

https://dspace.org/

Developing a self-sustaining secondary construction materials market in South Africa

Macozoma, Dennis Skhumbuzo

2008-03-11T08:29:23Z
http://hdl.handle.net/10539/4640

Downloaded from a DSpace repository. https://dspace.org/

DEVELOPING A SELF-SUSTAINING SECONDARY CONSTRUCTION MATERIALS MARKET IN SOUTH AFRICA

Dennis Skhumbuzo Macozoma

A dissertation submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, to fulfil the requirements for the degree of Master of Science in Engineering.

Johannesburg 2006

Prepared by:

D. S. MACOZOMA

Student number: 9302094T

Department of Transport

Telephone: (012) 309 3170/3242

Facsimile: (012) 309 3948

Date:

December 2006

ACKNOWLEDGEMENTS

The author wishes to thank his supervisors Professor Y. Ballim, Deputy Vice Chancellor (Academic), and previously Head of the School of Civil and Environmental Engineering, at the University of the Witwatersrand, and Professor L Dison of Reinforced Earth Mining Services for all the guidance, comments and discussions held on the topic of this research project.

The author also wishes to thank the International Council for Research and Innovation in Building and Construction (CIB) for the opportunity to initiate research in the areas of Sustainable Construction, and Construction and Demolition Waste Management through a fellowship to the University of Florida, USA in June 2001.

The author specifically wishes to thank Professor Charles J Kibert and Dr Abdol Chini of the University of Florida, USA; and other members of the CIB Task Group 39 on Building Deconstruction and Material Reuse.

Finally the Author wishes to acknowledge support provided by the CSIR Building and Construction Technology at the early stages of the research work in the areas of Sustainable Construction, and Construction and Demolition Waste Management.

ABSTRACT

Sustainable development has become part of Government policy across the world. In the construction industry it has been introduced through the promotion of "sustainable construction" or "green construction". International trends show a gradual move away from wasteful construction industry practices that include high resource consumption, material wastage, inefficiencies in construction processes and a high percentage of waste that find its way to waste disposal sites and illegal dumps. This research report seeks to promote sustainable construction and waste minimisation as preferred models for achieving a balance in the economic, social and environmental impacts of development. It reviews South Africa's construction and demolition site practice from the perspective of construction and demolition waste management, assessing waste management practice and the resultant waste disposal. To gauge South Africa's performance it benchmarks South African practice against those of the United States, United Kingdom, Germany and the Netherlands. This approach highlights gaps in South Africa's current practice and also provides some valuable lessons that can be used to ensure compliance with sustainable construction principles. Finally the research report proposes a framework for developing a self-sustaining secondary construction materials market in South Africa, which can prove to be a valuable tool for ensuring the absorption of sustainable construction in the construction industry.

CONTENTS

ACKNOWLEDGEMENTS 3
ABSTRACT 4
CHAPTER1: CONTEXT 8
1.1 Rationale for Research Project – Main Argument 9
1.2 Problem Statement 10
1.3 Aim and Objectives 12
1.4 Methodology 13
1.5 Definition of Construction and Demolition (C&D) Waste 14
CHAPTER 2: BACKGROUND 18
2.1 Overview of sustainable development, sustainable construction and sustainable waste management 19
2.1.1 Sustainable Development 19
2.1.2 Sustainable Construction 20
2.1.3 Sustainable Waste Management 22
2.2 Construction 24
2.3 Demolition 27
2.4 Waste Management 30
CHAPTER 3:REVIEW OF CURRENT C&D WASTE MANAGEMENT PRACTICE 37
3.1 Introduction 38
3.2 Generation and Storage 38
3.2.1 South Africa 39
3.2.2 Other Countries 40
3.3 Composition 41
3.3.1 South Africa 42
3.3.2 Other Countries 42
3.4 Quantities 46
3.4.1 South Africa 46
3.4.2 Other countries 50
3.5 Collection and Transportation 52
3.6 Waste Disposal 53
3.6.1 South Africa 53
3.6.2 Other Countries 55
3.7 Waste Recovery, Reuse and Recycling 58
3.7.1 Waste Recovery 58
3.7.2 Reuse 59
3.7.3 Recycling 59
3.7.4 South Africa 60
3.7.5 Other Countries 62
3.8 Review of the Regulatory Environment 70
3.8.1 South Africa 70
3.8.2 Other Countries 73
3.9 Review of secondary construction materials markets 81
3.9.1 South Africa 81
3.9.2 Other Countries 91
3.10 Lessons for South Africa 95

CHAPTER 4: STRATEGIES FOR SUSTAINABLE C&D WASTE MANAGEMENT 98
4.1 Construction sites 99
4.1.1 Waste avoidance 99
4.1.2 Waste specifications 101
4.1.3 Model contract language 103
4.1.4 Waste management plans 106
4.1.5 Plan implementation 115
4.1.6 Support 116
4.2 Demolition sites 119
4.2.1 Building deconstruction 119
4.2.2 Waste material salvage 126
4.3 Implications for waste management 127
CHAPTER 5: SURVEY – CONSTRUCTION INDUSTRY C&D WASTE MANAGEMENT PRACTICE 129
5.1 Introduction 130
5.2 Survey questionnaire 130
5.3 Response rate 131
5.4 Findings 132
5.4.1 Construction activities 132
5.4.2 Waste management activities 133
5.4.3 Environmental issues 134
5.4.4 Economics of reuse, recycling and secondary markets 135
5.4.5 Regulations standards and specifications 136
5.4.6 Role of Government 136
5.4.7 Public awareness and perceptions 137
5.5 Summary 138
CHAPTER 6: PROPOSED FRAMEWORK FOR DEVELOPING A SELF-SUSTAINING SECONDARY CONSTRUCTION MATERIALS MARKET IN SOUTH AFRICA 140
6.1 Introduction 141
6.2 Status of materials flow in construction 141
6.3 Establishing a secondary construction materials market 145
6.3.1 Identification of priority commodities 146
6.3.2 Identification of stakeholders 147
6.3.3 Materials flow analysis 148
6.3.4 Waste characterisation study 149
6.3.5 Enabling environment 150
6.3.6 Market development initiatives 152
6.3.7 Technology options 153
6.3.8 Administration, information and communication systems 154
6.3.9 Incentives 155
6.3.10 Promotion of best practice 156
6.4 Ensuring successful implementation of the proposed framework 157
CHAPTER 7: CONTRIBUTION OF RESEARCH PROJECT AND FURTHER WORK 159
7.1 Research report 160
7.2 Further research work 161
CONCLUSIONS AND RECOMMENDATIONS 163
Conclusions 164

Recommendations....168
REFERENCES....172
APPENDIX....176
A1. WASTE ANALYSIS AND ASSESSMENT....177
A2. WORKSHEETS FOR WASTE ANALYSIS AND RECYCLING ANALYSIS....179
A3: SAMPLE WASTE MANAGEMENT PLAN....181
A4. PRINCIPLES OF DESIGN FOR DECONSTRUCTION AND THE HIERARCHY OF RECYCLING....183
A5. MATERIAL CONSIDERATIONS....186
A6. SURVEY QUESTIONNAIRE....187

CHAPTER1: CONTEXT

1.1 Rationale for Research Project – Main Argument

Sustainable development is now an established part of Government policy across the world. Since its origins in the Brundtland Report in 1987, it has found application in many sectors and industries and has had various interpretations, all underpinned by a common imperative to balance the economic, social and environmental impacts of development. In the construction industry it has been adopted through the promotion of what is termed "Sustainable Construction" or "Green Construction". As will be explained later, this approach calls for the regeneration of construction industry activities from the perspective of the entire life-cycle of buildings and/or civil structures.

Much work has been done from the days when sustainable construction or even sustainable development was hypothesised, debated and proven to work. This study is not intended to question or advance the theoretical basis for the introduction or promotion of sustainable development and its manifestation in the construction industry (i.e. sustainable construction). Having done prior research in the area of sustainable construction, and having seen its application in practice elsewhere (e.g. United Stated, Germany and so on), the author seeks to promote the adoption of sustainable construction in South Africa in order to strengthen the construction industry's contribution to environmental protection and economic development. This research project intends to demonstrate opportunities for construction process improvement, secondary material recovery and waste minimisation to enable the development of a viable secondary construction materials market, to enable positive

economic spin-offs from "green" construction activities, and to enable the preservation of the environment.

The author's contribution to the field of sustainable construction thus far has been the assessment of international best practice in improving construction site and demolition site activities in line with the principles of sustainable construction, and the consolidation of this information into single point reference manuals for use by those interested in adopting this approach, particularly developing countries. The two manuals produced in 2001 i.e. "Building Deconstruction" and "Construction Site Waste Management and Minimisation" were published under the auspices of the International Council for Research and Innovation in Building and Construction (CIB) and are now available for use across the world[1]. Through this research project the author intends to further contribute to the field by proposing a framework that can be used by South Africa to create a viable secondary construction materials market, which will be a valuable tool to ensuring the absorption of sustainable construction by the construction industry.

1.2 Problem Statement

The construction industry generates a considerable amount of waste in the various stages of the construction, demolition and renovation activities. A large proportion of this waste is eventually disposed of, primarily at waste disposal sites and in illegal dumpsites. There is a growing concern from environmentalists and economists alike with respect to the increasing amount of wastage, both economic and environmental,

[1] These manuals are referred to in relevant sections of this report and are also included in references.

which results from the poor management of construction processes and the ineffective management of waste arising from these processes.

Studies across the world have found that of the materials that are purchased originally for construction processes, at least 9% end up as waste due to wastage on site[2]. In addition, waste arising from construction, demolition and renovation activities accounts for as much as 40% of the total waste generated by countries. Furthermore such waste, termed construction and demolition waste (C&D waste), accounts for 15-30% of the waste that is disposed of in landfill sites in most countries[3].

A review of international trends[4] indicates a move towards the adoption of sustainable development principles in both the construction and waste management sectors. The sustainable construction and waste minimisation models of the construction and waste sectors are very interrelated, and both emphasise the need to better manage the consumption of resources, while ensuring that consumption does not impact negatively on the environment. They stress that the best way of regenerating construction activities and ensuring minimum waste is to preserve the inherent value of construction materials and products.

Through timely interventions in the construction materials cycle, many materials can be salvaged and their value preserved in order to ensure that their use is extended through applications such as reuse and recycling. Although this is both logical and practical, experience shows that major challenges in such industry regeneration

[2] Ekanayake and Ofori, 2000.
[3] McDonald and Smithers, 1996.
[4] Based on work of the CIB Task Group 39 on Building Deconstruction and Material Reuse, and the interim reports of the author under this MSc research project that have culminated in this report.

include changing people's perceptions towards waste minimisation and secondary materials; creating a demand for secondary materials; and developing a sustainable secondary construction materials market in order to absorb recovered waste and ensure sufficient supply of secondary materials to customers.

1.3 Aim and Objectives

The aim of this research project was to demonstrate the value of adopting sustainable construction as an approach for construction industry regeneration to comply with the principles of sustainable development, and to propose a framework for creating a self-sustaining secondary construction materials market, which can be a valuable tool for ensuring the absorption of sustainable construction in the South African construction industry.

In detail, the objectives were:

- To establish the current status of C&D waste management in South Africa and benchmark it against selected countries;
- To review emerging trends in sustainable C&D waste management in the construction and demolition sectors; and
- To propose a framework for the establishment of a sustainable secondary construction materials market in South Africa.

1.4 Methodology

This study has been conducted using a combination of information gathering mechanisms. Firstly the study used conventional desktop based information gathering, which incorporates a literature survey and review; information gathering through the internet and related web based applications; and a review of the author's previous research work in this area. Secondly, the author used interactive information gathering mechanisms that include an industry survey using a questionnaire; interviews with selected industry practitioners; and site visits to selected areas. Thirdly, the author was able to access the knowledge and experience of international experts in the domains of sustainable construction and C&D waste management through his affiliation with the CIB[5] Task Group 39 that is tasked with conducting research on and promoting building deconstruction and material reuse as preferred alternatives to building demolition and landfilling.

