by the waste contractor
Are full size materials being cut to fit: Yes
Are there any fuels, chemicals, paints etc. stored on the site: Some paint tins are stored on site
Are these materials bunded, secure and labelled: Materials are secure and labelled but unbunded. However they are stored in doors in a secure area
Do quantities exceed 200 litres: No

Is there any fuel dispensing mechanism on site, is this bunded etc.: None on site
Are these materials stored away from watercourses and drainage areas: Yes
Is any of the machinery leaking: No
Is there a spill kit available on site: No but a spill kit is available on the fuel delivery truck if required
Is there any evidence of leakages on site: No

11. Packaging

Are there any specific disposal routes for packaging: Packaging is unsegregated and mixed in with general waste. The packaging is segregated by the waste management contractor and processed for recycling
Is the packaging separated for recycling: No, only by the waste contractor
Is there any ways of minimising the packaging on site: Yes, packaging could be minimised through consultation with suppliers and there may be a possibility of introducing take back schemes. Failing this plastic should be segregated to avoid contamination so that it is of good quality when being sent for recycling
Is the packaging over-engineered for its requirements: On some products it is. It is anticipated that plastic waste will increase during the fit out stage of the project
What happens to the packaging of the product: Packaging is mixed with the general waste and then sent for recycling to the waste contractor.

12. Equipment

Is the equipment on site in good condition: Yes
Is there plans to purchase any new equipment: Not at present for this project

Is there any WEEE generated on the site: Not at present
How is old equipment and WEEE disposed of: It is unknown how it would be disposed of but it is likely that it would be mixed in with general waste

13. Water

Is there any watercourses on the site or in close proximity: No
Are hosepipes fitted with triggers: No, some hoses are constantly leaking
Is there any evidence of run-off: No
Have vehicles or machinery been washed and has this run-off been contained: No vehicle washing has occurred on site during this visit or previous visits
Is the consumption of water monitored: No

14. Waste

How was the waste contractor chosen: Contractor was chosen due to cost
Can the number of skips used on site be reduced: Only one non segregated skip on site. It may be advantageous to the main contractor financially to increase the number of skips and carry out segregation of the waste
Is recycling carried out: No
Are the skips and bins clearly marked: No
Is hazardous waste contaminating 'clean' waste: All waste is mixed so hazardous waste such as paint tins and mastic tubes are contaminating clean waste

Is the correct amount of materials ordered as necessary: Yes
Are materials collected for recycling: Yes, the waste management contractor collects the waste and carries out the necessary recycling
Are there any other waste streams such as canteen or office waste: Yes both waste streams are in existence but only in small quantities
Are there recyclables mixed in with the general waste: Yes
Are the skips appropriate for the site: Segregation is required so more skips are needed
Are they emptied regularly: No, skips are sometimes overflowing
Are pallets recycled or re-used: Some are reused but others are discarded despite being useable
Is there any hazardous waste being produced on site: Not in any significant quantities
Is there waste documentation on site: Only dockets for the removal of skips off site
Is there a copy of the carriers licence on site: No
Is the site manager aware of his duty of care: It can be assumed that he isn't as waste is being buried in the ground despite the knowledge that site inspections are being carried out weekly by an external party

15. Conclusion

Opportunities for improvement:

Based on the visit for this audit the following improvements are needed;

- Waste needs to be segregated into the main waste streams prior to removal off site.

- A timber skip is an urgent requirement on the site.
- Fly tipping waste into the ground needs to stop immediately, this is completely unacceptable.
- Materials that are no longer needed at the workface, such as insulation, should be gathered and stored in a central area for future reuse.
- The crates that the roofing slates were delivered in could be reused for other purposes such as the storage of materials.
- Slate wastage could be broken down and reused for landscaping towards the end of the job.
- Breaking out of blocks is occurring to facilitate the installation of building services. This should have been planned for in advance.
- There is Efflorescence visible in a number of areas on the block work. This can be avoided by storing concrete blocks in a dry place off the ground in order to prevent absorption of moisture from the damp soil below. The Efflorescence should be removed prior to plastering.
- Window sills are being cut from longer lengths to fit. These should have been ordered to size in order to prevent cutting and subsequent wastage.

Barriers to overcome:

There is a lack of on site management input into waste minimisation and management on site. Waste is being allowed to be dumped into the ground and covered over and this point before any needs to be rectified before any other positive options for waste management can be considered. Once the site manager is on board then good practice waste management and minimisation will have a better chance of success on this and future projects.

Management process improvement needed:

As above, both senior and on site management must get together and set priorities for both waste management and its minimisation. Without this changes are very unlikely to happen as site operatives will not be motivated to carry out waste minimisation on their own accord.

Suggested actions:

Waste needs to be segregated and fly tipping of waste on site needs to be eliminated. Any waste currently in the ground should be removed and disposed of correctly. Waste management and minimisation needs to be implemented from the top down by top level

management as this way it will have the best chance of success. Future projects need to implement waste management plans as a minimum.
Additional Information: None

Signed: Jan Gottsche **Title:** Student – GMIT

Notes

6.20 Conclusions

It is clear from the observations made on site as part of this thesis that what is now needed is a clear and concise waste management plan that will be fully implemented and endorsed by ever worker on site. The reduction of waste, the correct segregation and the minimisation of waste will require close supervision but once policies have been implemented they should become part of the day to day running of the construction company and its associated projects. The introduction of good practice waste management may initially be viewed in a negative light but just as quality assurance and health and safety have become the norm on construction sites it is anticipated that waste management techniques will become completely effective. Generally people are willing to contribute positively to the environment but it may be difficult to change habits and culture initially. In a discussion with the on-site management team it was mentioned that the younger generation will be more likely and ready to accept waste minimisation and management techniques whereas the older generation working on site will be more difficult to convince. This shows that old habits may not go away quickly but over time good practice waste management will be successful.

Construction workers will need to be constantly trained and communication on site will be a key to achieving any waste minimisation targets. Another possibility would be to introduce contractual obligations with the introduction of penalty charges in the event of non-compliance. As well as this a system that promotes competition and enthusiasm towards waste minimisation and management using incentives may provide the necessary motivation required. The key element to the successful waste management on site is the involvement, commitment and perception of the construction operatives working on the site.

On examination of the skip contents it became apparent that there was a general disregard for throwing waste materials into the skip. Some of the materials placed in the skip were still useable and fit for purpose. The general waste skip also contained materials that could easily have been segregated with minimal effort in order to reduce waste costs. The difficulties of waste management and minimisation became apparent throughout the course of the site visits. It is extremely difficult for one person to oversee the compliance of waste management and to be in charge of running the site day to day so a waste champion is now needed to monitor the sites compliance to the company's waste management policy. The workers attitudes and current practices indicate that they could not be relied on to monitor themselves. During the observation period it was found that on site personnel are not utilised efficiently in the area of minimising waste production on site.

The question of reducing waste on the site can be interpreted in two ways; the waste creation process and the waste disposal process. The waste creation process currently shows a need to increase the workmanship skills on the efficient use of materials, tighter ordering of materials in order to reduce the wastage allowances and reducing the amount of packaging waste. These are areas that the main contractor, sub-contractor and the manufacturers need to address and if carried out successfully could lead to financial benefits. The waste disposal process observed shows that there is a requirement to segregate waste to allow for better recycling and that this segregation needs to be encouraged and monitored. Also of note was the fact that sub-contractors such as the roofing contractors are taking valuable waste materials, namely lead, home which results in a reduction of the amount of waste on site but leaves the main contractor with little value in the waste products.

From the observations made on the case study and the research carried out as part of the thesis it is clear that waste minimisation can be carried out quite easily once waste minimisation is considered at an early stage and is linked into the contract documents. The on-site segregation of waste and the reuse of materials are two of the most common methods that are adopted in order to minimise waste on construction sites. There is no reason why these two methods cannot be adopted immediately on the case study project. As well as this waste management and minimisation is seen as an ad hoc activity that does not form part of the core construction activities whereas eventually it is anticipated that good practice waste management and minimisation will become part of the day to day activities on site.

In order for Carey Developments to now move forward and implement a successful waste management plan there are two key areas that will require attention; these are training and process optimisation.

The training of workers on site is seen as a key component of the successful implementation of a waste management plan. It was clear from the on-site practices that training in the area of waste management is not being carried out and there is a lack of information provided to workers during the induction process. Poor comprehension and recall may also be attributing to the lack of commitment to the waste minimisation process. It is now suggested that training should be carried out to include a detailed explanation of waste management and minimisation that will be required on the site. This should be provided during the site induction and an emphasis should be placed on getting staff members involved in the process. Following the induction the worker could be asked to complete a brief questionnaire in order to establish their level of understanding and then will be required to sign a declaration that they will carry out waste management in line with company policy. As well as this self-monitoring can be encouraged by highlighting the benefits of good practice waste management and minimisation and outlining the ways in which a worker can contribute.

Process optimisation and the process of waste handling is also seen as a substantial issue as it affects the overall costs of the project and also will have a bearing on the success of the project once KPIs have been introduced. Costs will be minimised by reducing the handling and labour time required to deal with construction waste and the best option in achieving these reductions is to separate waste at the source of its creation. Training can encourage workers to source segregate but the appropriate facilities must be put in place in order to allow the workers achieve this. To facilitate good results as mentioned previously the bins should be placed in the large open area on each floor. These bins should be suitably identified by the correct signage and workers then have the opportunity to segregate their own waste which eliminates the need for a labourer employed by the main contractor to carry out this work. Costs will then be lowered because of the reduction in the handling of the waste as well as providing a cleaner and safer working environment.

Once the waste management plan has been implemented on site it is important that the progress of waste management and the associated targets are monitored through the collection of on-site data regarding the types and quantities of the waste being produced. This will enable the early detection of any problems that may arise and reduce the dependence of obtaining this data from the waste management contractor. The success of the waste management plan will also require the co-operation of all sub-contractors and site operatives in order to successfully plan material requirements and allow for the handling and appropriate storage of waste on site.

The two main stages of the project that have been identified as needing a major review in order for waste minimisation to be encouraged are the contractual stage and the construction stage of the project. During the contractual stage the client, main contractor and the design team play important roles in waste reduction through the incorporation of waste minimisation techniques through briefing and the use of contract tender clauses that would require a certain level of waste minimisation. The construction stage now requires a structured methodology that can be incorporated throughout this stage in order to minimise waste.

The following factors were identified during the observation period as areas where changes are needed in order to achieve good practice waste minimisation and management;

- The role of the site manager and the main contractor.
- A lack of partnership throughout the supply chain.
- The casual attitude towards waste taken by the sub-contractors on site.
- The lack of appropriate take back schemes for materials and packaging.
- Lack of interest in recycling and waste minimisation.
- The design and form of the building.
- Forward planning for waste minimisation.

It is good practice to produce a waste management plan but if this plan is not adhered to then its production in the first place becomes irrelevant. Once the plan is in place it is important that Carey Developments continue to implement good practice waste management and minimisation and that the waste management plan does not just become another document that will sit on the shelf in the office. The waste management plan is intended to be a practical document which will need to be constantly updated and its policies monitored on site. It is envisaged that good practice waste management and minimisation will become part of the day to day activities on site through good training and communication as well as forward planning in all aspects of possible waste production.

6.21 Summary

The site visits and the observations made during these visits have contributed to this thesis becoming a practical document. Through the visits it was possible to gain an insight into the reality of on-site practices and consequently the issues that now required attention. Through this experience the author has gained a practical knowledge of the day to day requirements of an effective waste management plan and through this learning experience a good practice waste management plan will be developed.

This chapter has investigated the practical side of the thesis and identified problems which have arisen on site. The next chapter will outline the market availability for the recycling of construction waste in Ireland and will show the path of the waste from site to the recycling stage.

7.0 Chapter seven - Recycling markets for construction waste in Ireland

7.1 Aims and objectives

The previous chapter investigated the practical side of the thesis and identified problems which have arisen on the case study site. This chapter contains information on the recycling and reclamation markets in Ireland as well as the barriers to having this market availability.

This chapter will give an insight into the:

- Government policy and legislation on recycling markets.
- Impact of legislation on recycling markets for construction waste.
- Market possibilities in Ireland.
- Environmental benefits of reuse and recycling.
- Embodied energy and carbon footprint of materials.
- Sourcing of reclaimed materials.
- Market availability of recycled materials.
- Possibility of take back schemes.
- Case study of Barna Waste.
- Journey of a skip from site to recycling.
- Barriers to market development.
- Incentives and disincentives of recycling construction waste.

7.2 Introduction

Ireland is faced with a problem of recovering construction and demolition waste and the markets to ensure that these materials are reused on a large scale are lacking (LIFE, 2004). In 2010 3.5 million tonnes of construction and demolition waste was collected in Ireland (EPA, 2010). The quantity of construction and demolition waste has decreased over the last number of years due to the economic downturn but when the construction industry restarts it is important that these markets are in place and available. Ireland is faced with a situation where we have to export our waste for recovery because there is no alternative in

Ireland (Forfás, 2003). Waste that is being exported from construction waste streams are cardboard, plastic, gypsum and metal waste. The recycling of waste can generate a significant amount of revenue for the recycling company; in recent years, for example, the average price of traded plastic for recycling exceeded €300 per tonne. This figure is higher than the price per tonne of coal, wheat or iron ore (EEA, 2012).

In general construction waste is collected in mixed skips and is sent to a recycling facility for sorting and recovery or is sent to landfill. With mixed waste it is possible that a large amount of the valuable recyclable materials in the skip will be contaminated on arrival at the recycling facility. A visit was carried out to Barna Waste in order to audit their waste processing facilities. During the Barna Waste visit it was found that if liquids or hazardous wastes such as paint and oil are placed in the skip then it makes the recyclable materials in the skip worthless. This results in a large amount of the material being incinerated or placed in hazardous waste landfills and thus wastage of large amounts of these materials. It also may lead to waste being illegally disposed of; An EPA report entitled, *'The Nature and Extent of Unauthorised Waste Activity in Ireland'* (EPA, 2005) states that there is significant evidence of mismanagement of the construction and demolition waste stream. During the review process for this report it was found that unauthorised activities relating to construction and demolition waste far exceeded that of the cumulative instances of all the other waste reviewed. For example 500,000 tonnes of soil was accepted at unauthorised facilities in 2001. The report also found that the record keeping on sites in relation to construction waste was poor and that the industry lacked the appropriate awareness about waste management (EPA, 2005). In order to reduce the landfill requirements for construction and demolition waste there is a need to develop a long term and sustainable recycling market in Ireland. This is backed up by the information gathered during the questionnaire for this thesis which showed that the majority of respondents believed that waste prevention and minimisation will be a major issue in the future.

Pongracz et al. (2004) state that the theory of waste is based on industrial ecology; The theory states that waste management is carried out to prevent waste that causes harm to human health and the environment, promote resource use optimisation and sustainability. Industrial ecology is a method of studying the material and energy flows through industrial systems. The construction industry can be modelled as a network of processes that extract resources and turn these resources into products that can be sold to meet the needs of humanity. Industrial ecologists are concerned with the impacts that these activities have on the environment through the depletion of the earth's resources and the subsequent disposal of waste. The aim of industrial ecology is to reduce the environmental impacts and contribute to sustainable development (Von Malmborg, 2004). If this theory is applied to the construction industry it incorporates waste generation, storage, collection, transfer, transport, processing and disposal in a way that takes into account environmental considerations.

7.3 Environmental benefits of reuse and recycling

Reusing construction waste is a method of waste reduction that can help extend the supply of resources, prevent high quality waste from being reduced to a low quality product and reduces pollution more than recycling (Ofori and Ekanayake, 2003). From the extraction of the materials, processing, component assembly, transport and construction to disposal construction materials will have an environmental impact throughout their entire life cycle. The environmental benefits of reusing and recycling construction waste can be significant and is a very important environmental management tool for achieving sustainable development (Ofori and Ekanayake, 2003). The environmental benefits are that there is a decreased consumption of natural resources from quarrying virgin materials, the diversion of waste from landfill through reuse and recycling, reduced energy usage when compared with extracting new materials and reduced global warming (Boone et al., 2010; Lauritzen, 1994 and Yuan et al., 2011). Guthrie (1997) states that recycling waste without scientific research could result in environmental problems that are greater than the waste itself; The development of new materials from waste is a complex task that includes environmental, marketing, financial, legal and social aspects. The construction sector has an important role to play in improving the environment by improving the performance of buildings and infrastructure. The industry produces products with a very long longevity the industry in in a position to support environmental benefits by not only reusing and recycling materials but also through design, specification of materials, siting of buildings and the operation of buildings post construction.

7.4 Market development initiatives

Following the publication of the government's policy statement *'Changing our ways'* the 'Task force B4 - Recycling of construction and demolition waste' was set up by the forum for construction industry in 1999. In the task groups' final report a number of issues were raised in relation to the recycling of construction and demolition waste. These were;

A lack of existing recycling facilities along with the recommendation that recycling facilities should be *"strategically placed where the practice is technically and economically feasible."* Currently the infrastructure has improved and recycling facilities are widespread across the country.