Some of the stakeholders that were consulted in the various stages of the research work include the following:

Table 1: South African C&D waste stakeholders consulted during the study

Stakeholder	Description
Government	National – DEAT, DWAF and DPW Municipalities - Tshwane, Joburg, Ekurhuleni, City of Cape Town, Ethekwini, Buffalo City, Kimberley, Mangaung, Nkomazi, Mbombela and Nelson Mandela
Construction Industry	Demolishers Contractors NHBRC
Waste Management	Waste collectors Landfill sites

[5] International Council for Research and Innovation in Building and Construction

Secondary Markets	Recyclers Salvagers Secondary material outlets

Table 2: International C&D waste practitioners consulted during the study

Name	**Organisation**
Professor Charles Kibert	University of Florida, USA
Dr Abdol Chini	University of Florida, USA
Mr Bradley Guy	University of Florida, USA
Ms Gillian Hobbs	Building Research Establishment, UK
Mr Frank Shultmann	University of Karlsruhe, Germany
Mr Bart Te Dorsthorst	Delft University of Technology, The Netherlands
Task Group 39 and the Working Commission on Sustainable Construction	International Council for Research and Innovation in Building and Construction (CIB)

1.5 Definition of Construction and Demolition (C&D) Waste

Construction and demolition waste means non-hazardous waste resulting from the construction, remodelling, repair and demolition of structures. Structures include both residential and non-residential buildings, public works projects such as roads, bridges, piers and dams. It also results from natural disasters such as earthquakes, hurricanes and tornadoes. C&D waste includes but is not limited to concrete, bricks, masonry, ceramics, metals, plastic, paper, cardboard, gypsum drywall, timber, insulation, asphalt, glass, carpeting, roofing, site clearance, excavation material and site sweepings. Some wastes are not included in the definition of C&D waste because of their nature e.g. paints and other liquid wastes, asbestos and other hazardous wastes, putrescible waste, tires, appliances and containers with residue[6].

[6] Food waste forms part of municipal waste and should be handled separately on site. Commingled management with C&D waste causes problems in waste characterisation.
Hazardous waste is a specialised waste type that is high risk and is (or should be) isolated on site for handling by specialists.

There however is considerable difference in how various localities, regions and countries define construction and demolition waste. This has been identified as a major shortcoming/challenge as it impacts negatively on the accuracy of measurement of the C&D waste problem. Needless to say, if the problem cannot be measured accurately, it is difficult to plan adequately for its management, which in turn results in ineffective measures that are implemented to address the problem. For illustration purposes, C&D waste definitions that are used in the United States, the UK and Germany are provided below.

United States

Construction and demolition waste means non-hazardous waste resulting from the construction, remodelling, repair and demolition of structures. Structures include both residential and non-residential buildings, public works projects such as roads, bridges, piers and dams. C&D waste also results from natural disasters such as earthquakes and tornadoes. It includes but is not limited to concrete, bricks, masonry, ceramics, metals, plastic, paper, cardboard, gypsum drywall, timber, insulation, asphalt, glass, carpeting, roofing, site clearance, excavation material and site sweepings. Some wastes are not included in the definition of C&D waste because of their nature. These include paints and other liquid wastes, asbestos and other hazardous wastes, putrescible waste, tires, appliances and containers with residue.

United Kingdom

Construction and demolition waste arises from the repair, maintenance, new build and demolition of residential and commercial buildings. The main categories are construction (including renovation), excavation and demolition wastes. Construction

waste comprises a mixture of inert and active wastes. Examples include but are not limited to concrete, bricks, blocks, aggregate, metals, excess mortar/concrete, timber products, plastic packaging and products, plasterboard and plaster, paper, cardboard, vegetation. Excavation waste comprises soil/clay that is excavated during construction site preparation. Demolition waste includes waste from the demolition of structures and parts of structures and includes recycled/reclaimed materials where appropriate. Examples include but are not limited to concrete, masonry, paper, cardboard, plastic, asphalt and wood based waste.

Germany

Construction and demolition waste covers a wide range of materials, for instance:

- Waste arising from the total or partial demolition of buildings and/or civil infrastructure;
- Waste arising from the construction of buildings and/or civil infrastructure;
- Soil, rocks and vegetation arising from land levelling, civil works and/or general foundations;
- Road planning and associated materials arising from road maintenance activities.

In Germany, construction and demolition waste was classified according to a waste catalogue issued by the Länder Working Group on Waste (LAGA Katalog), which distinguishes between the main groups shown below:

31409 Demolition debris

31410 Road construction debris

31411 Excavation debris

31441 Contaminated demolition waste and excavation debris

91206 Waste from construction sites

31407 Ceramic and stone wastes

31408 Glass waste

31423; 31424 Contaminated soil

31436 Asbestos waste

31438 Gypsum waste

54912 Bitumen, asphalt waste

55508 Painting materials

57 Various plastic and rubber waste

58 Textile waste

The main difference in C&D waste definitions is the inclusion or exclusion of hazardous waste, municipal waste that is generated on construction or demolition sites and sometimes excavation material and/or waste from civil works e.g. road construction. This study has chosen to adopt the American definition of C&D waste mainly due to the author's use of this definition in previous related research.

This report contains seven chapters, viz. Chapter1 covers the context that informs the study undertaken; Chapter 2 describes the background of sustainable development, sustainable construction and sustainable waste management. It also discusses construction, demolition and waste management industries; Chapter 3 reviews current construction and demolition (C&D) waste management practice and benchmarks South Africa against some of the leading countries in this area; Chapter 4 discusses strategies for sustainable C&D waste management that are finding increased application globally; Chapter 5 proposes a framework for developing a self-sustaining secondary construction materials market in South Africa; Chapter 6 discusses the findings of a survey conducted in South Africa; and Chapter 7 defines the contribution made by this study in this field and identifies further work required.

CHAPTER 2: BACKGROUND

2.1 Overview of sustainable development, sustainable construction and sustainable waste management

2.1.1 Sustainable Development

Sustainable development emerged in the mid-to-late eighties as a result of growing concern at the time about the indiscriminate nature that humankind was consuming resources and abusing the environment. Since the Brundtland report of 1987, sustainable development has evolved from a concept, which was increasingly being debated at academic platforms, into a key policy component of many governments across the world. Central to sustainable development have been the underlying principles of resource preservation and the prevention of environmental degradation. A set of criteria for sustainable development have been developed over time (see Table 3), and these have shifted focus from the traditional parameters of time, cost and quality to more comprehensive sustainability parameters of reduced energy consumption, reduced resource use, environmental protection and human development.

Table 3: Principles of sustainable development[7]

Principles of Sustainable Development	
Environmental	• Conserve the earth's vitality and diversity • Conserve life support systems • Use renewable resources sustainably • Minimise use of non-renewable resources • Minimise pollution and damage to the environment and health of all living creatures • Conserve the cultural and historical environment
Economic	• Promote equity between nations and generations • Avoid unequal exchange

[7] Du Plessis C, 1998.

	• Do not impoverish one group to enrich another • Ensure real-cost pricing • Encourage ethical procurement and investment policies • Promote equitable distribution of costs and benefits • Support local economies
Social	• Allow improvement in the quality of human life • Promote social equity amongst all peoples • Allow for cultural and social integrity • Foster self-reliance and self-determination • Encourage participation and co-operation in decision making on all levels from the individual to the international • Empower people and provide opportunity for capacity enhancement

2.1.2 Sustainable Construction

The construction industry is one of the sectors that stimulate and enhance economic development potential. Its activities include the provision of infrastructure and services that enable the sourcing, production, movement and consumption of goods and related services. It also enables mobility and access, ensuring that countries and regions are able to interact and trade. It has been highlighted many times that construction industry operations are sometimes (if not often) wasteful, not friendly to the environment, and rely heavily on natural resources.

Applied to the construction industry, sustainable development has focused on how industry performance can be "greened". This necessitated a re-look at the key drivers of the performance of the construction industry, the basis for evaluating industry performance and the accounting mechanisms of the industry. Some of the findings of previous research work revealed that the industry was driven by key criteria foci of time, cost and quality; payment for services was strongly related to quantities

consumed; and that accounting was primarily on the basis of the "economic bottom line". It was also found that traditional construction project cycles focused only on the construction (or capital) phase, while less emphasis was placed on the entire life cycle of projects.

The proponents of green construction or "sustainable construction" have worked tirelessly to expand the concept of "life cycle accounting" in order to address some of its key shortcomings. They have argued that it was not sufficient to just know the costs of a project throughout its life cycle, but that it was important to devise mechanisms that would begin to address these "life cycle impacts" thereby mitigating the final costs of projects over their lifetime. One such proponent, Charles Kibert [8], stressed the need to understand the concept of "sustainability in construction". He developed a list of sustainability principles that were super imposed on the traditional two-dimensional model of life cycle assessment (LCA) and produced a model for sustainable construction. (See figure 1)

[8] Kibert Charles J, 1994.

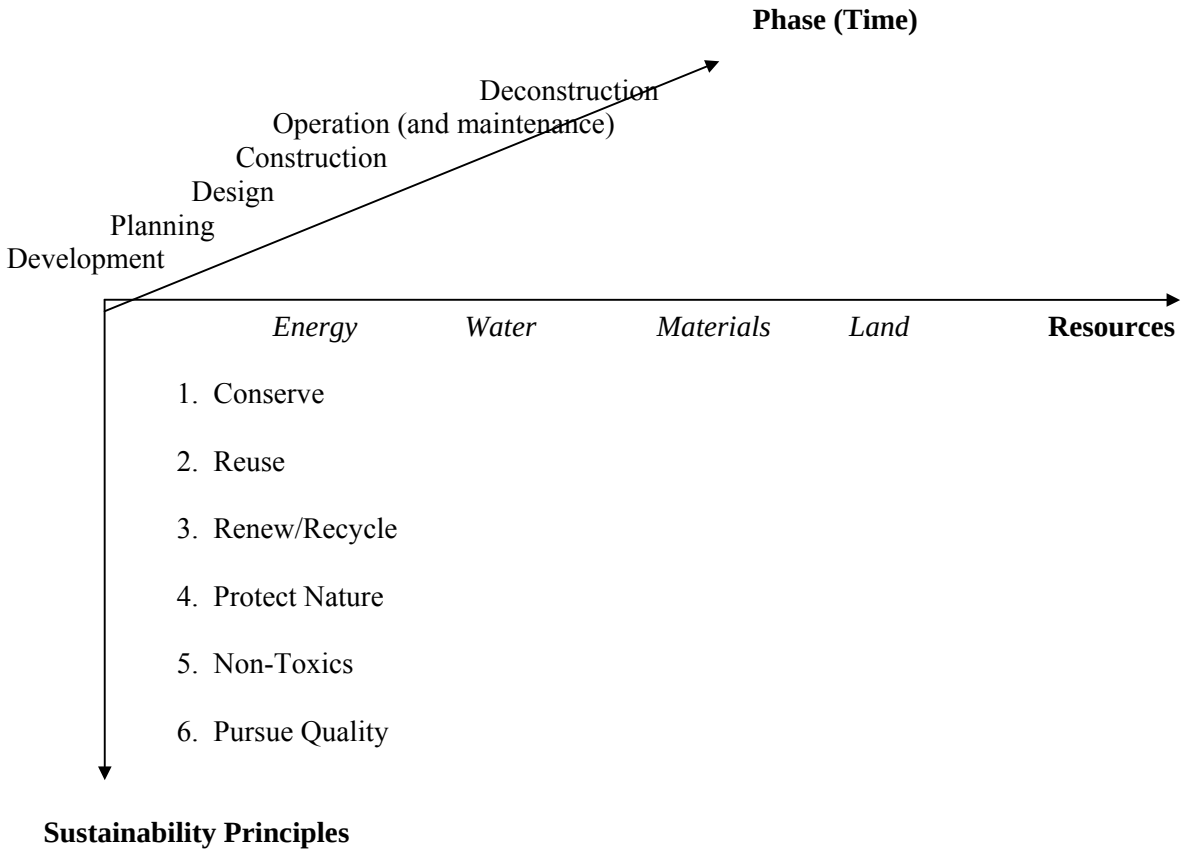

Figure 1: A conceptual model for sustainable construction

2.1.3 Sustainable Waste Management

With respect to waste management, the proponents of sustainable development have argued that the traditional life cycle pattern of consumption of products has followed a liner metabolism pattern of consumption which begins with virgin resource extraction, followed by product use and then ending up with disposal (mainly) by landfill. The danger of this pattern is that it has an inherent assumption that on the one hand the earth has "unlimited resources" and on the other, there is a "bottomless pit" that will continuously absorb all the waste that needs to be disposed off. This clearly is not the case and some countries have begun to "feel the pinch" with respect to the depletion of resources and the lack of availability of landfill airspace.