Limited facilities are in existence in Ireland along with the recommendation that *"urgent efforts should be made to establish the recycling infrastructure that has been identified as necessary in the statutory waste management plans."* (FCI, 2001)

As a result of this the Irish government set targets in the 'Changing our ways' document of 85 per cent recovery of construction and demolition waste by 2013. The targets set out by the EU in the Waste Framework Directive (2008/98/EC) are that Member States must by 2020 recycle 70 per cent by weight for construction and demolition waste. The DEMCON 20/20 project was an attempt to solve this issue and move towards reaching these targets.

7.4.1 DEMCON 20/20

The Life 98 ENV/IRL/000495 project, known as DEMCON 20/20 was initiated by Cork City Council and supported financially by the European Commission LIFE Environment programme. Initially the project was to have a length of 36 months but this was extended to four years. The project ran from 1st of November 1998 to 31st of October 2002. This project is a good example of waste management in Ireland that can be replicated elsewhere. It should be noted that this project only dealt with inert waste.

The projects aim was to set up a pilot plant that could be replicated elsewhere to process materials that consisted mainly of soils with an aggregate size of 50mm or less. The project also aimed to investigate the development of markets and recycle materials to help solve over reliance on landfills. The site chosen for the project was a former landfill site and the material recycled on site was to be used for various purposes on the landfill site, primarily to cap the landfill and create an amenity site and also outside the landfill site. During the length of the project 701,055 tonnes of inert material was received on the site and 636,488 tonnes of this waste was processed for reuse. This equates to almost 160,000 tonnes per annum (LIFE 98, 2003). The total cost of the project was 2.33 million euro. The project demonstrates that recycling of materials on a large scale is possible in Ireland and is a good example of a successful recycling facility.

7.4.2 Rx3 – Rethink, Recycle, Remake

A market development group was developed by the Department of the Environment, Heritage and Local Government (DoEHLG), now the DECLG, in July 2004. The group is in charge of developing recycling markets in Ireland in line with the commitment set out in the policy document, 'Delivering Change' (2002). The primary focus currently is on paper, plastics and organics but there are plans for studies on other recycled materials from different waste streams. In 2008 the department appointed RPS as the market development programme implementation team (MDPIT) and in 2009 the MDPIT was re named as Rx3 – Rethink, Recycle, Remake. The Rx3 group is tasked with managing and delivering the 'Market development programme for waste resources 2007 – 2011.' Currently the group is working on a number of projects to develop markets for recycled materials in Ireland.
In a report published by the Rx3 group entitled, *'The Irish recycled plastic waste arisings study'* it was found that while plastics make up only a small percentage of construction materials, the lifespan for these materials is often several decades. The amount of plastic waste collected in construction waste was estimated at 26,462 tonnes in 2011 (Rx3, 2011). This figure was generated by using the total quantity of construction and demolition was collected in 2011 (1,323,117 tonnes (EPA, 2010)) to which a 2 per cent plastic content was applied. The report also found that a lot of the construction waste collected for recovery ends up being sent to landfill because it is contaminated, of poor quality, a lack of markets for the product and an insufficient separation process.

7.4.3 Market development programme for waste resources 2007 – 2011

The market development programme aimed to reduce our dependence on overseas recycling and helped to promote recycling of waste in Ireland. The group identified barriers to the reprocessing of waste in Ireland and focused specifically on three waste streams, namely, organics, paper and plastics. The programme was prepared by RPS and identified existing markets and strategies to address the barriers that were identified for the three waste streams. The group also expanded the co-operation between North and South on developing markets for recycling waste. The following diagram from the report outlines the potential reuses of some construction materials;

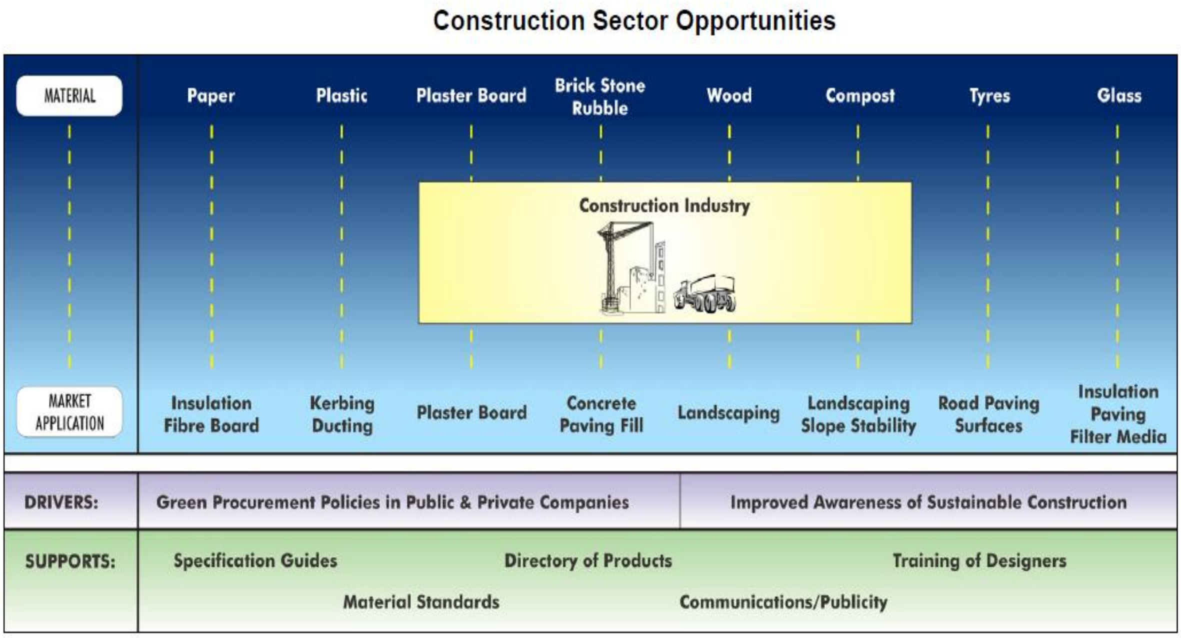


Figure 7.1 Construction sector opportunities for recycling (Source: DoEHLG, 2011)

7.4.4 FÁS and CIF

A handbook for contractors and site managers was produced by FÁS and CIF entitled *'Construction and demolition waste management.'* In the handbook there is a section on recycling markets for construction and demolition waste. The handbook outlines the constraints on the use of recycled construction waste which includes; statutory controls, poor feedstock guarantees, the high level of investment required, environmental concerns, market conditions, lack of appropriate standards, uncertain flow of recycled aggregates and poor segregation at the waste source (FÁS, 2002).

The document goes on to state that it is necessary to develop waste infrastructure in Ireland to produce substitute products for the construction industry. The perception of the recycled products must also be changed; the current attitudes that recycled materials are of lower quality and more expensive needs to be reversed. Developing significant long term markets will be vital to establishing a construction waste recycling industry in Ireland.

7.4.5 Market development outside Ireland

In 2010 the market for recycled construction materials in Europe was €744.1 million and this figure is estimated to reach €1.3 billion by 2016 (Frost and Sullivan, 2011). The report found that in an effort to reduce the industries dependence on virgin materials improved methods of recycling and reusing materials are being adopted. For example, in Europe, in 2010 56.2 per cent of plastic waste from the construction industry was diverted from landfill through recycling (20 per cent) and energy recovery (32.6 per cent). This was an increase of 4.3 per cent over the 2009 figures (Plastics Europe, 2012).

In the UK the ‘Halving waste to landfill’ commitment was designed by WRAP to support and encourage the construction sector to reduce waste. Since its launch in 2008, over 600 companies and organisations have signed up. Signatories of the initiative are required to set targets for waste reduction, set a baseline from which to measure this target and embed the target within the corporate policy of the company.

In a number of countries across Europe there are regulations in place regarding the reuse of construction materials. These regulations assist in the development of recycling markets in these countries. In Germany the “LAGA” technical rules govern the use of material from waste and mineral by-products, In France there are regulations for the disposal and re-use of waste in road-based applications, In Denmark regulations are in place for the recycling of residual products and soil in construction, In Italy there are regulations for the re-use of construction waste based on technical parameters, In the Netherlands the Building Material Decree – BMD covers the reuse of waste as a raw material and in Belgium the regulations are based on the BMD regulations from the Netherlands (Chateau, 2007).

7.5 Practical examples

7.5.1 Plasterboard

A joint project between the UK Environment Agency and WRAP produced a quality protocol for the recycled gypsum from plasterboard waste. The Protocol sets out the end of waste criteria for the production and use of recycled gypsum. The aim of the protocol is to increase market confidence in the quality of products made from recycled gypsum waste and encourages recovery and recycling. The use of the protocol means that gypsum loses its waste tag once it has been recycled to an agreed standard. This in turn boosts the recycling markets for the recycling of gypsum. PAS 109 was also developed by WRAP with the British Standards Institution and provides a specification for producing recycled gypsum of a consistent quality from waste plasterboard.

7.5.2 Timber

In 2012 WRAP and the Wood Recyclers Association in the UK developed a specification that sets out the quality requirements for wood recyclers that sell their products to markets that use recovered wood. The specification is PAS 111 and is the first specification of its type. Potential customers can now be certain that the recycled wood they are purchasing is of a consistent and verifiable quality. The specification increase the confidence among the end users and specifications of this type will drive the growth of the recycling markets. This in turn helps to divert more waste from landfill into recycled products or energy recovery.

7.5.3 Plastic

The British Standards Institution has developed PAS 103 that classifies and grades the quality of waste plastics intended for recycling. This system improves the quality of plastic waste being collected and therefore the value of the material increases and the markets for the recycled waste will expand.

7.6 The impact of legislation on recycling markets

The revised waste hierarchy set out in the Waste Framework Directive 2008 (Article 4) places ‘preparing for reuse’ and ‘prevention’ above other methods of waste processing. Both of these methods are classed as ‘reuse’. However the revised legislation outlines certain waste processes such as crushing blocks and chipping wood that are no longer considered to be recycling and have been downgraded to disposal. This could have an effect on the EPA reported recycling percentages as the crushing of blocks and concrete makes up a large percentage of the construction waste recycling that takes place in Ireland (EPA, 2010). To date in Ireland waste policy for the construction industry has mainly been focused at reducing the amount of waste being sent to landfill through recycling and what are needed now are policies that relate to the reuse of materials.

There are two methods that could be used by policy makers to encourage the use of recycled materials in construction, namely; Imposing taxes and providing subsidies. Economists such as Pearce and Turner (1990) and Lesser et al. (1997) see the introduction of additional taxes as a way to minimise the negative impacts caused by extracting construction resources. Imposing additional taxes on landfill and the use of primary materials will increase the costs involved and may encourage contractors to avoid landfilling and choose recycled materials. Sloman (2000) and Shoegren at al. (2001) found that policy makers can also encourage the use of recycled materials through the use of subsidies. Subsidies could be offered to those using recycled materials and disposing of their waste at recycling centres. This would result in a lower cost of using recycled materials and also lower the costs of bringing waste to a recycling centre. Care should be taken however when implementing a tax such as an aggregate tax, the British Aggregate Association reported in 2004 that the UK aggregate levy has failed to deliver environmental improvements and in fact it is damaging the environment. The report states that spoil heaps are environmentally intrusive and are caused by diverting demand away from primary materials (BAA, 2004). It is important that aspects such as this are thought through prior to any decisions on an aggregate tax.

7.7 Standards in Ireland

The National Roads Authority Ireland has a number of standards in place for the use of recycled aggregates on road projects in Ireland. The standards include specifications for the use of recycled aggregate in the road base and in the structural concrete. As well as this the NRA also have a guideline on the management of waste produced on national road projects. The European Committee for standardization (CEN) are responsible for developing standards for the construction industry. European Standard IS EN 206-1 relates to the use of recycled aggregates in concrete production and this standard is currently in place in Ireland. Other standards include EN 13285 and EN 13242 which relate to unbound mixtures.

While there are standards in place for recycled aggregates, standards in other areas are lacking. The development of standards for recycled materials will greatly improve the market confidence of the products reliability and consistency. The current lack of standards within the industry prevents the potential market growth of recycled products.

7.8 Market possibilities in Ireland

Duran et al. (2006) developed a model to investigate the viability of recycling centres in Ireland, in Dublin, Limerick and a mobile recycling centre. Data was collected and recycling costs were estimated based on a number of assumptions. The results found that these recycling centres are economically viable and these centres would benefit from economies of scale, i.e. the larger the centre the cheaper the disposal costs. When a recycling centre is placed close to an area with a large population, the higher demand for recycled materials would result in lower costs and thus enabling the operator to charge lower prices (Duran et al, 2005).

It should be noted however that this paper was developed in 2005 and the market conditions due to the economic downturn may not be the same as during the research period of the paper. It is now important that when the industry comes out of recession that the appropriate facilities are in place so that construction waste can be processed for recycling. There are also other numerous market possibilities such as architectural salvage that can be used to lower the amount of waste produced by the industry.

7.9 Why reclaim materials?

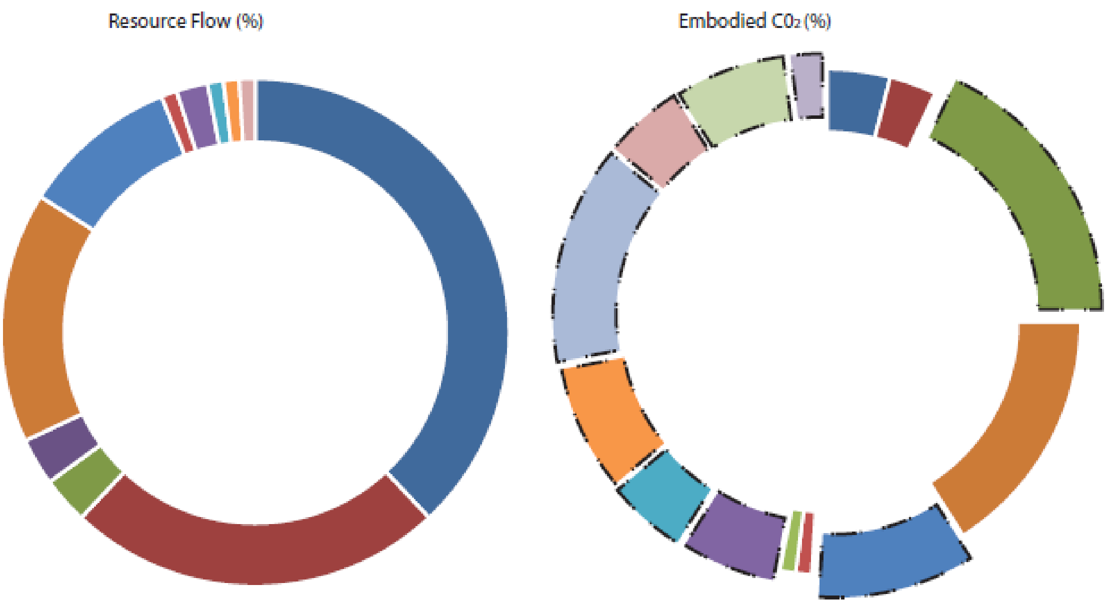
Lazarus (2005) and Lazarus and Hillary (2006) outline the benefits of reclaiming and reusing as opposed to sending waste to landfill. It was found that up to 95 per cent of the embodied impact of materials can be saved through good reclamation practices. If waste or surplus materials are reclaimed then the need for new products or materials needed to replace them is eliminated. This is turn lowers the energy required in the manufacturing process, lowers carbon emissions as well as the ecological footprint which would have occurred by manufacturing new products. As well as this the need to send waste or materials to landfill is reduced. Kay and Essex (2008) state that reclaiming materials for reuse should be chosen ahead of energy generation from waste as this involves an energy intensive process and then the requirement for new materials to be produced to supplement the materials that have been used for energy production.

7.10 Embodied energy and carbon footprint

Embodied energy and carbon foot printing are two topics of growing interest within the construction industry. A considerable amount of energy is used in the manufacturing processes and the subsequent transportation of the materials. Conserving or minimising this energy will help to reduce greenhouse gas emissions and reduce the cost of the materials (Reddy and Jagadish, 2002). Embodied energy is the energy associated with the extraction, transport and processing of the construction materials or components required to construct the building. The energy used comes mainly from the use of fossil fuels to heat and power the production processes and the subsequent transport of the materials. Also included in the embodied energy is the energy required to demolish and remove the structure at the end of its life. Embodied energy and carbon foot printing are closely related. Embodied energy can be used in the context of materials whereas the carbon footprint extends to the energy required to heat and light the building following its completion. The embodied energy is particularly important in construction as it represents the most significant proportion of the whole life impact of the building (Monahan and

Powell, 2010). A lot of work has been carried out in the industry on quantifying the embodied energy in construction by consultancies such as Davis Langdon and Carbon8.