Sustainable waste management necessitates the broadening of the concept of waste management from just an "end-of-pipe" approach of collecting ever increasing volumes of waste for disposal; to a comprehensive process of "waste minimisation" which looks at the life cycle of materials and products that end up as waste with a view to maintaining their value throughout the supply chain. The latter approach presents opportunities for intervention in the waste cycle from generation through to disposal. Revisiting the waste hierarchy, sustainable waste management can be achieved through the application of Table 4.

Table 4: Waste management hierarchy

Waste Management Hierarchy		
Waste Avoidance	Prevention (cleaner production)	Most Desirable
	Demand management (human behaviour & lifestyle)	
	Reduction (source control)	
Waste Minimisation	Recovery (salvage)	
	Reuse (immediate use)	
	Recycling (reprocessing)	
	Composting (biological reprocessing)	
Waste Treatment	Incineration: Energy recovery	
	Incineration: Volume reduction	
	Chemical treatment (neutralisation)	Least Desirable
Waste Disposal	Landfill	

2.2 Construction

The construction industry forms the backbone of economies across the world. It provides physical infrastructure and services that stimulate and enhance economic activities and enable social development. The industry has evolved from the ancient labour intensive industry that produced relatively simple buildings that were material intensive and designed rather conservatively; into an industry that uses a complex system of building designs, building methods, and building materials increasingly relying on skilled labour and sophisticated plant. In an effort to achieve the most cost effective designs, building materials have advanced in form (material types); composition (reinforcing and composites); volume (smaller sections) and weight (light weight). Building construction methods have also developed, changing the way buildings are founded; assembly methods and sequencing; the way components are connected; and the speed of construction.

Unfortunately these developments have also created problems that did not necessarily exist before. For instance, the use of materials containing asbestos and lead paint about two decades ago has created present day problems of environmental safety in buildings as these materials have subsequently been found to be toxic. The use of composite materials in buildings e.g. differing core and cover walling products, and fibre reinforced plastics, limits the amount of useful building materials that can be recovered and separated for subsequent recycling. In addition, the different types of fasteners used in connections e.g. nails and adhesives limit the ability to recover good quality building components due to e.g. the difficulty of separating the joined sections and the resultant damage.

The construction industry has been found to be quite wasteful in a number of areas. Construction process waste can be categorised into the broad areas of equipment waste, labour waste, process waste and material waste. Briefly described;

- Equipment waste relates to the level of efficiency in using plant on site. On many occasions expensive plant has been procured or hired; and due to breakdowns and delays in repairs it ends up spending long periods of time idle on site. In addition, certain tasks are done mechanically when labour methods could be cheaper;
- Labour waste refers to the effectiveness and cost efficient use of labour on site. It includes failure to use proper skilled labour in the right areas on site, high incidences of injury and absenteeism on site, using inappropriate performance measures for payment etc.;
- Process waste refers to shortcomings such as design errors, errors in material procurement, down times, poor activity sequencing etc.
- Material waste refers to the amount of procured material that never gets used on site due to breakage, weather damage and off-cuts, and waste material that is generated during construction processes.

International studies have found that the construction industry contributes significantly to resource consumption and environmental abuse. Some of the available statistics indicate that the construction and operation of the built environment accounts for[9]:

- 12-16% of fresh water consumption;
- 25% of wood harvested;

[9] Macozoma, (Construction waste), 2002.

- 30-40% of energy consumption;
- 40% of virgin materials extracted;
- 20-30% of greenhouse emissions;

Building obsolescence is becoming a major cost element in the built environment. For instance there are high capital costs associated with the replacement of obsolete buildings with new developments, obsolete buildings have no value and their demolition means a loss of the embodied energy. In addition, the building removal process itself has a substantial cost including waste disposal costs and the associated environmental impacts. Recent developments have seen a shift from the age-old approach of designing buildings as "eternal entities" to the current notion of "finite contemporary buildings". The major shortcoming of the eternal building approach has been the inherent inflexibility that makes building modification to suit a changing environment a cumbersome exercise. Craven *et al*[10] pointed out that buildings with such inflexibility tend to generate more waste when modified and sometimes leave no other option but to be demolished. Internationally investment is being channelled into research to develop models and strategies that enable building design that will yield buildings with the necessary flexibility, to allow relatively easy modification to adapt to changing environments and easy disassembly at the end of life.

As stated above, the construction industry has traditionally operated under tight performance criteria of quality, time and cost. These criteria have sometimes conflicted and a balance has sometimes been difficult to strike. For instance, the proponents of mechanised construction have argued that in cases where government

[10] Craven *et al*, 1994.

policy prescribes the maximisation of labour intensive construction, the training and use of labour to deliver infrastructure has resulted in time delays, material wastage and in some cases compromised quality. However, those in favour of labour intensive construction have counter argued that tender and design specifications give an advantage to mechanised construction methods, and if this is addressed, labour intensive construction can result in cost savings, more employment creation and no compromise in quality albeit at a slightly longer delivery period. Nonetheless, the mechanisation of construction processes, and the industrialisation of building component manufacture and building assembly were attempts aimed at reducing the time spent on site while ensuring good quality construction at reasonable cost.

2.3 Demolition

The demolition industry has evolved from a labour intensive, low technology industry into a highly sophisticated, equipment intensive industry. Traditionally the building removal process needed nothing more than basic labour with simple tools to pull down relatively simple buildings. This era was particularly conducive to building deconstruction (defined in section 4.2.1) and material salvage, as hand stripping was suitable for the removal of building components. As with other industries, the demolition industry underwent industrialisation, mechanising operations and replacing labour with machines in the process. This was partly due to the increase in the level of complexity in building design and construction methods and equipment.

While in retrospect traditional building removal performance concerns may have predominantly been around issues of safety, recent concerns include the duration, cost

and environmental impact. Demolishers have thus been required to satisfy tight contract time and cost requirements while ensuring compliance with all relevant health, safety and environmental regulations. These have often conflicted, resulting in tradeoffs that have not always supported the tenets of sustainable development e.g. speedy building removal on site is better achieved by demolition with explosives, however this method reduces the building to a pile of rubble that has a mixed composition with contaminants, and this limits material recovery while increasing the amount of waste that is disposed by landfill.

While traditionally the demolisher made much of his revenues from the recovery and resale of useful secondary materials, modern day demolishers make much of their revenues from the rapid demolition of buildings and the disposal of waste materials. The latter was of course previously accepted as a "cost of development" when materials and disposal sites were assumed to be in abundance, however such an approach (basis for payment) currently acts against the rationale of sustainable development i.e. resource conservation and environmental protection.

There are various types of demolition methods and they differ according to the type of technology used, the type of demolition application, the duration of the demolition process when using a specific method and the cost associated with it. (See figures 2 and 3) Kasai *et al*[11] identified eight factors that affect the choice of demolition method and McGrath *et al*[12] later proposed an additional three (see Table 5). They state that any building will be subject to a unique combination of these factors.

[11] Kasai *et al*, 1988.
[12] McGrath *et al*, 2000.

Table 5: Factors that affect the choice of demolition method

Factors	Description	Comment
▪ The structural form of the building	Building type, technology and materials	Physical considerations
▪ The scale of construction	Level of complexity	
▪ Location of building	Space for access, mobility and storage	
▪ Permitted levels of nuisance according to local regulations	Allowable noise, vibration and dust levels	
▪ Scope of demolition	Complete or partial demolition	
▪ Use of the building	Ordinary or contaminated structure	
▪ Safety	For workers and the environment	
▪ Duration of demolition process	Time constraints	
▪ Proposed end use scenario of materials	Intended use of materials after demolition	
▪ Culture of demolition firm	Method, equipment and practice of contractor	Non-physical considerations
▪ Monetary cost	Cost burden of different methods to contractor	



Figure 2: Demolition with plant



Figure 3: Demolition with explosives

Demolition methods can be grouped into eight main categories. The various methods have different characteristics i.e. the basis for demolition is different; they have differing energy requirements; yield waste with different characteristics; and will work for different situations. Table 6 gives a summary of each category of demolition methods.

Table 6: Demolition methods[13]

Demolition Methods		
Category	**Types**	**Comment**
By hand	Labour intensive	Time consuming Allows for component recovery
Pulling	Wire rope Vehicle	Limitations on building height Good for partial demolition
Impact	Balling Pusher arm Impact breakers	Control of debris a concern
Abrasion	Hammer drill Diamond cutters	Speed and noise considerations critical
Heating	Thermal cutting Cutting torch (plasma, powder, oxygen-fuel gas) Electrical conductors	Energy requirements Toxic emissions may be generated
Freezing	Cryogenic	Time consuming Limited use Expensive
Expansion	Gas Bristar	Noise during drilling only Slow Good for working in close proximity to other buildings
Explosion	High detonation Low detonation	Cordoning off area critical Dust, vibration and noise
Bending	Jack up (point loads)	Rarely used

Factors such as safety for both the workers and the environment, and the possibility of a presence of toxic substances in buildings to be removed are important and should be considered prior to the application of all demolition methods.

2.4 Waste Management

The construction industry as a sector has been found to generate a significant amount of C&D waste e.g. about 40% of the waste stream of a country (this excludes mining and power station wastes), and about 15-30% of the waste that ends up in landfill

[13] Based on Te Dorsthorst *et al*, 2000 and McGrath *et al*, 2000.

sites[14]. At construction site level it is estimated that up to 15% of materials purchased end up as waste while at demolition sites up to 100% of the waste generated can end up as waste destined for landfill (after the usual stripping of basic high value products). Demolition sites usually generate the highest proportion of C&D waste, followed by renovations while construction sites generate the least. For instance in the US, Franklin Associates found that 48% of C&D was generated at demolition sites followed by 44% from renovations and only 8% resulting from construction site activities.[15]

Although it may seem as though construction activities present the least problem in terms of C&D waste generation, a closer look will show that this is still very significant. For instance it has been found that up to 80% of a homebuilder's waste stream is recyclable[16]. If recovered for reuse and recycling this waste could reduce the cost of waste disposal, reduce procurement costs of virgin materials through the reuse of materials on site where appropriate and also possibly generate revenue through the sale of such material to the public. Although the disposal costs of construction site waste form as little as 0.5% of the total budget of a typical home, contractors know that this can affect their profits since they generally operate within a tight (approximately 5%) profit margin[17].

As described above, material waste forms only part of the total waste generated during construction. In addition the construction process is also known for other types of wastage, i.e. wastage relating to equipment use, human resource related wastage,

[14] McDonalds and Smithers, 1996.
[15] Franklin Associates, 1998.
[16] Construction site waste: A new profit centre, http://oikos.com/esb/46/sitewaste.html
[17] Construction site waste: A new profit centre, http://oikos.com/esb/46/sitewaste.html

time delays, errors in design, reading plans and in procurement etc. Table 7 gives a breakdown of some of the waste types and the related causes.

Table 7: Sources and causes of construction site waste[18]

Design	Operational	Material handling	Procurement
Lack of attention paid to dimensional coordination of products Changes made to the design while construction is in progress Designer's inexperience in method and sequence of construction Lack of attention paid to standard sizes available on the market Designer's unfamiliarity with alternative products Complexity of detailing in the Drawings Lack of information in the drawings Errors in contract documents Incomplete contract documents at commencement of project Selection of low quality products	Errors by tradespersons or laborers Accidents due to negligence Damage to work done caused by subsequent trades Use of incorrect material, thus requiring replacement Required quantity unclear due to improper planning Delays in passing of information to the contractor on types and sizes of products to be used Equipment malfunctioning Inclement weather	Damages during transportation Inappropriate storage leading to damage or deterioration Materials supplied in loose form Use of whatever material which are close to working place Unfriendly attitudes of project team and Laborers Theft	Ordering errors (e.g. ordering significantly more or less) Lack of possibilities to order small quantities Purchased products that do not comply with specification

As shown in Table 7, construction site waste is generated as a result of various activities. During the construction process building materials need to be cut, trimmed

[18] Ekanayake and Ofori, 2000.

and machined to desired dimensions according to building designs. This leads to material off-cuts that become waste. Human error sometimes leads to wrong material sizes and material damage. Waste is also caused by poor reading, communication and/or understanding of designs. The procurement process also leads to material waste due to error in the ordering process, material damage during transportation and material damage during offloading. Poor material storage also contributes to the generation of site waste. If materials are stored too close to the job-face, the construction crew sometimes bumps the material during construction damaging corners and breaking some materials in the process. In cases where materials are stored outside, rainy weather conditions may lead to material damage e.g. cement and gypsum drywall.