When considering the benefits that could be achieved by increasing reuse and reclamation habits then the materials that have the highest environmental impact must be considered. A figure produced by Lazarus (2005) below shows the contrast between resource usage and embodied energy. The results show that materials such as brick, glass, timber, metal, paint and plastic make up 5 per cent of the material usage but account for 31 per cent of the embodied carbon. This shows where the potential environmental savings can be made. Lazarus (2005) states that if the reuse of the five most common building materials (concrete, bricks, slate, timber and metal) was increased by 10-50 per cent then there would be an overall reduction of 11 per cent for all construction materials.



	Resource Flow (%)	Embodied CO2 (%)		Resource Flow (%)	Embodied CO2 (%)
Crushed rock	38	4	Fibre cement products	0	1
Sand & gravel	24	3	Bricks	2	6
Cement	3	18	Glass	1	5
Clinker	3	0	Steel	1	8
Slate	0	0	Other Metals	0	14
Readymade concrete	16	16	Timber	1	5
Concrete building blocks	10	10	Plastics	0	7
Concrete roofing tiles	1	1	Paints	0	2

Figure 7.2 Material usage compared to embodied energy (Source: Lazarus, 2005)

7.11 Sourcing reclaimed materials

The sourcing of reused materials will have an important role to play in the environmental impact from the chosen material. Lazarus (2005) states that, 20 per cent of the embodied energy of construction materials arises from their transport. Materials with a higher embodied energy can be transported a greater distance before the environmental benefit of using reclaimed materials is lost. The table below outlines these distances and some of the distances are quite considerable. This shows that the concept of having a national network in Ireland for reclaimed materials is possible and these markets will benefit from economies of scale.

Material	Distance (Miles)
Tiles	100
Slates	300
Bricks	250
Aggregates	150
Timber	1000
Steel Products	2500
Aluminium Products	7500

Table 7.1 Maximum distances before environmental benefit of reclaimed material is lost (Source: BRE Green Guide to specification)

7.12 Decision of where to dispose of construction waste

A contractor will send construction waste to a recycling centre as long as the cost involved is cheaper than that of sending it to landfill. In order to work out the cost involved Duran et al. (2005) set out a formula that can be used to compare the two costs. A contractor will chose recycling over landfill when;

$$\mathbf{Tl + Cl > Tr + Cr + Er}$$

Where;

Tl is the cost per tonne of transporting unsorted waste to landfill site.
Cl is the cost per tonne of disposing of unsorted waste in landfill.
Tr is the cost per tonne of transporting waste to a recycling centre.
Cr is the cost per tonne of bringing waste to a recycling centre.
Er is the extra costs per tonne incurred by the waste producer of bringing waste to recycling centre.

7.13 Potential market availability

Outlined below are some examples of companies that are available in Ireland for the processing of construction waste. As well as these examples a visit will be carried out to Barna Waste in Galway to access how they process the waste and where the waste is being sent post removal off site. According to the EPAs 2010 Waste Report there are currently 443 waste facilities that are permitted to accept construction and demolition waste in Ireland. The visit to Barna waste is an attempt to gain an insight into what happens to construction waste at such a facility.

7.13.1 Timber

In Tynagh, Co. Galway, Connaught Timber operates a wood waste recovery facility which processes used pallets and waste wood. The company is registered with REPAK and the EPA and is permitted to collect waste wood in twenty local authority areas in Ireland. The company recycles all wood waste and can provide certificates along with monthly and annual reports for Repak returns. Waste wood can be delivered to their facility or collected by their vehicles throughout Ireland.

7.13.2 Blocks, rubble, waste concrete

Over the past number of years, Roadstone Wood Ltd has opened three construction and demolition recycling centres in Ireland. The recycling centres accept segregated inert materials such as concrete, blocks, bricks, tiles, slates, ceramics and asphalt. The company accepts waste from waste contractors but also offers reduced charges for pick-up of the materials when compared to that of skip hire. Only materials which are segregated at source are accepted by the facility. The recycling centres operated by the company are permitted under the Waste Management Regulations 1998 and each centre is issued with a permit by the relevant local authority.

7.13.3 Metal

There are numerous companies offering metal recycling facilities in Ireland because of the value of this material. A recycling contractor can provide a specific skip on site for the recycling of metal, one such contractor is Walsh waste. Walsh waste provide a specific service to the construction industry and all metal types are accepted including aluminium, steel, copper etc. All the metal recovered is then 100 per cent recycled and reused.

7.13.4 Gypsum/ Plasterboard

The BRL Group operate a gypsum recycling plant in Magherafelt, Co. Derry. The company collects waste from sites and processes the waste to produce a recycled gypsum product. When the plasterboard is received at the site the paper and metal is separated and different grades of recycled gypsum are produced. The company utilises 97 per cent of the gypsum waste that is processed.

7.13.5 Insulation

Rehab Recycle collects and recycles EPS insulation from businesses and industry. Rehab Enterprises have now started to recycle clean EPS in Ireland but unfortunately only in Dublin. The EPS is collected in reusable $2m^3$ bags and the company collects the bag on a regular or ‘call in’ basis.

7.13.6 Packaging waste and paper/ plastic waste

Packaging waste is a common waste and can be recycled by most waste contractors. In Galway, Barna Waste provide facilities for the recycling of packaging waste such as plastic and cardboard and other various paper and plastic wastes produced on site.

7.14 Take back schemes

A take back scheme is an agreement that can be set up between suppliers and the contractor so that any excess materials or packaging waste can be returned and then recycled back into the manufacturing process. The system can use a reverse logistics type approach whereby when the new materials are delivered to the site the materials or waste to be returned is sent back on the same truck. An example would be plasterboard; any off cuts or excess materials left over could be returned to the supplier and reused in the manufacturing process. As well as the environmental benefits of reuse the contractor will also benefit from reduced waste disposal costs. As well as material take back schemes it may be possible to set up a take back scheme for packaging with the supplier. On average, one third of the waste leaving a construction site is packaging waste that includes cardboard, plastic and timber (DEFRA, 2012). The majority of this waste could be sent back through take back schemes to be recycled.

As part of the research for this thesis a number of material producers and suppliers were contacted to establish whether they offer a take back scheme in Ireland. The responses are outlined below;

Supplier	**Material**	**Scheme Yes/ No**	**Comment**
Rockwool	Insulation	No	Only available in UK (Wales).
Isover	Insulation	No	
Kingspan	Insulation	No	Only available in UK (Chesire).
Xtratherm	Insulation	No	
Kore	Insualtion	No	
Airpacks	Insulation	No	They do recycle their own waste back

			into the manufacturing process (EPS only). *
Quinn-therm	Insualtion	No	
Ecowise	Insulation	No	Their systems produce little or no waste e.g. bonded bead insulation.
Gyproc	Plaserboard	No	Sister company (British Gypsum) in UK do offer a scheme. **
Lafarge	Plasterboard	No	Only available in UK.
Mc Donaghs	Builders Providers	No	
Chadwicks	Builders Providers	No	
Mc Mahon	Builders Providers	No	May be possible but would need to consult on contractors requirements first.
Brooks	Builders Providers	No	Not economically viable at present.
Newell Roofing	Roofing Products	No	
Munster Joinery	Doors & Windows	Yes	Only for ‘bubble wrapping.’

Table 7.2 Availability of take back schemes in Ireland

* Airpacks Ltd said that they currently recycle all of their own EPS waste but are currently not in a position to offer this service to their customers. One of the main reasons is the potential for the returned materials to be contaminated with mortar for example.

** There currently is not enough gypsum waste being generated in Ireland to have a similar scheme in Ireland.

7.15 Site visit to Barna Waste, Co. Galway

7.15.1 Methodology

The aim of the visit was to establish the final destination of the waste that leaves the site chosen for the case study of this thesis. Barna Waste is the waste contractor on the job so a visit was organised to identify the procedures and processes involved in dealing with the waste once it leaves the site.

7.15.2 Introduction

Barna Waste was founded in 1993 in Galway and their head office is located at the Carrowbrowne site on the Headford Road, Galway. The facility is a waste transfer station, a materials recovery facility, a composting facility for organic waste and a civic amenity site. The facility consists of nine acres with 7.5 acres under roof. The site has been developed and is constantly evolving to be one of Ireland's largest and best equipped sites that can manage construction and demolition waste produced in Ireland. The company aims to reduce the volume of waste going to landfill which in turn will reduce the costs incurred by the construction contractor. Barna Waste can also work with construction contractors to help them develop their waste management requirements and formulate a plan for the on-site need for construction waste containers. The company has also achieved ISO 14001 accreditation.

A visit was carried out on the 19th of July 2012 and the facilities manager, Campbell Finnie, provided the author with a tour of the facility and all the necessary information required to compile information on the final destination of the construction waste streams.

7.15.3 EPA Licence

The EPA licence number for the facility is 106-2 and this licence is for the operation and development of a non-hazardous waste transfer facility that is permitted to accept municipal, industrial, commercial, organic wastes and construction and demolition waste. The facility is permitted to accept 166,000 tonnes of waste per year. The licence also includes a provision for the construction of a new building which will house a construction and demolition waste recovery area. The licence states that the facility must be operated in a way that ensures that the activities on the site do not cause environmental pollution and the licensee must carry out environmental monitoring and submit the results to the EPA. The EPA licence sets out the conditions under which the Barna Waste facility must be operated and managed.

Section 3.14 of the licence states that the construction and demolition waste recovery area must be fully enclosed on a concrete slab with systems in place to control and reduce noise and dust emissions. Following the segregation waste storage bays must be provided for the storage of the recovered materials.

Section 4.8 states that only construction and demolition waste can be accepted in this area and waste can only be stored in this area prior to being subjected to other recovery activities or transport off site. All stockpiles of materials must be maintained so that dust generation is minimised.

7.15.4 Waste collection permit

In accordance with section 34 (1) of the Waste Management Act 1996 the collection of waste requires a waste collection permit from a relevant local authority. Barna Wastes permit number for waste collection is; WCP-MO-08-0604-01

7.15.5 Waste acceptance

Waste type	Max tonnes per annum *A	Max tonnes per annum *B
Household	55,500	55,500
Commercial	17,500	17,500
Construction & Demolition	30,000	50,000
Industrial	23,000	23,000
Biodegradable	40,000	20,000
TOTAL	166,000	166,000

Table 7.3 Barna waste, waste acceptance

*A With four composting aisles in proposed new building.

*B With two composting aisles and construction and demolition waste recovery area in proposed new building.

7.15.6 Skip sizes available

Type	Capacity		Height		Length		Width	
	Cu. Mtrs	Cu. Yds	Meters	Feet	Meters	Feet	Meters	Feet
Mini	1.5	2	0.76	2’6”	1.2	4’	0.91	3'
Midi	3	4	0.97	3’2”	1.83	6’	1.29	4’3”
Builders *	4.6	6	1.22	4’	2.6	8’6”	1.52	5’
Large	9.2	12	1.68	5’6”	3.7	12’2”	1.78	5’10”
Ro-Ro**								

Table 7.4 Availability of skip sizes

* Builders skip available in both 6 cubic yards and 8 cubic yards.

**** Roll on/ roll off skip - These skips are also available from Barna Waste and can be used when projects involve the production of a large amount of waste.

7.15.7 Waste cycle from site to recovery

The following is the cycle for the collection, processing and shipping of waste materials generated on a construction site to their recovery by Barna Waste.

Step 1. The waste is either source segregated or placed in a mixed construction and demolition waste skip.

Picture 7.1 Mixed waste skip on site

Step 2. The skips or waste containers are collected from site by Barna Waste.

Step 3. On arrival at the materials recovery facility the waste is weighed on the weighbridge. Then the segregated waste goes to its appropriate section or if the waste is mixed it goes to a centralised processing area for segregation by hand. This area can be seen in the picture below, the skip is tipped out to the right of the picture where the black bags are.

Picture 7.2 Centralised sorting area

Step 4. Materials are segregated into their waste streams and sent to the specific area of the facility that deals with that waste. (Details below)

Step 5. The materials undergo their specific treatment and are prepared for shipping off site or disposal to landfill or incineration. (Details below) It is estimated by Barna Waste that as little as 5% of construction and demolition waste that enters their materials recovery facility will end up being used for incineration or landfilling. Currently none of the segregated materials are returned to their original suppliers for reuse.

Details of the cycle of various waste streams are outlined below;

7.15.8 Timber

Timber waste arrives at the facility either in a mixed skip or in a segregated skip. The timber is first separated from the rest of the waste and brought to a holding area.

Picture 7.3 Timber holding area

Following this the timber is shredded and can then be sent for use in two areas; the first is for use as a landfill cover – the shredded timber is sent to Greenstar at their landfill in Kilconnel and the second market is for use by Eirebloc. Eirebloc use the shredded timber to manufacture the separator blocks used in pallets. Prior to shredding, if the wood is treated with paint, for example, or if it is ‘green’ wood waste then it is only suitable for use as landfill cover and cannot be sold to Eirebloc.

Picture 7.4 Shredded timber

7.15.9 Plastic

Plastic waste is separated from the mixed waste and is held in a temporary holding area.

Picture 7.5 Plastic temporary holding area

Following this stage the plastic is further separated into hard and soft plastics and baled for export to the Far East. The hard plastics can contain plastics such as PVC windows and piping and the soft fraction is plastic that has been used for packaging.

Picture 7.6 Baled hard plastic

Picture 7.7 Baled soft plastic

If a construction contractor separates the plastic fraction of the waste then the skip is provided to the site free of charge bar a service charge for its delivery. The skip provided will be a covered skip to prevent the waste from getting wet or contaminated. Another option is the use of a baler on site, again these bales will be collected free of charge from the site. Barna Waste currently does not rent balers to the industry but a large contractor may find it beneficial to buy a baler for use on site.

7.15.10 Cardboard and paper

The cardboard and paper fraction of the construction and demolition waste stream is separated out and stored temporarily in the central processing area.

Picture 7.8 Cardboard temporary holding area

This waste is then fed into the manual picking line and sorted into specific waste streams that are ready to be baled. The bales are then ready for shipping off site to be recycled.

Picture 7.9 Baled cardboard

Picture 7.10 Baled paper and cardboard

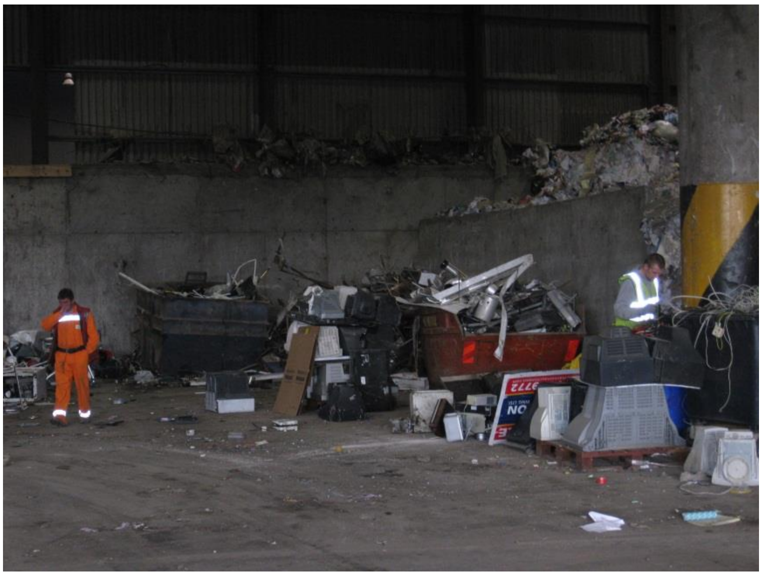
As with the plastic waste stream if a construction contractor separates the cardboard and paper fraction of the waste then the skip is provided to the site free of charge bar a service charge for its delivery. The skip provided will be a covered skip to prevent the waste from getting wet or contaminated. Another option is the use of a baler on site, again these bales will be collected free of charge from the site.

7.15.11 Plasterboard/ Gypsum

The plasterboard or gypsum waste is separated from the mixed waste and held in a holding bay. Barna Waste does not process any gypsum waste and the waste is sent off site for recycling elsewhere. There are currently no companies offering a recycling facility for gypsum waste in the Republic of Ireland so the waste is shipped to the UK for reprocessing. Smaller skips are available for hire to cater for the segregation of waste streams such as Gypsum.

7.15.12 Metal

The metal waste can enter Barna Waste in either a mixed skip or a segregated metal skip. Segregating the metal into its own skip will allow the construction contractor to gain a revenue because Barna Waste do not charge for the placement of a metal skip on site and will pay the contractor to take away the waste at an agreed rate depending on the type of metal. Once the metal enters Barna Waste it is separated out from the other waste.



Picture 7.11 Metal segregation stage

Following this segregation it is moved to a holding bay prior to being baled.

Picture 7.12 Metal waste holding bay

The bales are then sent to Galway Metal in Oranmore for reprocessing.

Picture 7.13 Baled metal waste

7.15.13 Insulation

Insulation such as Rockwool and EPS cannot currently be recycled in Ireland. This waste is sent from Barna Waste to either the landfill site operated by Greenstar or to the incinerator in Co. Meath operated by Indaver. Aeroboard insulation however is recyclable by Barna Waste.

7.15.14 Concrete/ rubble etc.

This waste stream is held in an outdoor area prior to screening and crushing.

Picture 7.14 Concrete/ rubble waste holding area

Due to the low quantities of construction waste being received because of the economic downturn, this waste is currently only being processed once a year. The waste is processed by crushing and screening the waste to remove unwanted contaminants and can then be used as a fill material. Currently the waste is being used to fill an adjacent site where Barna Waste intends to construct a new garage in the future.

Picture 7.15 Concrete/ rubble used as fill

7.15.15 Hazardous waste

The Barna Waste facility does not accept any hazardous materials.

7.15.16 Organic waste

The organic waste fraction of the construction waste, for example canteen waste is separated and sent to the composting facility on site. Here the waste is held in holding bays prior to processing.

Picture 7.16 Organic waste holding bay

Once the material has been held here for a certain amount of time it is then sent through the trommel screens to remove non organic waste and is processed into compost. The compost can then be used off site for landfill cover.

Picture 7.17 Conveyors and trommel screens

Picture 7.18 Compost

Barna Waste stated that it is willing to provide an organic waste bin on site if required. The bin would be similar to the brown bin found in homes around the country and it would then be collected in tandem with other bins in the locality. Waste that could be placed in the brown bin include plants, leaves, hedge clippings, saw dust and wood shavings, food waste and paper towels. This bin is available in 120ltr, 240ltr and 360ltr sizes.

7.15.17 Canteen waste

Canteen waste such as plastic bottles, cartons and food trays are all recyclable and Barna Waste bales these for export.

Picture 7.19 Baled canteen waste

7.15.18 Office waste

Office waste is 100 per cent recyclable and can either be shredded for confidentiality or recycled with other paper waste.

Picture 7.20 Baled office waste

7.15.19 Final Destination

The baled waste in then placed into containers and sent for recycling off site. The majority of Barna Wastes markets for this waste are in the UK or the Far East in countries such as China.

Picture 7.21 Shipping containers

Waste Type	Market/ End Destination
Timber	Shredded and used as landfill cover or used to manufacture pallet blocks.
Plastic	Sent to Far – East for recycling.
Cardboard/ Paper	Sent to the UK for recycling.
Plasterboard	Sent to UK for reprocessing.
Metal	Sent to Galway Metal and then to China for reprocessing and recycling.
Insulation	Sent to landfill or incineration.
Concrete/ Rubble	Used as fill on site at Barna Waste.

Table 7.5 Final destination of waste

7.15.20 RDF – Refuse Derived Fuel

Currently Barna Waste does not offer this facility but in 2013 this facility will be coming on line at this site. Following processing the RDF can be burned to produce heat and electricity or used as fuel in cement Kilns. Barna Waste plan to export the RDF produced at this site to the Netherlands for use in power plants there.

7.15.21 Waste costs per tonne

Waste Type	Price per tonne (€)*	Comment
Timber	50	
Rubble and Soil	50	
Plastic	80	Only service charge
Plasterboard/ Gypsum	100	
Paper	50	Only service charge
Polystyrene	50	
Glass	100	
Food	120	
Cardboard	32	Only service charge
Inert/ Stone	50	
Mixed C&D	158	
Mixed metal	50	Can generate revenue
Mixed recyclables	80	

Table 7.6 Waste types and cost per tonne

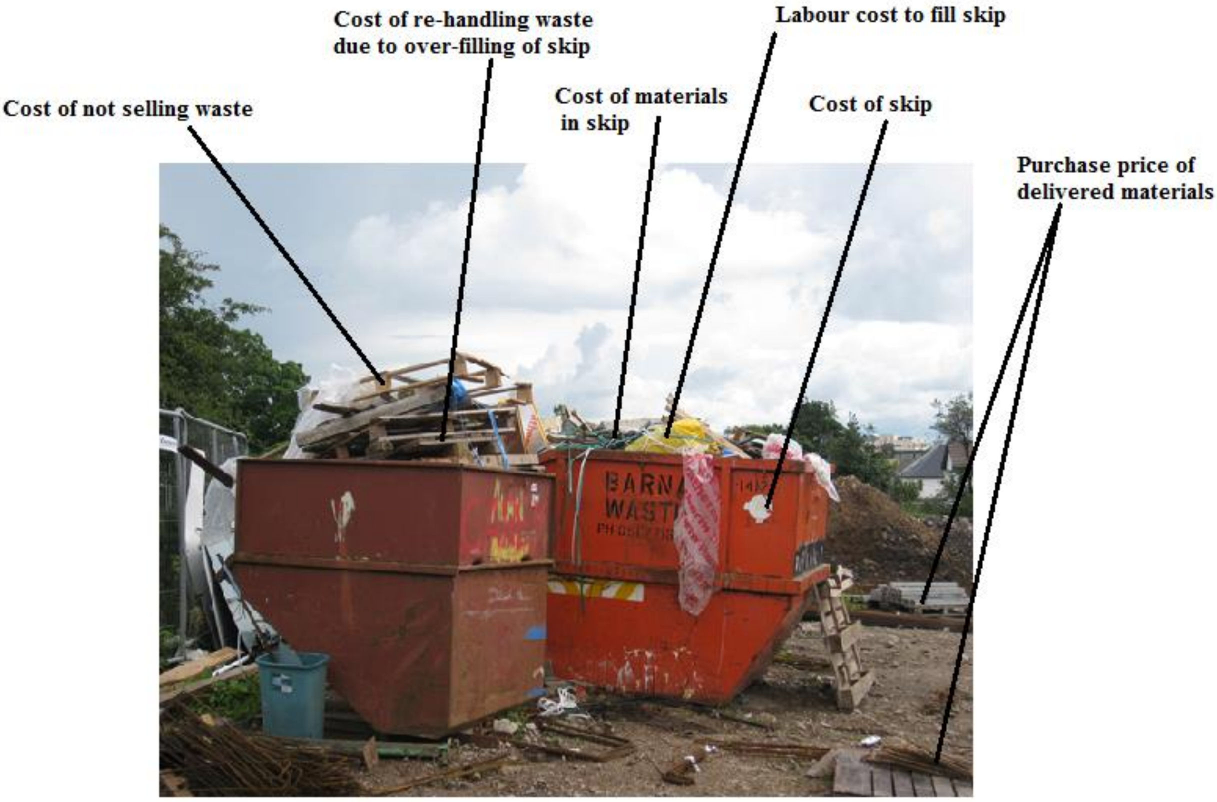
* Additional charge of VAT at 13.5% (Price applicable if waste is segregated).

7.15.22 Record keeping

On entering the site the waste is weighed and when the truck is empty it is weighed again. The difference in weight is what the producer of the waste must pay for. All construction and demolition waste skips operate on a pay by weight basis with a cap on the highest payment per skip. There are no specific records kept of the weight of each waste stream from the skip but if the construction contractor requires this to be done it can be organised through Barna Waste and a report can then be produced for the construction contractor. Records are kept of all waste leaving the site by Barna Waste and these quantities are freely available from the company. It is important that a construction contractor carries out audits of the waste management contractor periodically. As the producer of the waste the construction contractor has a responsibility to ensure that the waste is being disposed of correctly and should check that the waste permits are current. This will also give the construction contractor information on waste production, the quantity of waste being diverted from landfill, the recycling rates as well as the associated charges.

7.15.23 Recommendations

Barna Waste recommend that contractors separate their waste on site into the main waste streams for example; timber, plastic, cardboard/ paper, metal, plasterboard and insulation. The cost of the segregated skips is also lower and in the case of metal segregation can actually generate revenue for the construction contractor. For comparison a mixed skip will cost €158 euro/tonne to send to Barna Waste whereas a timber skip costs just €50/ tonne. Skips for Cardboard/ paper and plastics are not charged for bar a service charge for delivering the skip. There are a number of items that cannot be placed in construction waste skips such as paint tins, asbestos, medical waste, florescent tubes, solvents, liquids, oil, hazardous waste and a mixed skip can only contain a maximum of 10 per cent plasterboard. The true cost of waste is outlined in the picture below;



Picture 7.22 True cost of waste

7.16 Incentives and disincentives of reusing or recycling construction waste

The table below outlines some incentives and disincentives that pertain to the reuse and recycling of construction and demolition waste;

Table 7.7 Incentives and disincentives of recycling or reusing C&D waste

Excavated Soil	
Incentives	**Disincentives**
Soil is an easily separated waste fraction.	Landfills may not accept excavated materials unless they require them.
Soil is not considered a waste until it leaves the site.	Recovery of excavated soil from certain areas may be restricted (Habitats Directive).
Waste permits and regulations are in place to manage this waste stream.	
Concrete based waste	

CEN standards for recycled aggregates and unbound materials.	There are no government incentives to use recycled aggregates.
NRA specifications for road base and structural concrete.	Cost of setting up recycling facilities is high.
Increasing landfill levy.	Transport costs to recycling facilities are high.
Increased disposal and transport costs.	Difficulty of separation from plaster or plasterboard.
Packaging Waste	
Can help achieve Irelands packaging waste recovery target.	Difficult to segregate and store.
Improved producer responsibility.	Availability of markets.
Removing recyclable materials from waste stream can save on disposal costs.	Reluctance to set up take back schemes with suppliers.
Prevents wind-blown litter on site.	Waste is likely to become contaminated.
Will improve environmental image of the industry.	
Miscellaneous Waste	
Recycling waste can reduce overall costs.	Cost of materials is rising.
Landfill levy is rising.	Contamination is likely in mixed skips.
Mixed skips may not be accepted for landfill.	Lack of markets.
	High start-up costs for new recycling facilities.

7.17 Barriers to reuse and recovery

There are a number of barriers to reuse and recovery such as;

- The lack of specifications for recycled materials. This impedes designers from using recycled products for fear that they may not be appropriate to the required application.

- The inconsistency of materials being recycled and produced by the recycling plant.

- The unreliability of supply to recycling plants leads to inconsistent supplies of recycled products, this leads to a lack of confidence in the supplier being able to supply goods on time.

- Contamination of materials sent for reuse. If mixed waste is sent for recycling the waste could be contaminated by other wastes within the skip, this will lower the possibilities of the waste being recycled into a useable product.

- The perception and willingness of clients to accept recycled materials.

- The cost of primary aggregates is still relatively low and this reduces the willingness of contractors to buy recycled materials.

- If a building is being demolished, it is often the case that this phase is required to be over as soon as possible. This does not provide a suitable platform to good segregation of the demolition material or an initial soft strip of a building.

- There is a lack of awareness of material buyers that there are alternative materials available that contain a recycled content and that some products are unsuitable for recycling.

- Access to cheap waste disposal has a severe impact on the recycling of waste. This is likely to change in the future as landfill space runs out.

- The high capital cost of developing recycling infrastructure prevents investors or companies in setting up a recycling company.

7.18 Barriers to market development

- The quality of materials received can be quite bad and proper source segregation is needed in order for a recycling facility to be able to process the waste for reuse (Zhao et al. 2009). Some materials sent to recycling facilities are not suitable for processing or recovery and this waste needs to be monitored at site level in order to ensure a consistent supply. It must also be noted that source segregation is not always possible due to space constraints on some sites.

- Cheaper alternatives are available to recovered materials because there is an easy and plentiful access to raw materials. There is also no aggregate tax in Ireland so the materials are often cheap and competitive against the alternative recycled product. This causes buyers to be reluctant to choose more environmentally friendly alternatives and the markets for recycled products had traditionally been weak.

- If the charges for a recycling facility are higher than the charges for landfill then it is likely that the waste will be sent to landfill. The contractor that wants to dispose of the waste will inevitably choose the cheapest disposal option. (Duran et al., 2005)

- There is a lack of confidence in recycled materials. New materials and aggregates are often specified when a recycled product would suffice (Knoeri et al., 2011). A cultural change takes time and is difficult to instil. Standards need to be implemented for recycled materials in order to engender more confidence.

7.19 Summary

At present the low cost of primary materials such as aggregates and the low cost of disposing waste to landfill is making it difficult for a good level of recycling to occur. A lot of construction waste is sent to landfill and users of aggregates favour the use of primary aggregates (Duran et al, 2005). However the environmental costs of doing this are very high and are having a negative impact on society. The contractors benefit from the low costs but society has to incur the environmental costs. Policy makers must now ensure that society does not have to bear this cost and this could be done by limiting the amount of construction waste being sent to landfill, enforcing the polluter pays principle and introducing an extra cost for virgin materials such as the aggregate tax in the UK. The creation of new markets would offer a suitable solution and benefits both the industry and society because the waste producer will incur lower disposal costs, the recycled materials will be cheaper and society incurs a much lower environmental cost.

This chapter has discussed the market availability for recycling and reclaiming waste in Ireland. The next chapter will outline the conclusions and recommendations reached through the study of this thesis.

8.0 Chapter eight - Conclusions and recommendations

8.1 Aims and objectives

The previous chapter discussed the market availability for recycling and reclaiming waste in Ireland. This chapter will provide the conclusions and recommendations reached from the study of this dissertation and will also outline the research limitations and the areas for further study. Although findings were presented in each chapter, this chapter provides a triangulation of those results. By combining the findings from each chapter conclusions can then be drawn.

This chapter will give an insight the:

- Conclusions and recommendations.
- Research limitations.
- Areas for further study.

8.2 Conclusions

The aim of this thesis was to investigate how a small to medium sized construction company in Ireland could implement and develop waste management strategies both within the company and practically on site in order to deliver economic, social and environmental benefits. This study has also investigated how to implement a waste management plan within a medium sized construction company in Ireland. The implementation of a waste management plan has been demonstrated through the use of a case study, literature review and questionnaires; and has been recognised as a valuable means of reducing construction waste on site as well as reducing the environmental impact of construction as a whole. One of the aims of this thesis was to examine the waste hierarchy opportunities that are available for construction and demolition waste in Ireland and to examine the effects of management strategies on construction and demolition waste reduction at the project level. As well as this the case study and questionnaire were undertaken to investigate current practices and attitudes towards construction waste management in Ireland. In addition all of the objectives that were set out at the beginning of the dissertation have been achieved.

It is clear from the literature review carried out for this thesis that construction activities consume large amounts of natural resources, energy and materials and also generates a large amount of waste. Through the literature review it was also found that there is adequate legislation in place or coming on line to deal with waste management now and into the future. The construction industry has a potential adverse effect on sustainable development and the large amount of waste produced is a big problem. It is important that in order for the construction industry to be sustainable into the future that this waste is managed correctly. Waste management is a separate practice to resource recovery, but the two should go hand in hand in the construction industry. The most important factor for on-site waste management is the on-site segregation of the waste. If this process fails then it becomes difficult for the waste to be recycled. At the outset this will take some extra time and training of the construction staff but once the segregation habits are established the waste segregation on site can be done at a small or no additional cost.

Segregating waste is good practice but the waste generation initially should be minimised. Waste minimisation can have financial benefits for a company because it can reduce the operating costs of the company. Implementing waste minimisation on site is about using common sense and a change in attitudes; it does not necessarily require the implementation of new technologies. It is often the case that implementing waste minimisation techniques incurs no cost and they can give benefits straight away. Typically the implementation of waste minimisation techniques requires three basic components; waste minimisation during the design stage, source reduction and recycling. Waste minimisation during the design stage has huge potential to impact positively on waste minimisation as it is during this stage that some of the major decisions are made such as the form of the building. On the case study site this option was not available as construction work had already started but on future projects waste minimisation should be considered during the design stage. Source reduction helps avoid waste generation while recycling helps to conserve natural resources and prevents wasted materials from entering the waste stream. The case study currently only segregates timber waste but Carey Developments should now begin to separate the waste on site into the main waste streams. Recycling is currently being carried out but only through the efforts of the waste management contractor once the waste has been removed off-site. There is huge potential for the minimisation of construction waste which arises through both design and the construction process. In order to reduce wastage rates it is important to focus on both issues.

It is clear that a change in the current waste management practices is needed in order to eliminate waste on the case study site. This will require a shift from thinking of construction waste as something that is unwanted and destined to be discarded to thinking of these materials as a resource that can be reused, recycled or recovered. Carey Developments can set a good example by setting waste minimisation, reuse and recycling into company policies and demonstrating a will to change. The culture of waste management can only be changed by Carey Developments working in partnership with sub-contractors, designers and suppliers to achieve good practice waste minimisation. It cannot be expected that a sub-contractor or labourers on the case study site will change their mind set on construction waste on their own but rather that the main contractor must make it clear from the outset that waste reduction, reuse and recycling will be expected from all construction parties on site.