The selected waste management system contributes to waste generation on site. For instance commingled waste disposal on site eliminates the opportunity for cost effective waste recovery at source in order to maximise the potential for waste reuse and recycling. (See figures 4 and 5) Sometimes the construction crew may be willing to separate waste only to be impeded by the site waste system e.g. the use of a single container; the use of small recyclable waste containers that fill up quickly and stay long periods before being emptied; or the distant location of recycling receptacles from the job-face. Sometimes a proper system may be in place, but the construction crew may not have the sufficient level of understanding of waste minimisation to effectively use the system e.g. the crew may not be able to differentiate between different waste types.



Figure 4: Commingled waste disposal



Figure 5: The use of single receptacles, which
fill up quickly and take long to be emptied

Waste disposal forms a major part of the incurred costs in demolition projects. Mass demolition has particularly high waste disposal costs since the whole building is generally reduced to a pile of rubble with mixed waste composition and sometimes contaminated with toxic substances. The heterogeneous nature of such rubble makes the sorting costs for recycling very high (or sorting becomes impossible due to the toxic contents), which makes such rubble suitable only for disposal by landfill (hence the costs). Demolition waste will generally contain a high proportion of inert waste material i.e. concrete, bricks and masonry. These materials have high density and thus have substantial weight. This increases the disposal costs at landfill sites that charge per ton of waste (sometimes the costs are so high that contractors opt for illegal dumping instead of disposal by landfill).

The method selected for the demolition process has a direct influence on the type and amount of waste that is generated in demolition activities. For instance the use of explosives for building demolition can only result in a pile of rubble. If no prior stripping was conducted to attempt to reduce the building to a concrete skeleton, the final rubble will inevitably be mixed debris with different materials. Also, partial

demolition can have mixed outcomes e.g. the partial demolition of wooden interior partitions in a building by hand will yield a homogeneous type of waste material (i.e. wood) that can be reused or recycled, whereas the partial demolition of a brick chimney by pulling with a vehicle may result in a pile of broken bricks that may not be suitable for reuse as bricks but may be suitable for crushing into recycled aggregates.

In addition to physical considerations there are process related factors that may influence the amount of C&D waste generated during demolition. For instance a tight contract schedule for the demolition of a building may eliminate the feasibility of incorporating source control into the demolition process. The contractor would be compelled to ensure the rapid transfer of C&D waste from site to a landfill. In addition, demolition sites in built up areas usually face a challenge of limited working space. The contractor may not be able to store useful waste material recovered from a building slated for demolition. Some demolishers have indicated that source control has cost implications in terms of the labour requirements that are associated with it. Thus in an effort to preserve their profit margins they would rather not experiment with waste recovery for reuse and recycling.



Figure 6: Rubble from a house demolition mainly bricks



Figure 7: Rubble from a demolished building mainly mixed debris

Building renovations are essentially a combination of construction and demolition site activities. The composition of waste will depend on the nature of renovations since renovations usually comprise partial demolition of the cladding, interior or structural fabric of a building. For instance the demolition of an interior wall may generate brick and mortar type waste, the removal of a roof structure may generate asphalt from roofing shingles and wood waste from the roof trusses, while the renovation of and entire house can generate mixed waste including bricks, ceiling drywall, carpets, ceramics etc. The size of renovation to be done should inform the level of source separation and waste reuse and/or recycling to be implemented in order to ensure that the whole exercise is economically sound.

CHAPTER 3:REVIEW OF CURRENT C&D WASTE MANAGEMENT PRACTICE

3.1 Introduction

This chapter intends to review South Africa's current practice in terms of C&D waste management and the state of understanding and embracing of the concept of sustainable construction in construction industry activities. It then benchmarks South Africa against progressive countries that are making strides in implementing sustainable construction and C&D waste management with a view of drawing lessons that can be used in the motivation for the establishment of a self-sustaining secondary construction materials market in South Africa.

3.2 Generation and Storage

Construction and demolition waste is generated as a result of construction industry processes and activities during new development, building renovation and/or maintenance and building removal. The characteristics of the generated waste depend on the following factors:

Table 8: Factors that determine the character of C&D waste generated

Factor	Description
Type of structure	Building or civil works e.g. building, road, bridge or dam
Size of structure	House or office building, single or multi-storey, Local or national road
Type of activity	Construction, remodelling, repair or building removal
Method of generation	Explosives, mechanical or labour based
Waste management process	Source separation or commingled handling
End – use scenario	Disposal at landfill site On site reuse or reuse elsewhere, Recycling

Construction and demolition waste can be stored in a number of ways on site depending on factors such as the type of waste, its size, its value, the size of the site, the types of waste facilities that are available for use on site etc. Some of the typical C&D waste storage options that are used in South Africa include:

- Commingled storage in waste containers on the jobsite
- Separate storage in designated containers for reuse, recycling and disposal
- Stockpiling in designated areas on site



Figure 8: Commingled site waste storage

3.2.1 South Africa

South Africa has thus far not commissioned a waste characterisation study to determine the exact breakdown of C&D waste in terms of sources of generation i.e. proportions from the construction, demolition and renovation activities.

3.2.2 Other Countries

In the *United States,* Franklin and Associates[19] found that 48% of the C&D waste generated resulted from demolition activities, 44% from renovations and only 8% from new construction.

In the *United Kingdom*, due to the introduction of the landfill tax on waste disposal in 1996, effort has been put into the management of waste upstream e.g. on site waste prevention and source separation for reuse and recycling purposes[20]. BRE has conducted studies to refine current figures on the amounts generated by construction, demolition and renovation.

The *Netherlands* is possibly the most advanced country in terms of influencing waste generation and handling practice. Since its ban of useful and combustible C&D waste from disposal by landfill in 1997, around 90 percent of C&D waste is redirected to reuse and recycling applications[21]. The ban encourages the source separation of C&D waste into component streams.

Germany has introduced regulatory measures that require C&D waste to be stored separately and be prepared for separate recovery at source.

[19] Franklin Associates, 1998.
[20] McGrath *et al*, 2000.
[21] Te Dorsthorst *et al*, 2000.

3.3 Composition

Construction and demolition waste composition depends on factors such as:

- The type of construction activity i.e. new construction, renovation or demolition;
- The type of structure i.e. residential, commercial or public works;
- The selected waste handling approach i.e. commingled disposal or source separation; and
- The point of analysis for composition i.e. on site or at disposal site.

The composition of C&D waste is highly variable. This can be attributed to factors such as the variation in building materials and construction methods, and to waste disposal practice on site. However, it is possible to draw general observations of the typical composition of C&D waste per type of activity. For instance, road demolition can be expected to generate a high percentage of asphalt (or concrete); house demolition can be expected to generate a high percentage of rubble (particularly bricks, concrete and ceramics); and the construction of a new commercial building can be expected to generate a high percentage of gypsum drywall, wood waste, aluminium/steel and packaging waste (and even composites).

Most site activities will produce waste which contains but is not limited to concrete, bricks, masonry, ceramics, metals, plastic, paper, cardboard, gypsum drywall, timber, insulation, asphalt, glass, carpeting, roofing, site clearance, excavation material and site sweepings as listed in the definition of C&D waste. Some of this waste is usually grouped together into specific categories as presented in Table 9.

Table 9: C&D waste by category

Waste category	Description
Building rubble	Concrete, bricks, ceramics and masonry
Building material waste	Material off-cuts and site wastage
Site clearance	Tree stumps, topsoil and vegetation
Excavation material	Soil and rock from trenches
Site sweepings	Soils, litter, small pieces of materials

3.3.1 South Africa

There seems to be limited published information on the composition of C&D waste on a national scale in South Africa. It may thus be useful to commission a waste characterisation study to obtain more information in this regard. However, studies that have been conducted indicate that much of the C&D waste that is generated comprises commingled building waste, which is mostly from construction sites, demolition sites and renovations; and asphalt waste from road construction, maintenance and rehabilitation. There are significant quantities of site clearance and excavation waste generation due to "greenfields development" of commercial, industrial and residential areas. South African construction methods are largely brick and mortar based, with significant use of concrete and steel, thus the composition of C&D waste is expected to differ significantly from that of countries such as the US for instance, particularly for residential buildings.

3.3.2 Other Countries

United States

A number of well respected institutions in the US including the National Association of Home Builders (NAHB) Research Centre, the Metropolitan Service District in

Portland, Oregon (METRO), consultants and the University of Florida have conducted many site waste assessments. The findings reveal that C&D waste composition is highly variable. This variability has been attributed to the different types of buildings and building methods that exist today. Also of importance is the stage at which a waste assessment is conducted i.e. at the waste source or at a landfill site. It is thus generally not possible to accurately determine the composition of C&D waste, particularly the national average.

Studies have however drawn general observations on the typical composition of C&D waste per type of construction activity in the US. For instance, for residential buildings, new construction typically contains a high proportion of wood waste followed by gypsum drywall waste; while for demolitions, the waste typically contains a high proportion of concrete and brick material (rubble). For illustration purposes only, figures 9-11 show typical C&D waste compositions for US residential construction activities. These diagrams have been taken from the findings of site assessments that were conducted by the NAHB Research Centre[22].

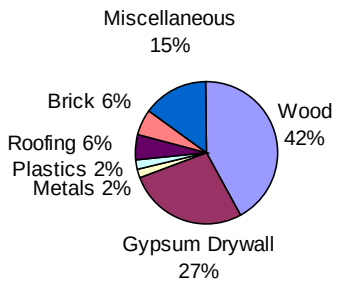

Figure 9: Sample composition of residential new construction waste

[22] Franklin Associates, 1998.

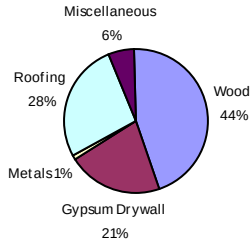

Figure 10: Sample composition of residential renovation waste

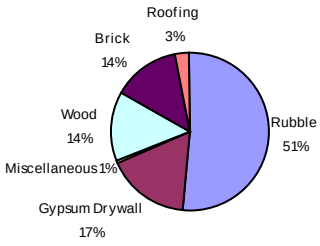

Figure 11: Sample composition of demolition waste

United Kingdom

Institutions such as the Department of the Environment, Transport and Regions (DETR), the EA, the Institute of Demolition Engineers, the National Federation of Demolition Contractors and BRE have conducted studies into C&D waste composition. Many of the findings show variation in C&D waste composition depending on the source of waste, the waste management approach adopted on site, construction methods and the point of analysis of the composition. As in the US, some general observations have been made on the typical waste types to be expected from

certain types of construction activities e.g. a larger proportion of rubble in demolition waste and a prevalence of packaging material on construction sites. BRE conducted a series of waste audits on different construction sites (types of buildings) using their innovative SMARTWaste software and found the composition presented in Table 10, the average composition is also presented in Figure 12[23].