It is important that a waste management plan should be formulated at the earliest possible stage of the project; the formal production of the waste management plan can be at a later stage but a waste management philosophy ought to be adopted by the designer at the earliest possible stage. The case study site currently does not have a waste management plan implemented but a plan has been developed as part of this thesis for Carey Developments to use on the case study site and also can be adapted for future projects. During the preliminary planning stage attention can be given to implementing a waste management approach that establishes the targets for the quantity of waste to be diverted from landfill and focus upon preventing waste, the reuse of materials and the recycling of any waste produced. The waste management plan must be supported by management and have a buy in requirement from the project team including sub-contractors. The plan can be constantly evolving and be reviewed at the appropriate stages. A waste management plan should not be seen as a complicated document or seen as a burden by the person nominated for its implementation. The person implementing the plan must be able to communicate, motivate and train the staff in good waste management practices. A training manual has also been produced for Carey Developments so that the task of training and communicating the plan can be made easier for the person implementing it. The aim of the waste management plan is for it to become common practice on the case study site, and future projects, and eventually merge into day to day activities. The preparation, implementation and documenting of a waste management plan will enable all parties to learn how to achieve good practice waste management. This can be achieved by recording summary information and performance outcomes along with lessons learnt. Tables to record the summary information, performance outcomes and lessons learnt have also been developed for Carey Developments. A waste management plan is an important document for construction companies and their clients, regardless of the company's size. The waste management plan produced through this thesis will help improve the company's environmental performance and reduce rising disposal costs as well as meeting regulatory controls.

The costs of disposing of construction and demolition waste are constantly rising causing contractors to re-evaluate their position on waste disposal methods and to choose whether to see waste as rubbish or as a possible resource. The need to implement a waste management plan stems from both a concern for cost and for protecting the environment. The increasing awareness of waste management has led to the development of waste management plans as an integral part of construction project management. Waste management plans focus mainly on the on-site management of waste; however there are opportunities to link a waste management plan into other stages. A waste management plan can also be embedded in a company's site procedures, for example; designing out waste, more efficient procurement strategies and management of sub-contractors. Planning for waste management should be included during the design and procurement stage in order for good practice to be achieved. All parties in the construction industry need to be proactive in relation to waste management and minimisation and a waste management plan should be used for all projects except minor site developments. Once the plan is developed it is imperative to its success that it is implemented on site and adhered to. In order to ensure that plans are successful summary reports along with audits need to be carried out at regular intervals on the project. An audit sheet has been developed for Carey Developments and is an appendix to this document. When the cost of gate fees, labour costs and haulage costs are considered then effective waste management and minimisation can lead to substantial cost savings. High transport and disposal costs serve to make the recovery of materials economical.

Ireland is faced with a problem of recovering construction and demolition waste and the markets to use these materials on a large scale is lacking. In 2010 3.5 million tonnes of construction and demolition waste was collected in Ireland, however the quantity of construction and demolition waste has decreased over the last number of years due to the economic downturn but when the construction industry restarts it is important that these markets are in place and available. At present the low cost of primary materials such as aggregates and the low cost of disposing waste to landfill is making it difficult for a good level of recycling to occur. A lot of construction waste is sent to landfill and users of aggregates favour the use of primary aggregates. However the environmental costs of doing this are very high and are having a negative impact on society. The contractors benefit from the low costs but society has to incur the environmental costs. Policy makers must now ensure that society does not have to bear this cost and this could be done by limiting the amount of construction waste being sent to landfill, enforcing the polluter pays principle and introducing an extra cost for virgin materials such as the aggregate tax in the UK. The creation of new markets would offer a suitable solution and benefits both the industry and society because the waste producer will incur lower disposal costs, the recycled materials will be cheaper and society incurs a much lower environmental cost. The traditional methods of construction and the lack of will to change mean that the general attitude towards using recycled materials in largely inhibitive. It is important that recycled materials are now officially certified and then accepted by all parties within the construction industry.

The case study for this thesis was seen as a good opportunity to develop an insight into the realities of the treatment of construction waste on construction sites in Ireland. The issue of waste management and the generation of waste is now becoming a more prevalent topic within construction companies and some companies are now developing waste management policies and plans in order to minimise the amount of waste being produced. Contractors are now beginning to see the benefits of waste management and are setting targets for a reduction in waste. This shift in attitudes is occurring mainly in large companies and it is now going to be necessary for small to medium sized companies in Ireland to develop similar policies in order to comply with future legislative requirements and avoid the rising costs of landfill and waste management. It is now becoming necessary for construction companies to develop some form of environmental management system and previous studies in this field have suggested that a high rate of success can be obtained

by implementing waste management strategies and this was one of the aims of the case study. Through the observations made during the site visits Carey Developments were advised on their future waste management requirements. One of the observations made was the illegal fly tipping of waste on site and this disregard for the environment is a clear breach of the law and needs to be prevented at all costs. Prior to Carey Developments initiating any new waste management practices, practices such as this must be stopped. Only then can the implementation of good practice waste management begin.
From the observations made on the case study and the research carried out as part of the thesis it is clear that waste minimisation can be carried out quite easily once waste minimisation is considered at an early stage and is linked into the contract documents. The on-site segregation of waste and the reuse of materials are two of the most common methods that are adopted in order to minimise waste on construction sites. There is no reason why these two methods cannot be adopted immediately on the case study project. As well as this waste management and minimisation is seen as an ad hoc activity that does not form part of the core construction activities whereas eventually it is anticipated that good practice waste management and minimisation will become part of the day to day activities on site. The site visits and the observations made during these visits have contributed to this thesis becoming a practical document. Through the visits it was possible to gain an insight into the reality of on-site practices and consequently the issues that required attention. Through this experience the author has gained a practical knowledge of the day to day requirements of an effective waste management plan and through this learning experience, a good practice waste management plan was developed. It is clear from the observations made during the case study and the results of the questionnaire that there is a lack of knowledge and training in the area of waste management among Irish contractors, even though they have a motivation and willingness to reduce waste production on site.

The use of a questionnaire provided a good insight into the current attitudes of main contractors towards waste management in Ireland. There were a number of positive aspects seen in the answers to the questionnaire as all of the respondents were motivated to reduce waste as part of their job, the majority of the companies surveyed had a waste management strategy in place and the majority of respondents stated that their previous experience of waste management has been positive. All of these points are positive as they provide a good basis for the implementation of good practice waste management and minimisation.

As stated previously it was found that there is a lack of training and knowledge within the industry and this was also found to be true from the questionnaire as the majority of the respondents had received no training in relation to waste management. The majority of respondents also believed that a lack of training and knowledge of waste management is a problem within the industry. It is important that even at management level the correct training is provided so that management can pass their knowledge of waste management onto the site operatives. Regular training should be provided to all personnel involved with waste management. The barriers to waste management were found to be; poorly defined responsibilities, waste management is not a goal of the main stakeholders and the lack of waste management policy was preventing companies from implementing waste reduction measures. The majority of respondents believe that waste prevention and minimisation will be a major issue for the construction industry in the future and that there are currently financial rewards to be gained from minimising, preventing and recycling waste. The questionnaire has provided a good insight into the current attitudes of main contractors towards waste management in Ireland. The answers have given the author a snap shot of the industry and the information gathered has also been integrated into the text of this thesis. Through the use of the questionnaire and the case study an insight into the current practices and attitudes within the industry has been gained.

The attitudes within the construction industry are slowly changing towards accepting the concept of good waste management and recycling. The larger companies have been more proactive with implementing waste management plans and providing training to their staff but small to medium sized companies such as Carey Developments are slower to adopt the same strategies. It is the authors' opinion that in order for waste management to be taken seriously legislative and policy changes will be required so that waste management becomes a mandatory obligation on all construction sites in the country. It is anticipated that through legislative changes and the realisation that financial gains can be achieved through good practice waste management that the small to medium sized companies in Ireland will begin to adopt similar strategies. This in time will lead to the construction industry becoming more sustainable and help to minimise the environmental impacts caused during the process.

8.3 Recommendations

There are a number of recommendations which have been drawn from the research carried out as part of this thesis. There recommendations are;

- Waste management plans should be made mandatory for all but minor developments such as one off houses. It is important that these waste management plans are produced during the design stage so that they can be submitted as part of the planning process.

- The benefits of waste management, waste minimisation and the use of recycled materials should be promoted by professional bodies such as the construction industry federation. Some main contractors in Ireland need to be convinced that waste management can provide benefits for the contractor and that the use of recycled materials is economically viable.

- The setting up of recycling plants to process construction waste and other wastes should be encouraged. The planning process for such a venture is often very complicated and difficult and private investors are slow to consider investing in these schemes. It is essential that when construction activity increases again after the recession that the appropriate facilities and markets are in place so that construction wastes can be turned into valuable resources.

- Standards for recycled products need to be published so that the perception of the industry can be changed towards these products. Standards will improve the confidence in using the products and architects and designers may be more likely to specify them.

- All parties within the construction process have a role to play in relation to waste management. Main contractors need to engage with suppliers and manufactures so that take back schemes for materials and packaging waste can be set up in Ireland. If this is not possible suppliers and manufacturers should be encouraged to use less packaging or to reuse packaging where possible.

- It is important that main contractors choose sub-contractors, suppliers and waste management contractors who will comply with their waste management objectives. Their selection could be based on past performance and only the companies who comply should be chosen. As well as this a client should only choose a main contractor who is aware of their waste management responsibilities.

8.4 Areas for further study

- The use of the questionnaire can be continued so that more contractors are surveyed; if this is done then the number of respondents can be increased and the results can be put through a statistical package. Once this has been completed it will give a more accurate account of the current attitudes of main contractors in relation to waste management in Ireland.

- Another need for further study is the need to dissect the newly evolving government legislation so that the policies can be identified and evaluated. It will then be possible to assess whether this legislation will hinder or assist in achieving good practice waste minimisation and management and whether or not it encourages the use of recycled materials.

- Further study could be carried out by observing the current practices on a number of sites rather than just one. This would give a better oversight into current waste management practices being carried out by main contractors in Ireland.

- The research carried out into recycling techniques for this thesis was somewhat limited to Barna Waste. Further research could be carried out to identify the best recycling opportunities and also the final destination for Irish construction waste.

8.5 Summary

This chapter has outlined the conclusions and recommendations made on the basis of the study carried out for this thesis. The research limitations and areas for further study have also been included. This is the final chapter of this thesis.

9.0 References

6EAP, (2011). *Final Report for the Assessment of the 6th Environment Action Programme.* (http://ec.europa.eu/environment/newprg/pdf/Ecologic_6EAP_Report.pdf)

Anson, M., Ko, J.M., and Lam, E.S.S., (2002). *Advances in Building Technology.* Page 1083.

Barrett, A., and Lawlor, J., (2010). *Questioning the Waste Hierarchy: The Case of a Region with a Low Population Density.* Journal of Environmental Planning and Management Volume 40, Issue 1, 1997.

Basel Convention, (1992). *Basel convention on the control of trans-boundary movements of hazardous wastes.* (http://archive.basel.int/text/con-e.pdf)

Bega, N., Morlota, J.C., Davidsonb, O., Okesseb, Y.A., Tyanib, L., Dentonc, F., Sokonac, Y., Thomasc, J.P., Rovered, E.L., Parikhe, J.K., Parikhe, K., and Rahmanf, A.A., (2002). *Linkages between climate change and sustainable development.* Climate Policy, Volume 2, Issues 2–3, Pages 129–144.

Begum, R.A., Siwara, C., Pereiraa, J.J., and Jaafar, A.H., (2009). *Attitude and behavioral factors in waste management in the construction industry of Malaysia.* Resources, Conservation and Recycling - Volume 53, Issue 6, Pages 321–328.

Beguma, B.A., Siwara, C., Pereiraa, J.J., and Jaafar, A.H., (2006). *A benefit–cost analysis on the economic feasibility of construction waste minimisation: The case of Malaysia.* Resources, Conservation and Recycling, Volume 48, Issue 1, Pages 86–98.

Beguma, R.A., Siwara, C., Pereiraa, J.J., and Jaafar, A.H., (2006). *Resources, Conservation and Recycling.* Volume 48, Issue 1, Pages 86–98.

Boones, W.E., Smith, E.D., Maurer, S.W., and Weinick, H., (2010). *Sustainable approaches to C&D waste management and global warming impacts.* International Journal of Environmental Technology & Management - Volume 13, Issue 1, Pages 21-36.

Bossink, B.A.G., and Brouwers, H.J.H., (1996). *Construction waste: Quantification and source evaluation.* Journal of Construction Engineering and Management. Volume 122, Issue 1, Pages 55-60.

British Aggregates Association, (2004). *Aggregates levy damages the environment.* Mining, Quarrying and Recycling - Volume 33, Issue 2, Page 6.

Brown, J.L., (2005). *Construction: Plastic bubbles lighten concrete deck.* Civil Engineering, Volume 75, Issue 12, Page 18.

Building Research Establishment Group, (2012). *Green Guide to specification.* (http://www.bre.co.uk/greenguide/podpage.jsp?id=2126)

Canadian Society for Civil Engineering, (2011). *Optimizing construction waste reuse: A BIM based technological approach.* Annual Conference - Canadian Society for Civil Engineering, Volume 3, Pages 2019-2027.

Castro, S.H., and Sánchez, M., (2002). *Environmental viewpoint on small-scale copper, gold and silver mining in Chile.* Journal of Cleaner Production - Volume 11, Issue 2, Pages 207–213.

Chan K.Y., and Li, X.D., (2001). *A study of the implementation of ISO 14001 environmental management systems in Hong Kong.* Journal of Environmental Planning and Management – Volume 44, Issue 5, Pages 589–601.

Chateau, L., (2007). *Environmental acceptability of beneficial use of waste as construction material—State of knowledge, current practices and future developments in Europe and in France.* Journal of Hazardous Materials - Volume 139, Issue 3, Pages 556–562.

Coelho, A., and de Brito, J., (2011). *Influence of construction and demolition waste management on the environmental impact of buildings.* Waste Management, Volume 32, Issue 3, Pages 532-541.

Cole, R.J., (2010). *Building environmental assessment methods: assessing construction practices.* Construction Management and Economics, Volume 18, Issue 8, Pages 949-957.

Connaughton, B., (2005). *Ireland and the European Union – Nice, enlargement and the future of Europe.* Pages 36 – 52.

Council of The European Union, (2006). *Review of the EU Sustainable Development Strategy (EU SDS) − Renewed Strategy.* (http://register.consilium.europa.eu/pdf/en/06/st10/st10917.en06.pdf)

Damnjanovic, I., Anderson, S., Wimsatt, A., Reinschmidt, K.F., and Pandit, D., (2008). *Evaluation of ways and procedures to reduce construction cost and increase competition.* (http://tti.tamu.edu/documents/0-6011-1.pdf)

Department for Environment, Food and Rural Affairs UK, (2011). *Guidance on applying the Waste Hierarchy.* (http://www.defra.gov.uk/publications/files/pb13530-waste-hierarchy-guidance.pdf)

Department for Environment, Food and Rural Affairs, (2008). *Non-statutory guidance for site waste management plans.* (http://archive.defra.gov.uk/environment/waste/topics/construction/pdf/swmp-guidance.pdf)

Department for environment, food and rural affairs, (2012). *Reduce packaging waste on your construction site*. (http://www.businesslink.gov.uk/bdotg/action/layer?topicId=1083183325)

Department for environment, food and rural affairs, UK. (2009). *The definition of waste summary of European court of justice judgments.* (http:/archive.defra.gov.uk/environment/waste/topics/documents/ECJCaseLaw20090209.pdf)

Department of the Environment, Community and Local Government, (2012). *Landfill Levy.* (http://www.environ.ie/en/Environment/Waste/LandfillLevy/)

Department of the Environment, Community and Local Government, (2012). *Landfill Levy*. (http://www.environ.ie/en/Environment/Waste/LandfillLevy/)

Department of the environment, heritage and local government, (1998). *Changing Our Ways waste report 1998.* (http://www.epa.ie/downloads/pubs/waste/plans/EPA_changing_our_ways_1998.pdf)

Department of the environment, heritage and local government, (2004). *National overview of waste management plans.* (http://www.environ.ie/en/Environment/Waste/PublicationsDocuments/FileDownLoad,1465,en.pdf)

Department of the environment, heritage and local government, (2009). *International Review of Waste Management Policy: Summary Report.* (http://www.environ.ie/en/Publications/Environment/Waste/WasteManagement/FileDownLoad,21596,en.pdf)

Department of the environment, heritage and local government, (2006). *Best practice guidelines on the preparation of waste management plans for construction and demolition projects.* (http://www.envirocentre.ie/includes/documents/BPGConstructionand%20demolition.pdf)

Department of the environment, heritage and local government, (2011). *Market development programme for waste resources 2007 – 2011.* (http://www.environ.ie/en/Publications/Environment/Waste/WasteManagement/FileDownLoad,3550,en.pdf)

Department of Trade and Industry, (2004). *Site Waste Management Plans - Guidance for Construction Contractors and Clients.* (http://www.constructingexcellence.org.uk/pdf/document/sitewastemanagement.pdf)

Dhir, R., Paine, K., Dyer, T., Tang, A., (2004). *Value-added recycling of domestic, industrial and construction arisings as concrete aggregate.* Concrete Engineering International, Volume 8, Issue 1, Pages 43-48.