Table 10: Waste composition per type of building

Waste type	Composition by Project Type %						
	Office	Housing 1	Housing 2	Housing 3	Leisure	Restaurant	Average
Timber	8	33	25	15	3	20	17.3
Concrete	2	18	0.5	10	3	-	5.6
Inert	1	-	0.5	27	11	27	11.1
Ceramic	2	-	-	11	-	4	2.8
Insulation	9	2	1	1	9	-	3.7
Plastic	4	17	37	5	4	10	12.8
Packaging	47	8	22	9	49	32	27.8
Metal	6	3	0.5	1	3	-	2.3
Plaster & Cement	10	1	0.5	2	3	-	2.8
Miscellaneous	11	18	13	19	15	7	13.8
Total	100	100	100	100	100	100	100

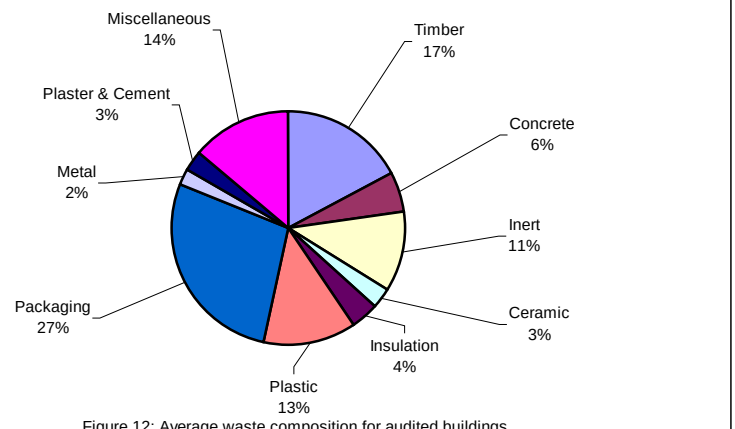

Figure 12: Average waste composition for audited buildings

[23] Hobbs and Hurley, 2001.

Germany

The French-German Institute for Environmental Research conducted research on existing buildings to determine waste composition figures for demolition activities. The buildings were first classified according to size, age and type, and then a building material inventory was conducted. The resulting bills of materials were analysed and an average composition of demolition waste material was derived. Figure 13 presents the findings for the Upper Rhine Region.[24]

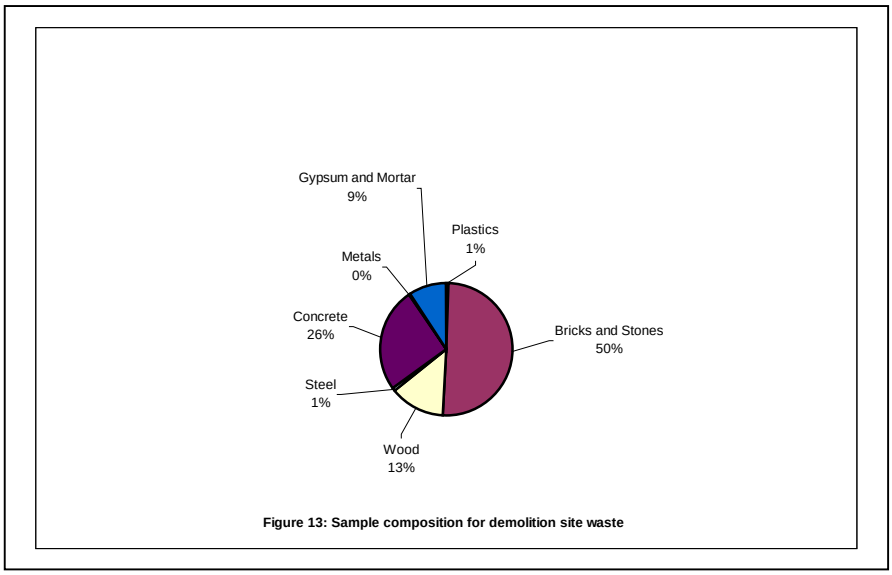

Figure 13: Sample composition for demolition site waste

3.4 Quantities

3.4.1 South Africa

The author conducted two studies to determine national C&D waste practice in South Africa. In both studies similar challenges were experienced, albeit with a noticeable

[24] Schultmann and Rentz, 2000.

improvement in awareness about C&D waste management in the second study. The constraints that were encountered during the studies limited access to good, reliable, accurate and up-to-date information on C&D waste practice. These constraints included:

- The absence of official, reliable and up-to-date figures of the total quantities of C&D waste that is generated by the construction industry;
- The absence of a national waste information system that would enable easy access to baseline data on waste management practice;
- The inconsistencies in the definition and classification of C&D waste;
- Poor record keeping of statistics relating to C&D waste management;
- The differences in measurement units between landfills with weighbridges and those without, which means that data has to be reconciled before use;
- Lack of interest, negative perceptions, lack of knowledge with respect to C&D waste management;
- Low response rates to questionnaires;
- The ad-hoc nature of waste reuse and recycling, which makes estimation difficult;
- The abundance of illegal dumping; and
- The commingled disposal of C&D waste with other waste types.

Nonetheless, C&D waste quantities have been estimated from both the existing statistics and the information gathered from various studies. It is currently estimated that the construction industry generates an estimated 5-8 million tonnes of C&D waste per annum. Of this amount over 1 million tonnes reach landfills every year. Table 11 gives a summary of C&D waste disposal by landfill in South Africa.

Table 11: C&D waste disposal by landfill in South Africa (2002)

Province	Municipalities Covered	Quantities (Tpa)* (Landfilled)	Comments
Eastern Cape	Buffalo City Nelson Mandela	64 000	No detailed classification of C&D waste. Extensive C&D waste reuse on site and in secondary markets. Extensive illegal dumping activity.
Free State	Mangaung Maluti-a-Phofung	Small	Generally small quantities of C&D waste generated, much of which ends up either in landfills or in reuse applications. Illegal dumping is a problem.
Gauteng	Joburg Tshwane Ekurhuleni	700 000	No detailed classification of C&D waste. Extensive waste reuse on site and in secondary markets. One rubble recycling operation. Established recycling markets for wood, glass, paper, plastic, metal etc. Illegal dumping extensive.
KwaZulu-Natal	Durban UThungulu	380 000	No detailed classification of C&D waste. Extensive waste reuse on site and in secondary markets. One rubble recycling operation. Established recycling markets for wood, glass, paper, plastic, metal etc. Illegal dumping extensive.
Limpopo	Polokwane	Small	C&D waste regarded as rubble. Generally small quantities of C&D waste generated, much of which ends up

			either in landfills or in reuse applications. Illegal dumping occurs.
Mpumalanga	Nkomazi Mbombela	Small	C&D waste regarded as rubble. One landfill does not encourage the disposal of C&D waste (rubble) Generally small quantities of C&D waste generated. Extensive waste reuse on site and in secondary markets. Illegal dumping extensive.
North West	Rustenburg	Small	C&D waste regarded as rubble. Generally small quantities of C&D waste generated, most of which end up in reuse applications and in landfills. Illegal dumping occurs.
Northern Cape	Kimberley	Small	C&D waste regarded as rubble. Generally small C&D waste quantities generated, most of which end up in reuse applications and landfill sites. Illegal dumping occurs.
Western Cape	City of Cape Town	240 000	No detailed classification of C&D waste. Extensive waste reuse on site and in secondary markets. One rubble recycling operation. Established recycling markets for wood, glass, paper, plastic, metal etc. Illegal dumping extensive.

Table 11 above gives a breakdown of C&D waste disposal by landfill per province.

Five of the nine provinces have not been able to provide quantities of C&D waste

received at landfill sites. They have however indicated that this is partly because there are hardly any significant quantities of C&D waste that are received in their landfill sites. It was also cited in some areas that municipalities were in a process of conducting waste assessment studies to determine waste practice, as previous records are either unreliable or not available.

It can also be observed in Table 11 that there is a serious problem with the definition and classification of C&D waste all around the country. Many areas only consider C&D waste to mean building rubble, which is actually only a part of what constitutes C&D waste. (See definition in Chapter 1) Needless to say, this creates a problem when attempting to quantify C&D waste, which also inevitably inhibits proper planning for its management.

3.4.2 Other countries

United States

Franklin Associates estimate that the US generates a total of 136 million tons of C&D waste per annum in their report to the US EPA. However, the figure is an estimate of building-related C&D waste only. The estimate for C&D waste resulting from public works such as bridges and roads could not be added due to limited information. The estimate comprises 43% (58.5 million tons) of residential C&D waste and 57% (77.5 million tons) of non-residential C&D waste. Further analysis indicates that 48% (65 million tons) of the total waste estimate comes from demolition activities, 44% (60 million tons) comes from renovations and the remaining 8% (11million tons) results from new construction.

United Kingdom

The DETR in conjunction with the Environmental Agency (EA) commissioned a survey that found that England and Wales produce an estimated 72.5 million tons of C&D waste per annum[25]. Of this figure, about 69.2 million tonnes is from England. (This figure excludes road planings and materials reused without processing, if these were considered the figure would rise to about 90-100 million tons.) The estimate comprises 33.8 million tons of inert C&D waste mainly from demolition activities, 23.7 million tons of soil (including stone and rock) from excavations and 15 million tons of mixed C&D waste. McGrath *et al*, present a breakdown of 30 million tons of demolition waste, 30 million tons of excavation waste and 10 million tons of construction waste.

The Netherlands

The Netherlands generates a total of 14-16 million tons per annum of C&D waste[26]. It is the second largest waste stream in the country, behind dredge mud and ahead of municipal waste. According to the EC report[27] C&D waste results from building, renovation and modernisation, and demolition activities. It estimates that 25% of the waste is from residential structures, 42% is from non-residential structures with about 33% resulting from civil works projects. Of the waste generated about 11-13.5 million tons of C&D waste is recovered for recycling.

[25] Hobbs and Hurley, 2001.
[26] Te Dorsthorst and Kowalczyk, 2001.
[27] Symonds, 1999.

Germany

According to the EC report, Germany generates an estimated 59 million tonnes per annum of C&D waste (excluding excavation soil and road planings). Fourty five million tons of this is inert waste (i.e. building rubble e.g. concrete, brick, ceramics etc.) and the remainder is mixed C&D waste. Schultmann further estimates that 45 million tonnes of C&D waste is generated as a result of demolition activities. Germany also generates a notably large quantity of excavation soil at 215 million tonnes per annum, which is used for various filling applications, topsoiling where appropriate and as a material input for various suitable products.

3.5 Collection and Transportation

Construction and demolition waste is collected and transported in a number of ways i.e. by government waste collection services, by private waste collection service providers or by the contractor (or builder) using his own vehicles. Commingled C&D waste is usually transported directly to waste disposal sites. The typical vehicles that are used for collection include 1 tonner light delivery vehicles (LDVs) to 10 tonner trucks for small operations e.g. residential activities, and 10 tonner trucks, 19m^3 vehicles and different size skips (up to 30 m^3) for commercial and public works projects. Recyclable C&D waste, depending on type, size and quantity, is collected with conventional or special purpose built vehicles that are suitable for the specific material types or containers on site and at transfer facilities.

Hazardous waste is potentially dangerous material and is (or should be) handled by qualified hazardous waste material handling companies for appropriate disposal. It

usually requires special protective clothing and equipment and also requires special storage containers and vehicles for collection and transportation for final disposal.

3.6 Waste Disposal

There are three main types of land disposal, i.e. sanitary and unpremitted landfill disposal, and illegal dumping. Construction and demolition waste practice varies by region. Research around the world indicates that C&D waste is disposed of in one or more of the following ways, i.e. using:

- Municipal general landfill sites;
- Private general landfill sites;
- Construction waste disposal facilities;
- Garden waste disposal facilities;
- Construction and garden waste disposal facilities; and
- Illegal dumpsites.

3.6.1 South Africa

A large proportion of South African waste is still disposed off by land[28], (i.e. landfill sites, illegal dumps, backfills etc.). The figures presented in Table 11 represent the figures recorded at landfill sites that accept more than 50 000 tons of total general waste per annum.

[28] A CSIR study in 1991 found that over 95% of waste in South Africa is disposed off by land.

There is a general problem of illegal dumping in all the provinces, with some provinces being worse than others. Some of the reasons for such a prevalence of illegal dumping are:

- Shortages in law enforcement capacity to ensure compliance.
- The advantage of illegal dumping, i.e. it is still cheaper to dump waste illegally and risk being caught and pay a fine than to dispose of C&D waste at a landfill site.
- Until recently, there has been a plethora of waste related legislation, which created confusion on final responsibility.
- Communities have not been actively involved, to a large extent, in the curbing of illegal dumping.



Figure 14: Illegal dumping of building rubble

The City of Cape Town has demonstrated pro-activity with its Mess Action Campaign to clean up illegal dumps.

3.6.2 Other Countries

United States

A large proportion of the C&D waste that is generated in the US ends up in landfill sites. According to Franklin Associates a survey conducted in 1994 found a total of 1900 C&D waste landfill sites in operation in the US[29]. The state of Florida had the most landfill sites at 280 (this number however subsequently reduced to 163 in 1998 due to stricter waste disposal regulations). Six other states have more than 100 C&D landfill sites each and at the bottom of the scale, four states have one C&D landfill site each while two states have none. Some of the C&D waste is disposed along with general waste in municipal solid waste (MSW) landfill sites. Unpermitted landfill sites are also quite common in many states. Local government has little control or record of these sites. Construction sites in some rural areas and small to medium sized cities still burn C&D waste in situ.

Construction and demolition waste has generally been considered to be of non-hazardous nature and thus was assumed not to present a risk of leachate generation at landfill sites. This has made C&D landfill sites much cheaper to develop and operate when compared to other landfill types. Tipping fees have thus generally been lower hence the high percentage of C&D waste that is disposed by landfill. According to Franklin Associates, a previous survey on landfill disposal was extrapolated to a final figure of 55.6 million tons per annum for the 1900 landfills in operation. If accurate, this figure would account for more than 40% of the estimated 136 million tons generated every year in the US. Little success has been achieved in quantifying the

[29] Franklin Associates, 1998.

amount of C&D waste that ends up in municipal landfill sites and unpermitted sites. However, Franklin Associates estimate that in total about 65-85% of C&D waste is disposed at landfills in the US.

Although tipping fees are generally low in the US compared to some European countries, a general increase has been observed over the years. The rates of increase differ according to location. The highest rate increases in tipping fees have occurred in the most populated areas such as the East Coast and West Coast. Waste Spec[30] found a correlation between increasing tipping fees at landfill sites and a move towards alternative waste management options. There seems to be a threshold of $50.00 beyond which people generally become more likely consider alternative waste handling options.

United Kingdom

McGrath *et al.* indicate that most of the estimated 10 million tons of waste from construction sites and the 30 million tons from the demolition sites end up in landfill sites because of poor current site practice. (The EC report estimates that 55% of C&D waste is disposed by landfill, excluding excavation soil and road planings). The landfill tax, introduced in 1996, separates C&D waste into two main categories i.e. inert waste, which is levied at £2/ton and active waste, which is levied at £11/ton. This means that those construction sites that do not control waste at source face high waste disposal costs (estimated to eat up to 25% of project profits).

[30] Triangle J Council of Governments, 1995.

The Netherlands

The Netherlands is possibly the first and only country where the total amount of C&D waste that is disposed by landfill is less than the amount that is reused and recycled. This is largely a consequence of the landfill ban on the disposal of useful C&D waste in Dutch landfill sites, which was enacted in 1997. Of the estimated 14-16 million tons of C&D waste that is generated every year, less than 10% finds final disposal in landfills, the rest is diverted to reuse and recycling applications mainly for road construction.

Prior to the landfill ban, landfill operators were permitted to accept C&D waste at no charge. In practice this applied to clean rubble that could be used without further processing as hardcore for roads. While this encouraged some source control, it put processing companies at direct competition with landfill sites for C&D waste, which negatively impacted on processors. The introduction of the ban ensures penalty for poor source control, requires processing plants to have certification and limits landfill disposal of C&D waste to less than 12% of reusable materials.

Germany

There are a total of 1600 landfill sites in Germany. According to the EC report, an estimated 83% of C&D waste materials (excluding excavation soil and asphalt planings) end up in landfill sites every year. Schultmann however points out that the disposal of C&D waste by landfill has been severely restricted lately by the legislative instruments that have been put in place. For instance, mineral and unsorted C&D

waste disposal at landfill sites is prohibited since 2001 according to the Technical Instructions for Municipal Waste (TA Siedlungsabfall). More restrictions are contained in the Recycling and Waste Management Act.

3.7 Waste Recovery, Reuse and Recycling

3.7.1 Waste Recovery

Waste recovery determines the amount of waste that can be redirected away from landfill sites to extended use applications i.e. reuse and recycling. The salvaging useful materials from waste can be achieved using mechanical or labour intensive methods depending on factors such as:

- The type of C&D waste;
- The level of contamination;
- The type of contamination;
- The size of waste particles; and
- The safety of the salvagers.

Some of the building components and materials that are usually salvaged for reuse include doors, doorframes, window frames, structural steel, brickwork, ceramics and flooring material. Those that are salvaged for reprocessing into recycled products include concrete, asphalt, asphalt roofing material, wood and gypsum wallboard.

A number of factors inhibit resource recovery at construction and demolition sites. Examples include time, labour costs, low landfill tipping fees, construction and demolition technologies used on site, the lack of planning for waste recovery and lack of design for disassembly.

3.7.2 Reuse

Reuse means the recovery of useful materials from the waste stream for immediate use (either on site or elsewhere) as secondary materials. Reusable materials account for a significant proportion of the total waste generated during site activities. If not recovered, such materials are unnecessarily dumped in landfill sites along with unwanted waste.

Studies around the world find C&D waste reuse to be quite extensive. However, some studies also reveal that in many cases such reuse often is an ad-hoc activity that was not part of a structured waste minimisation or material recovery plan. As a result, in most cases the records of salvaged materials, their condition and subsequent destination are not always available. Nonetheless, in cases where some information is available the typical applications of reusable materials include site levelling; site fills and landscaping; the use of off-cuts and surplus materials elsewhere on the project or in other projects; the salvage and resale of building materials for application in new housing, renovations and informal housing; and the use of waste materials in landfill engineering.

3.7.3 Recycling

Recycling means the reprocessing of salvaged useful waste materials that cannot be put into direct reuse to produce secondary materials and products. Recycling is a preferred option to landfill disposal, however it ranks below reuse on the end-use-

scenario hierarchy (or waste hierarchy) due to its energy requirements for reprocessing before reapplication[31]. (See figure 15)

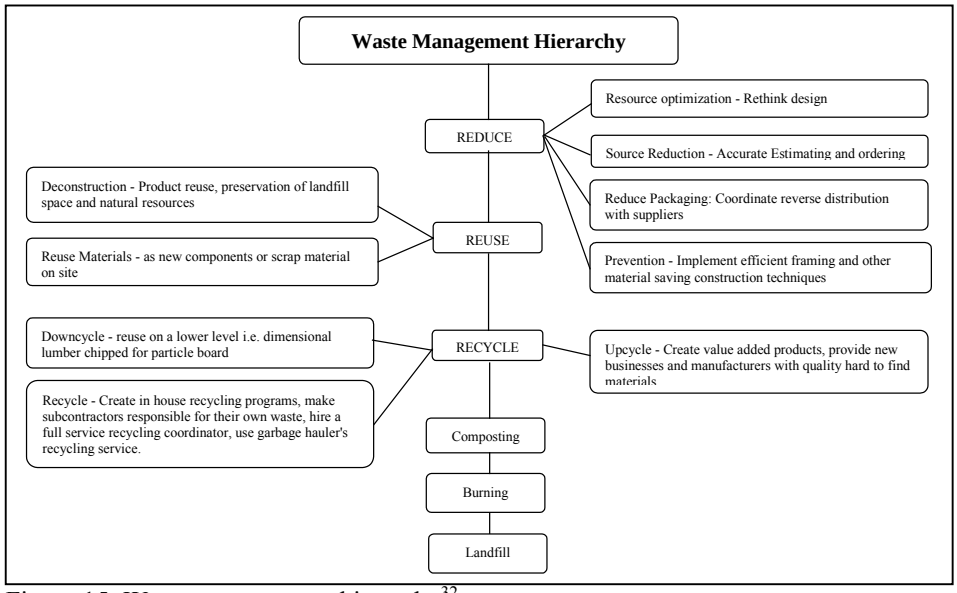

Figure 15: Waste management hierarchy[32]

3.7.4 South Africa

Innovative C&D waste management and minimisation has slowly been getting increasing interest in South Africa. An increasing number of demolishers are incorporating waste material recovery into their demolition plans, others have entered into agreements with waste salvagers to allow for waste material recovery on site before mass demolition.

Waste reuse has been happening for many years however, as is the case elsewhere, it has largely been ad-hoc. Some of the typical applications include the reuse of waste on site (or elsewhere) for fills etc., the use of rubble in landfills, the informal recovery

[31] Waste reuse should always be considered prior to a decision to recycle, and recycling prior to landfill disposal.
[32] Kibert et al, 2000.

of building components for housing needs, the recovery of secondary materials for resale in secondary markets and other non building related applications. The role-players include contractors, salvagers, landfills, the general public and secondary material retailers. Unfortunately, since this is largely not part of a waste plan, the quantities are usually not kept on record.



Figure 16: Reusable sinks recovered from buildings



Figure 17: Rubble recycled to fill material

Construction and demolition waste recycling currently seems feasible in the three metropolitan areas of Johannesburg, Durban and Cape Town, based on the quantities of C&D waste that are generated and the existing recycling activities. Traditional industries of glass, plastic, paper and cardboard, wood and metal can readily absorb the secondary material feedstock from construction and demolition activities (of course this will depend on quality criteria). Building rubble and concrete recycling is still small but has tremendous potential if given the right support, while asphalt recycling is a mature industry. More research work has to go into the recycling of the not so popular C&D waste materials such as gypsum, carpet padding and insulation.

If we consider South African recycling practice with respect to specific C&D waste materials we find that:

- Building rubble recycling is limited to single operations in the Western Cape (Cape town), Gauteng (Johannesburg) and KwaZulu-Natal (Durban). This is not

surprising, as the quantities of C&D waste appear to be the highest in these metropoles. However, even in these areas rubble recycling has a small market share. Nonetheless, there has been an increase in interest in the subject since 1999.

- Waste glass, paper, plastic and metals have existing markets and technologies are well established.
- Wood and asphalt recycling are also established markets that have been around for a long time. It should not be difficult to find applications or start up new ventures in specific cases[33].

Many stakeholders in the construction industry and waste sectors are beginning to realise the environmental benefits as well as the social and economic opportunities that are presented by recycling and developing secondary construction materials markets.

3.7.5 Other Countries

United States

No official study, on a national scale, has been conducted to determine the rate of waste diversion to reuse and recycling in the US. Franklin Associates contacted states representing more than 50% of the US population and many of them did not have recovery rate figures available. A total of five states were able to provide information on their recycling activity. (See table 12)

[33] It is acknowledged that markets may be better developed in the metropoles and more effort may be required in smaller towns

Table 12: State waste recovery rates

State	% Recovery Rate
Florida	46
Massachusetts	77
Oregon (METRO)	42
South Carolina	40
Vermont	37
Average	48

Kibert et al. analysed a number of deconstruction projects in different regions of the US and compiled a table of recovery rates per project[34]. (See Table 13)

Table 13: Recovery rates per deconstruction project

Location	Case Study	% Reuse/Recycling Rate
San Francisco, CA	Presidio	87
Fort McCoy, WI	US Army barracks	85
San Diego, CA	US Navy Motor Pool building	84
Marina, CA	Ford Ord	80-90
Twin Cities, MN	Army ammunition plant	60-80
Baltimore, MD	Four-unit residential housing	76
Port of Oakland, CA	Warehouse	70
Minneapolis, MN	Residential building	50-75

The figures contained in both tables, particularly the rates per deconstruction project are quite high. If these figures are indeed achievable then this is a good motivation for decision-makers and authorities to promote waste material recovery.

The concept of reuse in buildings can be broken down into three categories viz. building reuse, component reuse and material reuse. Many buildings are demolished not because they have reached the end of their design lives, but because their owners have no use for them in their current state, i.e. they are obsolete. There have been cases in the US where buildings have been relocated to different sites for reuse. This saves large quantities of waste and energy. If a building cannot be moved, then the next option would be to adapt it for a different use. Adapting a building for a different

[34] Kibert as quoted by Macozoma, 2001.

use can either mean changing the shell of a building or changing the interior of that building. This highly depends on the flexibility of a building.

Some of the examples of building reuse in the US include the conversion of commercial buildings to residential units in lower Manhattan, New York City and the renovation of the California Gas Company's old building into a state-of-the-art, energy efficient exhibit hall[35].