Duran, X., Lenihan, H., and O'Regan, B., (2005). *A model for assessing the economic viability of construction and demolition waste recycling—the case of Ireland.* (http://0-www.sciencedirect.com.library.gmit.ie/science/article/pii/S0921344905001242)

Environment Heritage and Local Government, (2011). *Draft Statement of Waste Policy - For Consultation.* (http://www.environ.ie/en/Publications/Environment/Waste/WasteManagement/FileDownLoad,23397,en.pdf)

Environment, community and local government, (2011). *Towards a new National Waste Policy Discussion Document August 2011.* (http://www.environ.ie/en/PublicationsDocuments/FileDownLoad,27540,en.pdf)

Environmental Protection Agency, (1995). *National Waste Database - Report for 1995.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_National_Waste_Report_19952.pdf)

Environmental Protection Agency, (2000). *National Waste Database Report 1998.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_national_waste_report_1998.pdf)

Environmental Protection Agency, (2002). *Environmental RTDI Programme 2000 – 2006 - A strategy for developing recycling markets in Ireland.* (http://www.epa.ie/downloads/pubs/research/waste/epa_recycling_markets_ertdi7_synthesis.pdf)

Environmental Protection Agency, (2002). *European waste catalogue and hazardous waste list.* (www.environ.ie/en/Publications/Environment/Waste/WEEE/FileDownLoad,1343,en.df)

Environmental Protection Agency, (2003). *National Waste Database Report 2001.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_national_waste_database_2001.pdf)

Environmental Protection Agency, (2005). *National Waste Report 2004.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_national_waste_report_2004.pdf)

Environmental Protection Agency, (2005). *The Nature and Extent of Unauthorised Waste Activity in Ireland.* (http://www.epa.ie/downloads/pubs/waste/unauthorisedwaste/epa_unauthorised_waste_activities.pdf)

Environmental Protection Agency, (2006). *National Waste Report 2005: Data Update.* (http://www.epa.ie/downloads/pubs/waste/stats/National%20Waste%20Report%202005.pdf)

Environmental Protection Agency, (2007). *National Waste Report 2006.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_national_waste_report_20063.pdf)

Environmental Protection Agency, (2009). *National Waste Report 2007.* (http://www.epa.ie/downloads/pubs/waste/stats/National_Waste_Report_2007.pdf)

Environmental Protection Agency, (2009). *National Waste Report 2008.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_National_Waste_Report_2008.pdf)

Environmental Protection Agency, (2010). *Focus on landfilling in Ireland.* (http://www.epa.ie/downloads/pubs/waste/stats/49017%20EPA%20Licensed%20Landfills%20(Web).pdf)

Environmental protection agency, (2010). *National waste report 2010.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_NWR_2010_web.pdf)

Environmental Protection Agency, (2011). *National Waste Report 2009.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_NWR_09_web.pdf)

Environmental Protection Agency, (2011). *Waste figures for 2009 show Ireland is well advanced towards achieving its EU waste objectives.* (http://www.epa.ie/news/pr/2011/february/name,30615,en.html)

Environmental Protection Agency, (2012). *Best Practice Guidance for Waste Data Management.*

(http://www.epa.ie/downloads/forms/wreport/nwr/EPA_Guidance_Manual_NWR11_LA_Survey.pdf)

Environmental Protection Agency, (2012). *EPA National Waste Report 2010- Ireland meets targets for most EU Directive requirements.* (http://www.epa.ie/news/pr/2012/name,31967,en.html)

Environmental Protection Agency, (2012). *Ireland's Environment - An Assessment 2012.* (http://www.epa.ie/downloads/pubs/indicators/00061_EPA_SoE_2012.pdf)

Environmental Protection Agency, (2012). *National Waste Report 2010.* (http://www.epa.ie/downloads/pubs/waste/stats/EPA_NWR_2010_web.pdf)

Esin, T., and Cosgun, N., (2007). *A study conducted to reduce construction waste generation in Turkey.* Building and Environment, Volume 42, Issue 4, Pages 1667-1674.

European Commission, (1989). *European Community Strategy for Waste Management of 1989 (SEC(89) 934 Final 1989).* (http://aei.pitt.edu/5679/1/5679.pdf)

European Commission, (2005). *Thematic Strategy on the Prevention and Recycling of Waste.* (http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0013:FIN:EN:PDF)

European Commission, (2005). *Thematic Strategy on the sustainable use of natural resources.* (http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0670:FIN:EN:PDF)

European Commission, (2008). *End of waste criteria, final report.* (http://susproc.jrc.ec.europa.eu/documents/Endofwastecriteriafinal.pdf)

European Commission, (2010). *Being wise with waste: the EU's approach to waste management.* (http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf)

European Commission, (2010). *Ireland asked to comply with court ruling on waste management.* (http://ec.europa.eu/ireland/press_office/media_centre/sept2010_en.htm#3)

European Commission, (2011). *Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions on the thematic strategy on the prevention and recycling of waste.*(http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0013:FIN:EN:PDF)

European Commission, (2011). *Roadmap to a Resource Efficient Europe.* (http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf)

European Commission, (2012). *Guidance on the interpretation of key provisions of Directive 2008/98/EC on waste.* (http://ec.europa.eu/environment/waste/framework/pdf/guidance_doc.pdf)

European Environment Agency, (2012). *Material Resources and Waste - 2012 Update.* (http://www.eea.europa.eu/publications/material-resources-and-waste-2014)

European Environmental Agency, (2012). *Environmental Terminology and Discovery Service.* (http://glossary.eea.europa.eu/EEAGlossary/W/waste_minimisation)

European Parliament, (2008). *Directive 2008/98/EC of the European parliament and of the council of 19 November 2008 on waste and repealing certain Directives.* (http:/eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0003:EN:PDF)

European Union, (1991). *Construction and demolition waste - the European Union priority waste streams programme.* (http://infohouse.p2ric.org/ref/17/16592.pdf)

European Union, (1991). *Council Directive 91/156/EEC of 18 March 1991 amending Directive 75/442/EEC on waste Official Journal*, Pages 32 - 37 (http://faolex.fao.org/docs/texts/eur38116.doc)

European Union, (2006). *Directive 2006/12/EC of the European parliament and of the council of 5 April 2006 on waste.* (http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:114:0009:0021:en:PDF)

European Union, (2010). *Being wise with waste: the EU's approach to waste management.* (http://ec.europa.eu/environment/waste/pdf/WASTE%20BROCHURE.pdf)

FÁS and CIF, (2002). *Construction and demolition waste management - A handbook for contractors & site managers.* (http://www.ncdwc.ie/html/documents/FAS_CIFHandbookonConstructionandDemolitionWasteManagement.pdf)

Fehrs, J.E., (1996). *Characterization of construction and demolition wood waste.* Proceedings of the conference on the use of recycled wood and paper in building applications, Pages 21-23.

Ferguson, J., (1994). *Waste from Construction and Duty of Care.* Proceedings of the ICE - Municipal Engineer, Volume 103, Issue 1, Pages 23 –29.

Forfás, A (2003) *Key waste management issues in Ireland.* (http://www.forfas.ie/media/forfas030701a_waste_management_update.pdf)

Forfás, B (2003) *Key waste management issues in Ireland.* (http://www.forfas.ie/media/forfas030701a_waste_management_update.pdf)

Forfás, IDA Ireland and Enterprise Ireland, (2010). *Consultation on draft statement of waste policy and Section 60 direction on a proposed cap to incineration capacity.* (http://www.forfas.ie/media/Submission%20to%20Consultation%20on%20Draft%20Statement%20of%20Waste%20Policy.pdf)

Formoso, T.C., Soibelman, M.L., Cesare, C.D., and Isatto, E.L., (2002). *Material waste in building industry: main causes and prevention.* Construction Engineer Manager Volume 4, Pages 316–325.

Forum for the construction industry – Task force B4. (2001). Recycling of construction and demolition waste. (http://www.ncdwc.ie/html/documents/FinalDoc-annualreport.pdf)

Fried, A.N., Marrocchino, E., Bradsell, C., and Roberts, J., (2005). *Unreinforced solid dense concrete block walls constructed using thin joint technology.* Structural Engineer, Volume 83, Issue 12, Pages 33-37.

Frost and Sullivan, (2011). *Strategic Analysis of the European Recycled Materials and Chemicals Market in Construction Industry.* (http://www.frost.com/prod/servlet/report-toc.pag?repid=M579-01-00-00-00)

Gamage, L.S.W., Osmani, M., and Glass, J., (2009). *An investigation into the impact of procurement systems on waste generation: The contractors' perspective.* Association of Researchers in Construction Management, ARCOM 2009 - Proceedings of the 25th Annual Conference, Pages 1031-1040.

Gonçalves, E., (2010). *One Planet Living - Innovative Partnerships for Sustainability, Development and Conservation.* (http://www.oneplanetliving.org/index.html)

Goodier, C.I., and Gibb, A.G.F., (2005). *Barriers and opportunities for offsite in the UK.* Systematic Innovation in the Management of Project and Processes, Helsinki -International Joint Symposium, Pages 148-158.

Grath, C.M., (2001). *Waste minimisation in practice.* Resources, Conservation and Recycling - Volume 32, Issues 3–4, Pages 227–238.

Greenwood, R.N., (2000). *Construction Waste Minimisation, Sustainable Energy and Environmental Technologies.* Pages 535-540.

Guthrie, P., (1995). *Waste Minimization and Recycling in Construction: A Review.* Construction Industry Research & Information Association, London.

Høseggen, R., Mathisen, H.M., and Hanssen, S.O., (2009). *The effect of suspended ceilings on energy performance and thermal comfort.* Energy and Buildings, Volume 41, Issue 2, Pages 234-245.

Huang, D., Xu, J., and Zhang, S., (2011). *Valuing the health risks of particulate air pollution in the Pearl River Delta, China.* Environmental Science & Policy - Volume 15, Issue 1, Pages 38–47.

Institution of Civil Engineers, (2008). *Demolition Protocol.* (http://www.ice.org.uk/getattachment/eb09d18a-cb12-4a27-a54a-651ec31705f1/Demolition-Protocol-2008.aspx)

Jaillon, L., Poon, C.S., and Chiang, Y.H., (2009). *Quantifying the waste reduction potential of using prefabrication in building construction in Hong Kong.* Waste Management, Volume 29, Issue 1, Pages 309-320.

Jasch, C., (2000). *Environmental performance evaluation and indicators.* Journal of Cleaner Production - Volume 8, Issue 1, Pages 79–88.

Just, R.E., Netanyahu, S., Olson, L.J., (2004). *Depletion of natural resources, technological uncertainty, and the adoption of technological substitutes.* (http://0-www.sciencedirect.com.library.gmit.ie/science/article/pii/S092876550400051X)

Kay, T., and Essex, J., (2009). *Pushing Reuse – Towards a low carbon construction industry.* Bioregional Development Group. Pages 4-29.

Knoeri, C., Binder, C.R., Althaus, H.J., (2011). *Resources, Conservation and Recycling*, Volume 55, Issue 11, Pages 1039-1050.

Knoeria, C., Binderb, C.R., and Althaus, H.J., (2011). *Decisions on recycling: Construction stakeholders' decisions regarding recycled mineral construction materials.* Resources, Conservation and Recycling - Volume 55, Issue 11, Pages 1039–1050.

Kuhre, W.L., (1998). *ISO 14031 – Environmental Performance Evaluation (EPE): Practice Tools and Techniques for Conducting an Environmental Performance Evaluation.* Prentice-Hall PTR, Upper Saddle River, NJ.

Kulatunga, U., Amaratunga, D., Haigh, R., and Rameezdeen, R., (2006). *Attitudes and perceptions of construction workforce on construction waste in Sri Lanka.* Management of Environmental Quality: An International Journal, Volume 17 Issue 1, Pages 57 – 72.

Lai, T., (2009). *Structural behaviour of BubbleDeck Slabs and their Application to Lightweight Bridge Decks.* Massachusetts Institute of Technology.

Lauritzen, E.K., (1994). *Economic and environmental benefits of recycling waste from the construction and demolition of buildings.* Industry and Environment - Volume 17, Issue 2, Pages 26-31.

Lazarus, N., (2005). *Potential for reducing the environmental impact of construction materials.* Bioregional Development Group, Pages 4-12.

Lazarus., N and Hilary, R., (2006). *Reclaimed building materials in the development of the Thames Gateway.* Bioregional Development Group, Pages 4-10.

Lee, J.C., Edil, T.B., Tinjum, J.M., and Benson, C.H., (2010). *Quantitative assessment of environmental and economic benefits of recycled materials in highway construction.* (http://0-trb.metapress.com.library.gmit.ie/content/00n008r378l51263/)

Lesser, J., Dodds, D., and Zerbe, R., (1997). *Environmental economics and policy.* Addison-Wesley, Reading, USA

Life Environment Programme, (2004). *Recovering and recycling construction and demolition waste.* A Summary Report of the Life Environment Programme.

LIFE98 ENV/IRL/000495, (2003). *Technical final report - Recovering and recycling construction and demolition waste.* (http://www.europabook.eu/projects/3159/demcon-2020-recovering-and-recycling-construction-and-demolition-waste)

Malmborg, F.V., (2004). *Networking for knowledge transfer: towards an understanding of local authority roles in regional industrial ecosystem management.* Business Strategy and the Environment, Pages 334–346.

Masudi, A.F., Rosmani, C., Hassan, C., Mahmood, N.Z., Mokhtar, S.N., and Sulaiman, N.M., (2011). *Quantification methods for construction waste generation at construction sites: A review.* Advanced Materials Research, Volumes 163-167, Pages 4564-4569.

Matthew B. Miles M.B., and Huberman, A.M., (1994). *Qualitative Data Analysis: An Expanded Sourcebook.* (http://www.eurosphere.uib.no/knowledgebase/workingpapers.htm)

Merino, M.D.R., Navarro, J.G., and Sáez, V., Paola, (2011). *Legal aspects which implement good practice measures in the management of construction and demolition waste.* Open Construction and Building Technology Journal, Volume 5, Issue 2, Pages 124-130.

Monahan, J., and Powell, J.C., (2010). *An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework.* Energy and Buildings - Volume 43, Issue 1, Pages 179–188.

Monahan, J., and Powell, J.C., (2011). *An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework.* Energy and Buildings, Volume 43, Issue 1, Pages 179-188.

Muldera, E., de Jongb T.P.R., and Feenstra, L., (2007*). Closed Cycle Construction: An integrated process for the separation and reuse of C&D waste.* Wascon 2006 6th International Conference: Developments in the re-use of mineral waste. Volume 27, Issue 10, Pages 1408–1415.

Najama, A., Rahmanb, A.A., Huqc, S., and Sokona, Y., (2003). *Integrating sustainable development into the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Climate Policy - Volume 3, Supplement 1, Pages S9 - S17.

O'Brien, R., (1998). *An overview of the methodological approach of action research.* (http://www.web.ca/robrien/papers/arfinal.html)

Odeleye, D., and Menzies, B., (2010). *Sustainable materials: Issues in implementing resource efficiency - UK policy and planning perspective.* 2nd International Conference on Sustainable Construction Materials and Technologies, Pages 1707-1718.

OECD/Eurostat, (2005). *OECD-Eurostat Joint Questionnaire on waste.* (http://archive.basel.int/text/con-e.pdf)

Ofori, G., and Ekanayake, L.L., (2003). *Material waste management in Singapore construction.* Proceedings of CIB Working Commissions International Symposium-Knowledge Construction.

Oireachtas, (2011*). Written Answers - Waste Disposal. Dáil Éireann Debate Vol. 741 No. 1*. (http://debates.oireachtas.ie/dail/2011/09/21/00093.asp)

Oladiran J., and Olatunji, J., (2009). *Innovative Waste Management Through the Use of Waste Management Plans on Construction Projects in Nigeria.* Architectural Engineering and Design Management, ISSN 1745-2007, Volume 5, Issue 3, Page 165.

Oladiran, O.J., (2004). *Implementation of Waste Management Plan: Importance, Contents, Procedures, Problems and Solutions.* Department of Building, Faculty of Environmental Sciences, University of Lagos, Akoka Yaba, Lagos, Nigeria.

Osmani, M., (2012). *Construction waste minimization in the UK: Current pressures for change and approaches.* Procedia - Social and Behavioural Sciences, Volume 40, Pages 37-40.

Osmani, M., Glass, J., and Price, A., (2006). *Architect and contractor attitudes to waste minimisation.* Proceedings of the Institution of Civil Engineers : Waste and Resource Management, Pages 65–72.

Osmani, M., Glass, J., and Price, A.D.F., (2007). *Architects' perspectives on construction waste reduction by design.* Waste Management - Volume 28, Issue 7, Pages 1147–1158.

Oxford University, (2012). *Oxford Dictionary.* (http://oxforddictionaries.com/definition/english/arisings)

Pachpor, P.D., Gupta, L.M., Deshpande, N.V., and Bedi, K., (2011). *Parametric study of castellated beam.* Advanced Materials Research, Volume 163-167, Pages 842-845.

Pachpor, P.D., Mittal, N.D., Gupta, L.N., and Deshpande, N.V., (2011). *Finite element analysis and comparison of castellated & cellular beam.* Advanced Materials Research, Volume 264-265, Pages 694-699.

Padfield, R., Papargyropoulou, E., Preece, C., and Abdullah, A.A.B., (2011). *Sustainable Construction Waste Management In Malaysia: A Contractor's Perspective.* Management and Innovation for a Sustainable Built Environment.