It is estimated that 20-30 percent of C&D waste was diverted from landfill sites and recovered for reuse and recycling in the US in 1996. The number of recycling facilities was estimated at 1800 in 1996. Of this total, 1000 recycled asphalt and concrete, 500 recycled wood and 300 were mixed waste recycling facilities. By 1998 this figure had increased to 3500. Looking at specific materials:

- Metals have the highest recycling rates of all recovered C&D waste. According to recent Steel Recycling Institute statistics, C&D steel had a recycling rate of 85% i.e. a total of 18.2 million out of 21.4 million tons that were generated. Year 2000 statistics indicate an increase to 95% recycling of structural steel (beams and plates) and 47.5% recycling of rebar and other types.
- Gershman, Brickner and Bratton (GBB) Inc. as quoted by Franklin Associates estimate that close to 50 million tons of milled pavement in the US is reused. Of this amount, 20-50% is reused in Reclaimed Asphalt Pavement (RAP).
- In the state of California 57% of the 8,2 million tons of concrete and asphalt waste was recycled in 1990.

[35] Fishbein as quoted by Macozoma, 2001.

- No official statistics have been found for the recycling of wood waste, but it is known that wood forms a significant part of the composition of C&D waste in the US. According to the 1996 survey mentioned above, 500 of the 1800 recycling facilities were wood processing plants, which means that a fair amount must be recycled. Problems have been experienced with the use of recovered lumber for structural purposes so this type of application is not expected to be high, but other applications such as the reprocessing of wood into furniture, mulch and animal bedding should be quite extensive.

United Kingdom

Approximately 3 million tonnes of C&D waste is reclaimed (i.e. salvage for reuse) in the UK (See Table 14). Thirty percent of this material is reclaimed within a radius of 30km of its source, 60% within 150km and 10% beyond 150km. Greater reuse of materials in mainstream construction would further increase the amount of materials being reclaimed. Reclamation involves less processing, greater employment and is often a more efficient use of resources than recycling. Therefore if deconstruction were a standard process, it would in turn increase the amount of materials being reclaimed.

Table 14: Size of reclamation industry in the UK

Sector	**Sales £ million**	**Employment**	**Tons 000's**
Architectural antiques			
Stone	17	2100	71
Timber	4	1100	7
Iron & steel	4	800	7
Clay	1	800	2
Ornamental antiques			
Stone	16	1170	22
Timber	36	1740	22

Iron	9	1000	9
Clay	1	100	1
Reclaimed materials			
Timber beams	42	3600	137
Timber flooring	29	2960	105
Clay bricks	31	4300	457
Clay roof tiles	63	3600	316
Clay and stone paving	694	1300	694
Stone walling	29	2450	118
Salvaged materials			
Iron and steel 11 2800 77	11	2800	77
Timber	36	7800	383
Antique bathrooms			
Sinks, baths, taps, WCs	41	1900	1
TOTAL	**389**	**39520**	**3430**

Approximately 24 million tons of inert C&D waste is recycled per annum. Work carried out by the Environment Agency & Minerals Planning Department of the DETR is expected to give a more accurate picture of the amount and type of inert waste recycling occurring throughout the UK. For illustration, Europe as a whole generates an estimated 180 – 350 million tons of C&D waste each year, with only about 28% being reused or recycled. Note that this is in the same ballpark as in the US.

Looking at specific materials:

- Timber recycling is increasing with new markets being sought in horticulture and energy recovery. The chipboard manufacturers are all now replacing virgin feedstock with up to 25% recycled wood fibre. The main constraints to this market are the location and quality of the material arising.
- Other materials such as plastics, cardboard and paper are not reaching the recycling sector from construction and demolition works. This would require greater segregation and the creation of collection systems that are currently not available.
- Metal recycling involves traditional recycling routes such as scrap yards.

The Netherlands

The Netherlands uses a total of 120 million tons of raw materials in the building industry each year. Only 85% of this quantity is actually produced in the Netherlands (i.e. a nett import of materials of 15%). Clearly this is not a good state of affairs and it can be understood why a landfill ban on the disposal of useful C&D waste material had to be introduced. The landfill ban has been successful in encouraging source separation and separate collection of useful waste for extended use applications (i.e. reuse and recycling) thereby redirecting a large proportion of the waste away from landfill sites. All sorting plants for the recovered waste are required to have a certificate of accreditation, which licenses them to dispose of unwanted C&D waste from their operations.

Of the 14-16 million tons of C&D waste produced, over 90% of the waste is recycled into secondary construction materials. Waste reuse without reprocessing is not as extensive in the Netherlands. While recycling is desirable, it consumes more energy than direct reuse, which may be cause for concern when looking ahead. Of the recycled quantities, about 80% is used in "on the ground" applications while only 20% is applied in "above ground" applications. According to the EC report the recycling rates for specific materials are as follows:

- 93 % of rubble (i.e. concrete, bricks and ceramics);
- 50% of wood;
- 5% of plastic; and
- 100% of metals.

In 1996 the total installed recycling capacity in the Netherlands was about 16.3 million tons. Total production in 1996 was less at 10.9 million tons, 10.4 million tons of which were actually applied. About 68 percent of it originated from demolishing operations, other sources being waste produced at large civil works projects, such as road construction (15 %) and building waste sorting installations (5%). Approximately 9% of it was produced at building sites, the remaining 3% from other sources.

Germany

Regulatory restrictions on the landfill disposal of mineral, unsorted and generally useful C&D waste have redirected waste into reuse and recycling applications. Germany has considerable capacity for the treatment of construction and demolition waste. There are about 650 recycling companies that operate around 1000 crushers of various types i.e. mobile, semi-mobile and stationary. However, the availability of processing facilities varies with region. For illustration purposes, Figure 18 gives the availability and location of recycling facilities for demolition waste in the region of the upper Rhine Valley, covering an area of 16450 km².

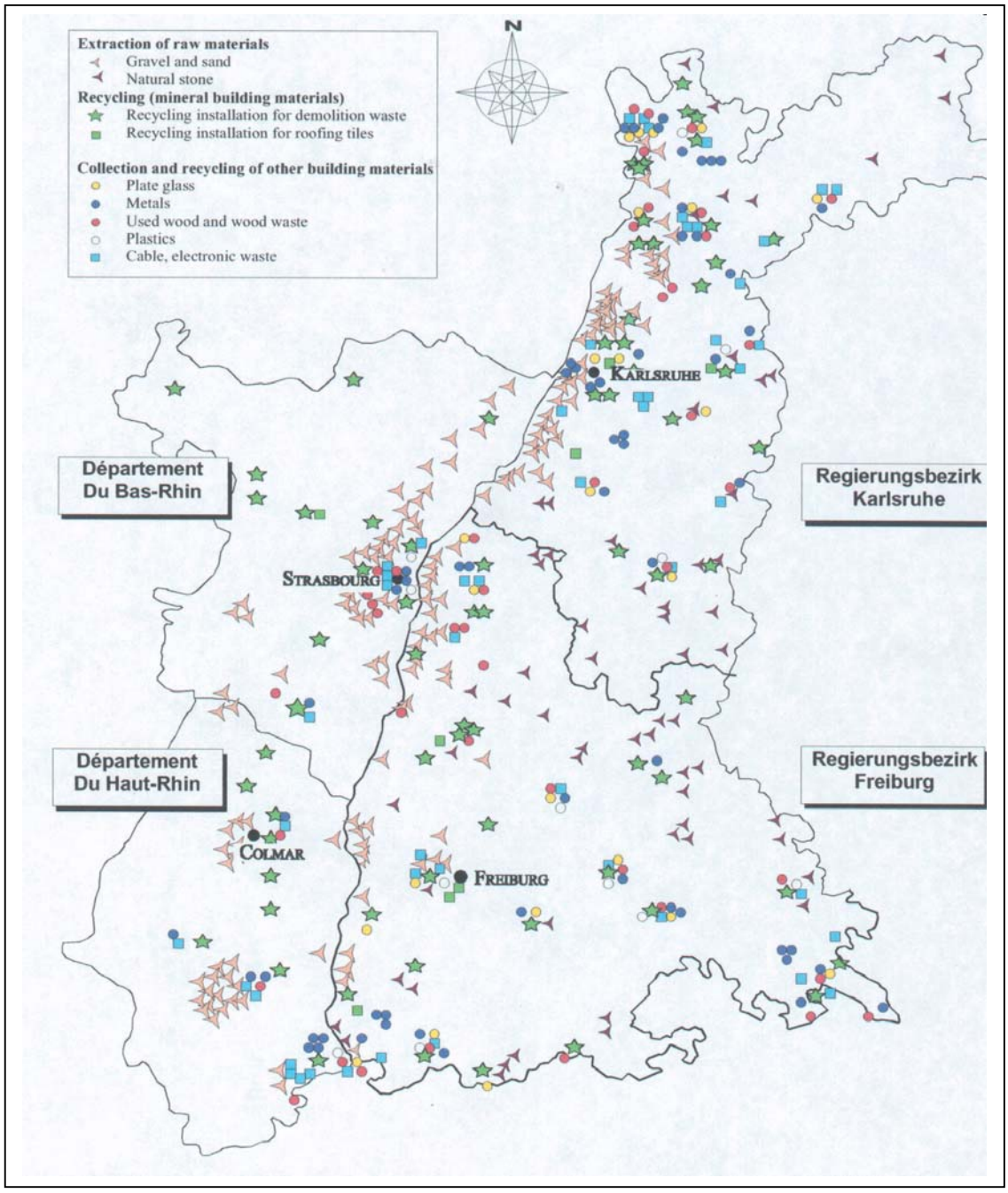

Figure 18: Material extraction and recycling in the Upper Rhine Valley[36]

According to the EC report, Germany only recycles 18% of the rubble generated (i.e. concrete, bricks and ceramics). The highest recycling rate is for road planings, which stands at 80%. C&D waste reuse and recycling can be stimulated by state of the art information systems such as waste exchanges. Waste exchanges present an

[36] Schultmann and Rentz, 2000.

opportunity for information dissemination and exchange in relation to available and/or wanted secondary C&D waste materials. The information can include material type, size, quantity, location and cost. Such systems can be run on a national scale, regionally or locally and can be administered by public or private entities. Furthermore, authorised used construction and demolition waste materials outlets are increasingly being established in Germany.

3.8 Review of the Regulatory Environment

3.8.1 South Africa

The South African waste management regulatory environment, has in the last decade, transformed from an ad-hoc, fragmented and ineffective waste control system as identified by the CSIR in 1991[37] to a more coherent, integrated environment that is driven by sustainability principles. The promulgation of the overarching Environment Conservation Act (ECA) no 73 of 1989 provided a solid foundation for the development of a South African environmental management system[38]. While it was still part of the old "command and control" paradigm, the ECA provided the basic definitions that are still being used today. It also established control systems for protecting the natural environment and controlling pollution, and dealt with issues of the environment in a range of sectors when there was still an absence of sector-specific legislation. (See figure 19) Various clauses of the ECA will be repealed over time as specific sector legislation is concluded or introduced.

[37] CSIR, 1991.
[38] Barnard, 1999.

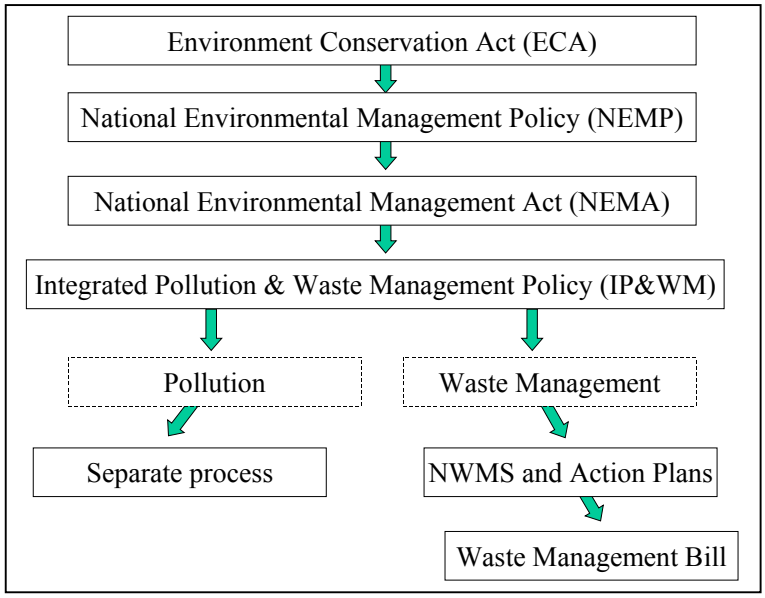

Figure 19: Developments in the waste regulatory environment

This was followed by the white paper on Environmental Management Policy (NEMP) in 1997 and the overarching National Environmental Management Act (NEMA) no 107 of 1998. The NEMP delineates government's broad policy on environmental management and the NEMA takes the environmental management process further by expanding on the environmental law reform programme. The NEMA provides for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment. It also serves as an enabling act for the promulgation of sector-specific legislation, which includes waste management legislation.