Pan, W., Gibb, A.F., and Dainty, A.R.J., (2007). *Perspective of UK house builders on the use of offsite modern methods of construction.* Construction Management and Economics, Volume 25, Issue 2, Pages 183-194.

Pan, W., Gibb, A.F., and Dainty, A.R.J., (2008). *Leading UK house builders' utilization of offsite construction methods.* Building Research and Information, Volume 36, Issue 1, Pages 56-67.

Pan, W., Gibb, A.G.F., and Sellars, A.B., (2010). *Maintenance cost implications of utilizing bathroom modules manufactured offsite.* Construction Management and Economics - Volume 26, Issue 10, Pages 1067-1077.

Pearce, D., and Turner, R., (1990). *Economics of natural resources and the environment.* International monetary fund – Joint library.

Planning and development act, (2000). *Irish statute book - planning and development act, 2000.* (http://www.irishstatutebook.ie/2000/en/act/pub/0030/index.html)

Plastics Europe, (2012). *Analysis of recovery of plastic waste in the building and construction sector 2010.* (http://www.plasticseurope.org/documents/document/20120316100543summary_of_plastic_b&c_waste_management_analysis160312.pdf)

Pongrácz, E., Phillips, P.S., and Keiski, R.L., (2004). *Evolving the Theory of Waste Management – Implications to waste minimization.* (http://www.oulu.fi/resopt/wasmin/pongracz5.pdf)

Price J.L. and Joseph, J.B., (2000). *Demand management – a basis for waste policy: a critical review of the applicability of the waste hierarchy in terms of achieving sustainable waste management.* Sustainable Development Volume 8, Issue 2, Pages 96-105.

Price, T., (2010). *Site waste management plans, the designer and the CDM principal contractor.* Association of Researchers in Construction Management, ARCOM 2010 - Proceedings of the 26th Annual Conference, Pages 1381-1390.

Railway Procurement Agency, (2007). *Appendix 15a: Construction and Demolition Waste Management Plan.* (http://www.rpa.ie/Documents/Railway%20Orders/Luas%20Line%20A1%20Railway%20Order/A1%20EIS%20for%20Website/LUAS%20LINE%20A1%20EIS%20APPENDIX%2015.pdf)

Rao, A., Jha, K.N., Misra, S., (2006). *Use of aggregates from recycled construction and demolition waste in concrete.* (http://0www.sciencedirect.com.library.gmit.ie/science/article/pii/S0921344906001315)

Reddy, B.V.V., and Jagadish, K.S., (2002). *Embodied energy of common and alternative building materials and technologies.* Energy and Buildings - Volume 35, Issue 2, Pages 129–137.

Rx3 - Rethink, Recycle, Remake, (2011). *The Irish recycled plastic waste arisings study.* (http://www.rx3.ie/MDGUploadedFiles/file/The%20Irish%20Recycled%20Plastic%20Waste%20Arisings%20Study.pdf)

Sardén, Y., and Engström, S., (2010). *Modern methods of construction: A solution for an industry characterized by uncertainty?* Association of Researchers in Construction Management, ARCOM 2010 - Proceedings of the 26th Annual Conference, Pages 1101-1110.

Sarrasin, B., (2005). *The mining industry and the regulatory framework in Madagascar: Some developmental and environmental issues.* Journal of Cleaner Production - Volume 14, Issues 3–4, Pages 388–396.

Saunders, J., and Wynn, P., (2004). *Attitudes towards waste minimisation amongst labour only sub-contractors.* Structural Survey, ISSN 0263-080X, Volume 22, Issue 3, Pages 148 – 155.

Schaefer, D.R., and Dillman, D.A., (1998). *Development of a standard email methodology.* (http://www.sesrc.wsu.edu/dillman/papers/1998/developmentofastandard.pdf)

Šelih, J., (2005). *Improvement of construction and demolition (C&D) waste management on construction sites.* Association of Researchers in Construction Management, ARCOM 2005 - Proceedings of the 21st Annual Conference, Volume 1, Pages 393-400.

SEPA and CIRIA, (2006). *The Small Environmental Guide for Construction Workers.* (www.sepa.org.uk/pdf/publications/leaflets/wastemin/env_guide_cons_workers.pdf)

Shaw, M.R., Treadaway, K.W., and Willis, S.T.P., (2003). *Effective use of building mass.* Renewable Energy, Volume 5, Issues 5–8, Pages 1028–1038.

Shen L.Y., and Tam, W.Y.V., (2002). *Implementing of environmental management in the Hong Kong construction industry.* International Journal of Project Management, Volume 20, Issue 7, Pages 535–543.

Shen, L.Y., Tam, V., Tam, C.M., and Drew, D., (2004). *Mapping approach for examining waste management on construction sites.* Journal of Construction Engineering and Management, Volume 130, Issue 4, Pages 472-481.

Shoegren, J., White, B., and Hanley, N., (2001). *Introduction to environmental economics.* Oxford University Press, Oxford.

Showalter, E.W., Mills, T., and Jarman, D., (1997). *Construction and demolition waste management: Developing a cost effective plan.* Hazardous and Industrial Wastes - Proceedings of the Mid-Atlantic Industrial Waste Conference, Pages 77-86.

Simon, F.G., (2006). *Improvement of materials efficiency for a sustainable resource management.* Materials Science Forum, Volume 539-543, Part 3, Pages 2305-2310.

Skoyles, E.R., and Skoyles, J.R., (1987). *Waste prevention on site.*

Sloman, J., (2000). *Economics.* Financial times and Prentice Hall, Essex, England.

Stanbury, W., and Thompson, F., (1995). *Toward a political economy of Government waste: First step, definitions.* Public administration review Volume 55, Issue 5, Pages 418-427.

Symonds in association with ARGUS, COWI and PRC Bouwcentrum, (1999). *Report to DGXI, European Commission - Construction and demolition waste management practices, and their economic impacts.* (http://ec.europa.eu/environment/waste/studies/cdw/cdw_chapter1-6.pdf)

Tam, V.W.Y., (2007). *Implementing a Waste-Management-Plan Method in Construction.* Fourth International Conference on Construction in the 21st Century "Accelerating Innovation in Engineering, Management and Technology."

Tam, V.W.Y., (2007). *On the effectiveness in implementing a waste-management-plan method in construction.* Waste Management - Volume 28, Issue 6, Pages 1072–1080.

Tam, V.W.Y., and Tam, C.M., (2006). *A review on the viable technology for construction waste recycling.* Resources, Conservation and Recycling, Volume 47, Issue 3, Pages 209-221.

Tam, W.Y.V., Tam, C.M., Tsui, W.S., and Ho, C.M., (2006). *Environmental indicators for environmental performance assessment in construction.* Journal of Building and Construction Management, Volume 10, Issue 1, Pages 46–56.

Taylor, M.D., Fisher, A., and Wamuziri, S.C., (2009). *A comparison of modern methods of bathroom construction: A project case study.* Association of Researchers in Construction Management, ARCOM 2009 - Proceedings of the 25th Annual Conference, Pages 1173-1182.

Teo M.M.M., and Loosemore, M., (2001). *A theory of waste behaviour in the construction industry.* Construction Management and Economics Volume 19, Issue 7.

Teo, M.M.M., Loosemore, M., Marosszeky, M., Karim K., and Gardner, D., (2000). *Operatives' Attitudes Towards Waste on Construction Project.* (http://www.arcom.ac.uk/-docs/proceedings/ar2000-509-517_Teo_et_al.pdf)

The Organisation for Economic co-operation and Development (OECD), (1998). *Final guidance document for distinguishing waste from non-waste.* (http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/EPOC/WMP(98)1/REV1&docLanguage=En)

Tibor, T., (1996). *ISO 14000: A Guide to the New Environmental Management Standards.* Irwin Professional Publication.

Tron, K., (1995). *Environmental performance evaluation - the link between management systems and reality.* International environmental management benchmarks: best practice experience from America, Japan and Europe, Pages 103-110.

Vaidya, A.S., (2009). *Lightweight composites for modular panelized construction.* Dissertation Abstracts International, Volume 70, Section B, Page 3068.

Walsh Waste, (2012). *Skip Hire.* (http://www.walshwaste.com/Services/Skip-Hire)

Waste Management Act, (1996). *Irish statute book – Waste management act 1996.* (http://www.irishstatutebook.ie/1996/en/act/pub/0010/print.html)

Working Group for Sustainable Construction, (2001). *Competitiveness of the construction industry - an agenda for sustainable construction in Europe.* (http://www.ceetb.eu/docs/Reports/Sust-con-final.pdf)

Worrell, E., Faaij, A.P.C., Phylipsen, G.J.M., and Blok, K., (1995). *An approach for analysing the potential for material efficiency improvement.* Resources, Conservation and Recycling, Volume 13, Issue 3-4, Pages 215-232.

WRAP UK, (2008). *Achieving good practice Waste Minimisation and Management.* (http://www.wrap.org.uk/sites/files/wrap/achieving%20good%20practice%20waste%20minimisation%20and%20management.pdf)

WRAP UK, (2010). *Assessing the costs and benefits of reducing waste in construction.* (http://www.wrap.org.uk/sites/files/wrap/CBA%20Summary%20Report1.pdf)

WRAP UK, (2010). *Delivering effective waste minimisation. A technical guidance for construction clients, design teams and contractors.* (http://www2.wrap.org.uk/downloads/Waste_min_Technical_FINAL1.bc26f163.4776.pdf)

WRAP UK, (2010). *Delivering good practice Waste Management.* (http://www2.wrap.org.uk/downloads/Waste_Management_Guidance_Note_8.ba8e9b67.5178.pdf)

WRAP UK, (2010). *Tipping skips case study.* (http://www.wrap.org.uk/sites/files/wrap/WRAP%20Case_Study_Report_Tipping_Skip%20approved.pdf)

WRAP UK, (2011). *Case study: Recycled content in construction - Opportunities in infrastructure.* (http://www2.wrap.org.uk/downloads/Case_study_-_waste_infrastructure_-_17.11.06.f2281599.2350.pdf)

WRAP UK, (2011). *The Net Waste Method – testing a new standard for measuring waste neutrality.* (http://www.wrap.org.uk/sites/files/wrap/Net%20Waste%20Brochure.pdf)

WRAP UK, (2012). A. *Delivering good practice Waste Management - Practical guidance for construction design teams and contractors.* (http://www.wrap.org.uk/sites/files/wrap/Waste%20man%20technical1.pdf)

Xavier D., Lenihan, H., O'Regan, B., (2005). *A model for assessing the economic viability of construction and demolition waste recycling—the case of Ireland.* (http://0-www.sciencedirect.com.library.gmit.ie/science/article/pii/S0921344905001242)

Yuan, F., Shen, L., and Li, Q., (2011). *Emerging analysis of the recycling options for construction and demolition waste.* Waste Management - Volume 31, Issue 12, Pages 2503–2511.

Yuan, H., and Shen, L., (2011). *Trend of the research on construction and demolition waste management.* Waste Management Volume 31, Issue 4, Pages 670–679.

Zhao, W., Leeftink, R.B., and Rotter, V.S., (2009). *Evaluation of the economic feasibility for the recycling of construction and demolition waste in China - The case of Chongqing.* Resources, Conservation and Recycling - Volume 54, Issue 6, Pages 377–389.

Appendices

Appendix A

Waste management plan checklist

Has time been set aside to prepare a waste management plan? ❑

Have the construction methods and materials been assessed for the amount of waste they produce? ❑

Will materials be ordered with less packaging or packaging that is returnable? ❑

Have the waste reduction decisions been recorded in the plan? ❑

Has someone been allocated the responsibility for the waste management plan? ❑

Is there a declaration from the client and main contractor in the plan? ❑

Has the type, quantity and stage when waste might occur been assessed? ❑

Have the workers which may produce waste been identified? ❑

Is there an area of the site set aside for the storage of materials and waste? Is the area secure from vandalism? ❑

Have targets been set for the quantity of waste likely to be produced? ❑

Are measures in place to deal with unexpected and expected hazardous waste? ❑

Has the reuse of materials on or off-site been considered? ❑

Has on site or of site materials processing been considered? ❑

Has consideration been given to the disposal of liquid wastes such as lubricants? ❑

Is there an agreement in place for the disposal of water and sewage? ❑

Is the duty of care being complied with? For example, are waste transfer notes being used and have the details of the waste carrier been checked? ❑

Is someone responsible for checking the waste leaving site and that the transfer notes are completed correctly? ❑

Do all locations receiving the site waste have the appropriate permits or licences? ❑

Have materials with a commercial value been identified for reuse or recycling? ❑

Have the quantities of materials been assessed in order to avoid over ordering? ❑

Can unused materials be returned to the supplier? ❑

Have recycled materials been considered? ❑

Can packaging be returned to the supplier? ❑

Will waste be separated on site? ❑

Are skips and waste containers clearly labelled or colour coded? ❑

Are the storage areas weatherproof and secure? ❑

Are loose materials netted? ❑

Is everyone aware of the waste management plan requirements? ❑

Do site inductions and toolbox talks include waste management issues? ❑

Are subcontractors aware of their responsibilities? ❑

Have all subcontractors agreed and understood the waste management plan? ❑

Are the waste management plan requirements set into the contracts? ❑

Are spot checks, monitoring and audits being carried out to ensure compliance? ❑

Is the plan being updated regularly? ❑

Are the appropriate waste management procedures being followed? ❑

Are regular reports being made on the waste quantities and the disposal routes and their costs? ❑

Are problems being recorded for use in the lessons learnt section? ❑

Is the waste management plan going to be kept for at least two years? ❑

Are the results being used to win future projects? ❑

Appendix B

Template waste management plan

Part 1 – General project details

- Person responsible for WMP.
- Client name and details of main parties.
- Principal contractor.
- Project title.
- Project location.
- Type of construction.
- Goals and aims of WMP.
- Scope of site, enabling works and associated works.
- Site layout.
- Duration of works.
- Communication routes.

Part 2 – Waste Management

- Identify the types and quantities of waste that will be produced.
- Set waste management targets and KPIs.
- Waste management system – procedures and processes.
- Identify waste management options.
- Estimated cost of waste management.
- Control and mitigation measures.
- Identify waste management sites and contractors for all wastes.
- Air quality and noise management.
- Hazardous waste management.
- Monitoring and waste auditing.
- Recording quantities and record keeping procedures.
- Demolition plans if applicable.

Part 3 – Material logistics plan

- Plan for efficient materials and waste handling.
- Traffic management.
- Key performance indicators and targets.
- Responsible persons, training & communication.
- Materials Requirement.
- Materials receipt, storage & management.
- Management of subcontractors.
- Appropriate logistical techniques.
- Site mobilization & construction.
- Project demobilization & completion.

Part 4 – Waste prevention strategies

- Waste management.
- Designing out waste.
- Procurement methods.
- Details on sub-contractor controls.
- Materials optimization.
- Re-use, recovery and recycling.
- Actions.
- Education and training of workforce.
- Measure how much waste and what types of waste are produced.

There are a variety of examples of best practice in the preparation of site waste management plans. These are included in the websites of the various organisations listed - please see the links below;

www.smartwaste.co.uk
www.ciria.org.uk
www.constructingexcellence.org
www.envirowise.gov.uk
www.greenwich-village.co.uk

www.bre.co.uk

www.carillionplc.co.uk

www.defra.gov.uk/environment

www.dti.gov.uk

www.netregs.gov.uk

www.wrap.org.uk

Appendix C

Appendix C contains tables that can be used during the implementation of good practice waste management.

Waste transfer note

Transferor. (Customer).	**Collection size.**
Customer:	**Load weight/ Volume:**
Contact name:	
Collection address:	**Job description:**
Collection date:	
Customer signature:	**Containment method:**
Print name:	

Waste type.	**EWC code.**	**Volume.**	**Weight. (kg)**
E.g. Mixed Waste	*20 03 01*	*10m3*	*250kg*

Transferee. (Waste carrier).	
Waste carrier:	**Employee signature:**
Licence number:	
Issued by:	**Employee name:**
Address:	
	Vehicle reg. number:
Telephone:	**Arrival time:**
E-mail:	**Departure time:**

Estimated waste arisings table

Work Package	Type of Waste (m³ or tonnes)													
	Con-crete	Inert	Veget-ation	Timber	Plastic	Insul-ation	Metals	Liquids	Pack-aging	Gypsum	Ceramic	Haz-ardous	Office & Canteen	Misc
Site Clearance														
Demolition														
Piling														
Drainage														
Earthworks														
Frame e.g. Timber/ Steel														
Envelope														
Glazing														
Roofing														
Mech & Elec														
Fit out														
Hard Landscaping														
Soft Landscaping														
Totals														
Grand total														

Responsibility for waste management

Works Package	Primary Waste Stream	Waste Management Responsibility
Brick and block work	*e.g. Bricks*	*Main Contractor*
Landscaping	*e.g. Topsoil & green waste*	*Main Contractor*
Office activities		
Canteen activities		
Building envelope		
Foundation and piling		
Structure		
Demolition and site clearance		
Groundwork's		
Dryliners		
Mech & Elec		
Trades		
Final clear away		

Record of waste licences and permits

			Waste Carrier			Disposal Site	
WasteDescription	**EWC Code**	**Origin**	**Name**	**Licence**	**Exp. Date**	**Name**	**Licence No.**
Canteen Waste	*e.g. 20 01 08*	*All Contractors*	*Barna Waste Ltd.*	*L12345*	*07/13*	*Barna Waste Transfer Station*	*LN12345*
C&D Waste							
Hazardous Waste							
Clinical Waste							
Topsoil etc.							

Waste Management Costs (use m³ or tonnes)

Waste Material	Waste Management Contractor	Waste Management Activity	Estimated quantity	Price Paid per unit	Price Gained per unit	Cost € +/-
Metals	*e.g. Galway Metal*	*Recycle*	*40*		*10*	*-400*
Soil						
Hardcore						
Concrete						
Timber						
Packaging						
Plasterboard						
Hazardous						

Review of waste quantities

Material	Estimated m³	Actual m³	Difference m³	Reason
Concrete	*e.g. 150*	*175*	*+25*	*Larger amount in demolition*
Green Waste				
Glass				
Canteen				
Timber				
Concrete				
Hazardous				
Plasterboard				
Pallets				
Metals				
Soil				
Hardcore				
Office				
Cable				
Insulation				
Packaging				

Mixed Waste				

Lessons Learned

1.	*e.g. Look at ways to reduce packaging during fit out stage.*
2.	
3.	
4.	
5.	
6.	
7.	
8.	Etc.

Appendix D

Site Visits Diary – Taylors Hill

4th of April

Today was the first visit to the case study site to meet with the site foreman and quantity surveyor. As part of the meeting we outlined what we would be doing on site and that I would visit more regularly once the job got up and running in order to monitor the waste management practices on site and then report back to Carey Developments on completion of the case study.

Friday 11th of May

A meeting with the managing director, Paul Carey, and other senior staff members at Carey Developments head office in Galway. Carey Developments expressed that they wanted to establish a site waste management plan as well as gaining an insight into current on site activities over the next ten weeks. Carey Developments also recently scored poorly on a job application in the area of waste management and are now looking at improving their knowledge and activities in the area of waste management. It is planned as part of this thesis to develop a waste management plan as well as a template for future use. Other documents that may be required are a carbon strategy for the company and a training manual to show how to train staff in relation to waste management. As part of the thesis site visits will be regularly made to the site in Taylors Hill and a report will be submitted to Carey Developments on completion of the project.

Tuesday 22nd May

Site visit with Dr. Mark Kelly. We had a discussion with the site foreman in order to inform him that the site visits would now become more regular. Questionnaires were given to the site foreman so that they could be distributed among the sub-contractors and then returned on completion.

Tuesday 29th of May

Visit to the site. The waste skip was empty having recently been emptied by the waste management contractor. There is a lot of wastage of mortar, useable blocks, insulation and the barrier for protecting the wall when filling in trenches. The weather today is very warm and humid and it is causing the mortar to go off very quickly resulting in high wastage. During weather of this type it may be more appropriate to use half bins of mortar in order to prevent this. There are also numerous plastic bands mixed in with the timber skip and the mini skips around the site have block waste in them. The entrance to the site today was very untidy.

Friday 1st of June

Visit to the site. Today I started to use the skip audit book which will be used for each skip on site. Due to the high wastage of insulation it is planned to contact the manufacturer in order to set up a take back scheme. (This turned out to be unsuccessful as the manufacturer does not take back waste for reuse). There is a lot of insulation being wasted.

Tuesday 5th of June

Visit to the site. Today there was very heavy rain so there is no block layer present on site. There is lots of insulation waste in the skip, some that are large in size. There are full blocks wasted around the site that could be reused. Material such as blocks and mortar waste that is being used as fill contains some rubbish and the timber skip is overflowing with waste; this will prevent the segregation of timber. The inside of the building where the work is taking place is very clean.

Friday 8th of June

Visit to the site. There was no additional rubbish in the skip. It was raining very heavily so there are no block layers or shuttering contractors working on site. There was no pictures taken today on account of the heavy rain.

Wednesday 13th of June

Visit to the site. There has been very little waste added to the skip and the waste contained in the skip is still mostly insulation and plastic packaging. Some of the insulation waste is of large and useable pieces. The timber skip is still full and overflowing; a timber skip is needed on site so that waste timber can be segregated from the general waste. There is still mortar and block waste being added to the general skip; this is bad as it drives up the weight of the skip and consequently the cost. There has been a large hole dug in the site to one corner so this will need to be monitored in order to see if any waste is placed into it and buried. The storage of some materials is poor as is the handling of materials at the work face. There were two sections of hollow core cut resulting in waste; these should have been ordered to the correct size in order to prevent this waste.

Tuesday 19th of June

Site visit with Dr. Mark Kelly. On this visit again there has been very little waste added to the skip. The carpenters have started to construct the temporary door frames in order to allow for the plasterers. The timber skip is still overflowing and it looks unlikely that this will be emptied. There are large pieces of useable DPC in the skip. There continues to be wastage of blocks but in comparison to the amount of block work on the project the wastage rates are ok. Overall the site is tidy.

Tuesday 26th of June

Visit to the site. The current waste skip is almost full and contains mostly insulation. The timber roof trusses as well as the windows and doors are now being delivered to site. The chasing for the electrical wires has started. There continues to be poor storage of materials. A new set of spot lights has been left outside and subsequently been damaged and in need of repair. There are two tele-porters operating; it should be assessed to see whether two are needed at all times. The generator is running for the concrete mixer despite no concrete being mixed. The storage containers are a mess as is the canteen and the drying room. In the drying room the dryer is on despite all the clothes already being dry.

Wednesday 4th of July

Visit to the site. Both the timber and the mixed waste skip are now overflowing. Wind-blown litter is prevalent around the skip and a cover is needed on the skip to prevent this. There is now timber being mixed in with the general waste despite its ability to be easily segregated. The large hole that was previously dug is now being filled with rubbish; this is totally unacceptable. It is evident from the block work in the hallways that some of the walls were constructed in the wrong place and now are being rebuilt in the correct spot. These walls should have been correctly constructed initially. The doors that are to be installed are being stored beneath a loading bay on the scaffolding where materials are being loaded. These doors are in danger of being damaged by falling debris. There is also poor storage of materials in other places.

Thursday 12th of July

Visit to the site. There is something not right about the waste on the site since the previous visit. The skip that is currently on site is the same skip as on the previous visit but it is now half full compared to being full on the last visit. The waste has not been compacted as I physically got into the skip and looked around for obvious pieces of waste that were on the top of the skip on a previous visit. The aforementioned hole in the ground now has a significant amount of rubbish in it and the full extent is not known as some of it is being covered over. There is some concrete wastage on the ground from concrete trucks and there is lots of insulation waste scattered around the site. The electricians have started installing wires and the trails from the sockets etc. are far too long. There is a lot of reworking and removal of block work taking place in the hallways in order to facilitate the mechanical and electrical services. Some hollow core is being placed on site and the roofing has also started. The battens on the roof that run over the felt have very long overruns which will produce a lot of useable timber waste. A water pipe that supplies water to the cement mixer is leaking and should be fixed. The window and door installer (Munster Joinery) are taking back some of their packaging (the bubble wrapping). This is a positive step towards waste minimisation but is unfortunately not dictated by the main contractor but is the installers' preference.

Wednesday 18th of July

Visit to the site. There is lots of mortar and concrete waste and again there is reworking and breaking out of block work to facilitate the electrical and mechanical services along the entire length of the corridor on two floors. The storage of blocks is poor in places and some materials are being used not for purpose; for example radon barrier is being used to cover cement bags beside the cement mixer. There are numerous pallets on site that could be reused in different applications if required.

Thursday 26th of July

Site visit with Dr. Mark Kelly. There is still lots of insulation waste that is reusable being placed in the skip. There is come insulation waste that are very similar sizes so perhaps these pieces could have been ordered to size in order to reduce waste. There continues to be waste being buried in the ground and alarmingly the quantity surveyor was driving the digger and covering up the waste when we arrived on site. There is also lots of insulation scattered around the site that should be gathered in a central location as it is still useable. There is also still mortar and concrete waste and more blocks are being broken out to allow for services. On the roofing felt there are numerous holes from careless walking on the material once it is in place; this will affect the future air tightness of the building. The toilets on site are in extremely poor condition. We were informed that so far only two skips have left the site and this adds to the theory that waste is constantly being dumped in the ground as according to my picture records there should have been at least three skips removed from the site.

3rd of August

Visit to the site carried out by Dr. Mark Kelly in the absence of the author.

10th of August

Visit to the site. The site is closed for builders holidays despite the author being told that there were no holidays taking place this year.

Tuesday 14th of August

Visit to the site. The waste skip is half full and there still continues to be a large amount of waste being buried in the ground. There are empty crates from the delivery of slates that could be reused for storage or at the very minimum recycled. The slate waste itself could be used as fill or else kept on site until the landscaping phase and used as cover in flower beds etc. there is one sample apartment finished and judging by the furnishings there will be a lot of packaging waste produced at the fit out stage. There continues to be insulation left lying around in various locations despite the work in that area moving onto a work phase that does not require this material. There is some efflorescence on some block work, this can be avoided by ensuring blocks are stored off wet soil in order to reduce water entering the blocks through capillary action. Window sills are being installed and some are required to be cut to fit; these sills should be ordered to the correct size in order to avoid this.

Wednesday 22nd of August

Visit to the site. Since the previous visit there has not been a lot of waste added to the skip. There are some large pieces of insulation in the skip which have been damaged due to poor storage and consequently have been thrown into the skip. This could have been avoided by storing the materials correctly. The same issues as recorded on previous visits continues to be prevalent with poor storage of materials and a failure to reuse materials contributing to waste production on site. An idle reduction policy is definitely needed as machinery is being left running needlessly which wastes a significant amount of diesel. This has been the last visit to the site.

Appendix E

Waste signage on site

The various colour codes for construction waste have been outlined below in accordance with standards developed in the UK. The list gives some examples of the wastes in each category and in some of the categories the waste can be further broken down.

If waste is separated on site it will help minimise the cost of waste and also maximise the opportunities to recover and recycle the waste.

Please watch out for these signs on site which will help you identify which waste container you should be using for each particular waste. Please note that note all of these may be used on your site.

INERT	Concrete, hard-core, rubble, blocks and bricks, soils and clay etc. This is for materials that will not decompose or create a hazard if buried.
METAL	Re-bar offcuts and scrap metal. Only un-contaminated metals, for example empty paint tins are not acceptable.
MIXED	Un-segregated waste or site litter. All waste that cannot be recycled and which is not contaminated.
GYPSUM	(White background). Plasterboard and any other gypsum products. This waste must not become contaminated.
WOOD	Timber and wood products. This waste should not contain wood which has been treated.

PACKAGING	(Brown) Cardboard, paper, plastic, shrink wrap etc.
HAZARDOUS	(Orange) Hazardous waste or contaminated waste such as Asbestos, old paint tins and used mastic tubes.
GLASS	All glass waste for example broken window glazing.
BIOHAZARD	An example would be hospital waste. During refurbishment or demolition of healthcare facilities exposure may occur.
OTHER	For example WEEE must be separated from other waste and must not be sent to landfill.

Appendix F

Chapter 17 – European waste catalogue

Construction and Demolition Waste (including excavated soil from contaminated sites)

17 01 Concrete, bricks, tiles, ceramics

17 01 01 Concrete

17 01 02 Bricks

17 01 03 Tiles and ceramics

17 01 06* Mixtures of, or separate fractions of concrete, bricks, tiles and ceramics containing dangerous substances

17 01 07 Mixture of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06

17 02 Wood, glass and plastic

17 02 01 Wood

17 02 02 Glass

17 02 03 Plastic

17 02 04* Glass, plastic and wood containing or contaminated with dangerous substances

17 03 Bituminous mixtures, coal tar and tarred products

17 03 01* Bituminous mixtures containing coal tar

17 03 02 Bituminous mixtures containing other than those mentioned in 17 03 01

17 03 03* Coal tar and tarred products

17 04 Metals (including their alloys)

17 04 01 Copper, bronze, brass

17 04 02 Aluminium

17 04 03 Lead

17 04 04 Zinc

17 04 05 Iron and Steel

17 04 06 Tin

17 04 07 Mixed metals

17 04 09* Metal waste contaminated with dangerous substances

17 04 10* Cables containing oil, coal tar and other dangerous substances

17 04 11 Cables other than those mentioned in 17 04 10

17 05 Soil (including excavated soil from contaminated sites), stones and dredged 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 waste containing mercury

17 09 02* Construction and demolition waste containing pcb (for example pcb-containing sealants, pcb-containing resin-based floorings, pcb-containing sealed glazing units, pcb-containing capacitors)

17 09 03* Other construction and demolition wastes (including mixed wastes) containing 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

* Any waste marked with an asterik (*) is considered as a hazardous waste pursuant to Directive 91/689/EEC on hazardous waste (European Waste

Catalogue and Hazardous Waste List (valid from 1/1/2002) Environmental Protection Agency, Ireland).

Appendix G

Eirebloc

Eirebloc is the newest entrant to the composite block manufacturing business in Europe.

In the period leading up to commencement, we conducted in-depth research into new ways of cleansing waste wood in preparation for use as a recycled raw material. Our project was born out of this research which was conducted in conjunction with the Life programme of the European Union. Commercial operations then commenced in a new, purpose-built factory in Cork, Ireland in 2008.

The business is a joint venture between Mid Cork Pallets & Packaging Ltd and Palfab Ltd - two highly successful players in the pallet manufacturing and timber processing industries for the past 35 years. Our combined activities, in various facets of timber- based industry, support the employment of about 300 people and bring over three decades of specialised knowledge, experience and entrepreneurial flair to the direction of Eirebloc.

The involvement of our owners in automated pallet manufacturing and production of pallet components over a long period brings to Eirebloc a keen insight into the nuances of the process. In particular, they bring an incisive appreciation of the vital importance of adherence to the fine tolerances (dimensional accuracy, moisture content, block density etc) that collectively determine the class of the finished product.

Our future expansion in the business lies squarely on our ability to reach buyers who expect quality as a given by disseminating the key message that ours is a constant search for perfection.

Our task is to keep our product positioned at the cutting edge of technological advancements in the industry worldwide. To this end, we continue to maximize use of our original research and development facilities, which are dedicated to monitoring and refining existing products and systems and probing new ways of improving product performance.

Environmental

Eirebloc is committed to a role of environmental leadership in all facets of the business. We fulfil this mission by a commitment to:

- Understanding environmental issues.
- Recognising that with business activity comes environmental responsibility.
- Developing innovative and flexible solutions to bring about change.
- Striving to buy and sell environmentally friendly products.
- Encourage all customers and suppliers to share in our mission.

Our Life Cycle Analysis study has concluded that using recycled wood enabled a 33% reduction in the environmental load when vetted against the use of virgin wood. As a significant portion of our raw material is recovered from construction and demolition wood and end-of-life packaging and pallet material, we take pride that we are true to our environmental best instincts.

Eirebloc's commitment to the environment is borne out of its involvement in two EU LIFE-Environment projects, Tyre-Wood Block and Clean Wood. Both of these projects are now completed and have had a significant impact on the processes and systems used in Eirebloc. Further details can be found under the Links page.

In March 2011, Eirebloc achieved FSC certification as further evidence of its commitment to the environment. The FSC is an independent international network promoting the responsible management of the world's forests. The FSC sets international standards for responsible forest management, and accredits independent third-party organizations that certify forest managers and forest-product producers to these standards. Eirebloc's is proud to have achieved the FSC standard for its composite pallet blocks.

Advantages

Characteristics	Benefits to user
Dimensions are consistently more accurate than solid block could ever be.	Enables automated pallet manufacturing lines to operate at faster speeds with a corresponding improvement in unit cost efficiencies.
Blocks sold pre-cut to exact size.	Significant saving in costs of handling, sawing and waste.
Superior nail retention qualities.	Longer life, safer handling.
Exceptionally low moisture content.	Decreases weight and so improves unit carriage costs, reduces risk of mould growth and is therefore more hygienic.
Splitting during nailing is eliminated.	Enhances safety and longevity.
Uses recycled materials.	Positive environmental profile.
Matches latest international phytosanitory standards.	Bacteria growth and other pests eliminated.
Readily moulded into a wide variety of shapes.	High degree of flexibility to satisfy customer expectations.
Highly competitive price.	Significant unit cost savings.

Product range

Current product range

Length (mm)	Width (mm)	Height (mm)	Blocks per pallet	
95	95	70	2,016	
95	95	75	2,016	
95	95	78	2,016	
95	95	90	1,728	
95	95	95	1,632	
145	100	78	1,512	
145	100	90	1,296	
145	100	95	1,224	

Appendix H

Skip audit dockets

Appendix I

Copy of questionnaire

Appendix J

Copy of questionnaire results

Appendix K

Copy of phone call results

These appendices are contained in the following pages.