The Integrated Pollution and Waste Management (IP&WM) Policy was promulgated in the year 2000. This policy sets out government's vision, principles, strategic goals and objectives for integrated pollution and waste management in South Africa. It also forms a point of departure for the National Waste Management Strategy (NWMS) and

its action plans of 1999. The NWMS forms the basis for the translation of the goals and objectives of the IP&WM policy into practice. South Africa has not had sector-specific legislation for waste management. Waste has thus primarily been managed by the overarching ECA. However, a draft National Waste Management Bill was developed in 2002 and still awaits promulgation into an Act.

The ECA defines waste as effectively "unwanted or unused" material. Some types of waste are excluded from the definition because they are covered in more detail elsewhere (i.e. in other sectoral or general legislation) e.g. effluent, litter on roads etc. According to the ECA, building rubble is excluded from the definition of waste if used for site levelling or backfilling. In cases where it is not, then general waste management principles apply. Other types of C&D waste that are not exactly "unusable" are covered by other legislation (sectoral or general). There is yet no uniform classification of C&D waste. This makes management difficult. Furthermore, to ensure compliance with legislation requires large resources, which government currently does not have.

Notwithstanding the above developments, waste management legislation is still found in a number of other sectoral and general legislation, as can be seen in Table 15 below.

Table 15: Waste related legislation that affects C&D waste management

Legislation	Waste Implication
National Water Act, No.36 of 1998	Prevention of pollution of water resources
Atmospheric Pollution Prevention Act, No 45 of 1965	Generation of emissions and dust that pollute the atmosphere
Minerals Act, No 50 of 1991	Control of waste created in mining property (or activities)
Conservation of Agricultural Resources Act, No 43 of 1983	Protection of natural environments from abuse by activities such as waste disposal
Health Act, No 63 of 1977	Control of waste that can potentially cause a

	health threat or nuisance
Occupational Health and Safety Act, No 85 of 1993	The protection of employees working in or with hazardous substances
Hazardous Substances Act, No 15 of 1973	Storage, handling, transportation and disposal of hazardous waste materials
Nuclear Energy Act, No 131 of 1993	Management of waste that may have been exposed to radioactivity
National Road Traffic Act, No 93 of 1996	Transportation of hazardous substances by road

3.8.2 Other Countries

United States

There are very few policies in place at Federal level in the US that mandate environmentally friendly construction, buildings, designs and materials. Over the past two decades, public concern and support for environmental protection have increased significantly. This has spurred the development of new and expensive policies that aim to substantially increase government's responsibilities for the environment and natural resources. The implementation of these policies however has generally been difficult.

Construction and demolition waste issues that have been proposed include:

- Restrictions on landfill site location;
- Compliance with groundwater monitoring requirements;
- Restrictions on the disposal of C&D waste in landfills;
- The increase of tipping fees; and
- The introduction of regulations that give people incentives to recycle.

The US has also recently been conducting studies on the concept of Extended Producer Responsibility (EPR)[39] with the hope to introduce legislation that focuses on manufacturer responsibility.

A number of states have introduced strict control measures to ensure environmental preservation. State and county regulatory agencies have passed legislation that puts strict controls on C&D waste disposal practice, illegal dumping and ground water protection. For instance:

- The state of **California**[40] passed the Integrated Waste Management Act of 1989 (AB 939), which challenged Californians to adopt a new approach to waste management involving the creation of less waste and maximizing the use of recyclable materials. AB939 mandated Californians to divert 25% of their waste from landfill sites by 1995 and 50% in 2000 based on 1990 statistics. Local governments have since implemented new waste prevention and collection programs. The California Integrated Waste Management Board (CIWMB) developed its first market development plan in 1993 in which C&D waste was identified as one of the priority waste streams that could contribute to the achievement of the targets. 1993 also saw the promulgation of AB 1909 (Public Resources code § 42005 – 42009) which converted the development of market development plans to a mandated activity. The CIWMB adopted the revised market development plan in August 1996. Recent legislative activity in the state of California includes the passing of an ordinance by the county of San Mateo. The law requires demolition contractors to pay a $50.00 per

[39] Originating in Germany, the EPR has already been implemented in some countries in Europe.
[40] California Integrated Waste Management Board (CIWMB), 1996.

ton deposit to the county that is fully refundable if the contractor can prove a 50% or higher recycling rate for generated waste material.

- **Florida** regulations have demanded only a general permit for C&D waste disposal facilities, with few requirements[41]. C&D waste landfills have generally not been required to comply with the strict requirements for MSW landfills because C&D waste has been considered to be inert, with no threat of leachate generation. Recently however, it has been found that C&D waste can contain hazardous substances. Regulations have now become stricter, particularly in terms of waste disposal practice and underground water monitoring. This has resulted in the number of C&D waste landfills in Florida reducing from 277 in 1996 to 163 in 1998.

United Kingdom

The Environmental Protection Act of 1990 (EPA 90) was the culmination of a long period of discussion of amendments to environmental law[42]. The Act covers a wide range of environmental topics, not all of which are relevant to waste management. Part I of the Act introduced the system of Integrated Pollution Control (IPC) which is applicable to the release of pollutants to air, water and land from certain processes, establishing the important new criteria of Best Available Techniques Not Entailing Excessive Cost (BATNEEC). Part II of the Act deals specifically with the deposit of waste on land. (Most waste management activities fall under the provisions of Part II.) Many of the provisions of the EPA 90 have been implemented by Regulations made by the Secretary of State for the Environment.

[41] Vleck as quoted by Macozoma, 2001.
[42] McGrath *et al*, 2000.

The Environment Act of 1995 established the Environment Agency and the Scottish Environment Protection Agency. The creation of these Agencies represented a major step towards truly integrated environmental management and control, as they brought together the regulators responsible for Integrated Pollution Control, water management and waste regulation. The 1995 Act makes numerous amendments to the Environmental Protection Act l990 and the other major environmental statutes. Many of these amendments relate to the powers and duties of the regulators, who now have greater scope to take preventative action when there is a likelihood of pollution.

Recent developments in the UK legislation environment include the proposal for the Development of a Waste Classification Scheme. The Environment Agency, in partnership with the waste industry, is developing a UK system of classifying waste. The UK system is intended to contain more information about the polluting potential of wastes than the existing EC Waste Catalogue.

The Netherlands

The Dutch regulatory reform with regard to sustainable resource use and construction practice dates back to when the Dutch National Environmental Policy Plan (NMP) was published in 1999 as a reaction to the Brundtland report[43]. This document contained intentions and guidelines toward sustainable building. This was subsequently followed by the implementation Plan on Building and Demolition Waste.

[43] Pietersen and Fraay, 1998.

A turning point in Dutch legislation was the promulgation of the Demolition and Construction Wastes Landfill Ban[44]. This became an important measure to promote waste diversion, reuse and recycling. The ban prohibits, *inter ali*a, the landfilling of reusable or burnable C&D waste and the use of unprocessed C&D waste. One of the key objectives of this ban was to promote the source separation of C&D waste into component streams, for easy separate collection and transportation to processing plants (instead of landfills). The ban covers not only reusable C&D waste, but also the residue from C&D waste processing facilities (i.e. sorting and crushing plants). The ban gives an advantage to processing plants and also means that some of the incinerators that were underused will now be used more efficiently.

In terms of provincial legislation, the waste disposal function is a competence of the provincial level. Provinces are authorized to include regulations in their Provincial Environmental Ordinances (PEO) to implement their Provincial Environmental Policy Plans. The Provinces can pursue environmental policies, which are stricter than the general environmental policies, within the constraints imposed by the general quality requirements laid down in Orders in Council and other regulations.

The twelve Provinces in the Netherlands regulate the disposal of commercial wastes (trade wastes) through their PEOs. By requiring notification of commercial waste disposals the Provinces intend to obtain more information about the waste streams and to monitor disposal and processing. These Ordinances require waste collection and processing companies to present quarterly reports to the Province on the waste volumes they have received. Commercial wastes may not be transported between

[44] Te Dorsthorst *et al*, 2000.

Provinces, unless an exemption is obtained. In this way the Provinces want to prevent unnecessary waste transport and they also want to ensure that the capacity of the processing plants and landfill sites (created at great cost) in their Provinces is used.

Another significant regulatory instrument in Dutch regulations was the passing of the Building Materials Decree. The Building Materials (Soil and Surface Waters Protection) Decree was introduced to do justice to the sometimes conflicting interests of the greatest possible reuse and the greatest possible protection of the soil and water. The Building Materials Decree introduced regulations on the use of building materials e.g. when they are placed they may not be mixed with the soil already present on site, it should be possible to remove them, and the materials must be removed when the structure is demolished. The Decree introduced two categories of materials. Category 1 building materials fully meet the requirements and may be used without isolation. Category 2 building materials only meet the requirements if they are isolated and are also subject to further requirements.

Germany

The Recycling and Waste Management Act (Kreislaufwirtschafts- und Abfallgesetz – KrW-/AbfG) contains the basic principles of German waste management and closed-loop recycling strategies[45]. It implements the European Council Directive 91/156/EEC (revised Framework Directive on Waste, amending Council Directive 75/442 EEC) and Council Directive 91/689 EEC on Hazardous Waste, into national legislation. The Recycling and Waste Management Act came into force two years after promulgation in 1996. The hierarchy of the Act assigns priority to waste prevention. Waste that

[45] Schultmann and Rentz, 2000.

cannot be prevented should be recovered. When neither prevention nor recovery is feasible or cost effective waste can be disposed.

According to Art. 5 of the Act waste recovery has priority over disposal (to the extent that recovery is technically possible and economically reasonable). Art. 7, 23 and 24 of the Act authorise the federal government to enact administrative orders and statutory ordinances with the aim of enforcing prevention, recovery and the reduction of contamination on wastes. The supplementary subsidiary regulations of the Recycling and Waste Management Act consist of various ordinances. These can be classified as follows:

1. The Ordinance on the Classification of Waste Requiring Special Supervision (Verordnung zur Bestimmung von besonders überwachungsbedürftigen Abfällen – BestbüAbfV);
2. The Ordinance on the Classification of Waste for Recovery that Requires Supervision (Verordnung zur Bestimmung von überwachungsbedürftigen Abfällen zur Verwertung – BestüVAbfV);
3. The Ordinance on the Furnishing of Proof (Verordnung über Verwertungs- und Beseitigungsnachweise – NachwV); and
4. The Ordinance on Licensing of Transport (Verordnung zur Transportgenehmigung – TgV).
5. The Ordinance on Waste Management Concepts and Waste Life Cycle Analysis (Verordnung über Abfallwirtschaftskonzepte und Abfallbilanzen – AbfKoBiV);
6. The Ordinance on Specialised Waste Management Companies (Verordnung über Entsorgungsfachbetriebe – EfbV); and

7. The Directive on the Activities and Approval of Waste Management Partnerships.

One of the major general administrative orders concerning construction and demolition waste is the Technical Instruction for Municipal Waste (TA Siedlungsabfall) that is originally based on Art. 14 of the former Law on Prevention and Disposal of Waste (Abfallgesetz of 27 August 1986). The TA Siedlungsabfall comes into force in stages, 2001 for C&D waste and in 2005 for municipal waste. It describes that C&D waste should be collected and prepared for recovery separately at the place of arising. Fractions which do not meet the requirements set out in the TA Siedlungsabfall will not be allowed to be landfilled and will have to be treated further. The German Government has even set targets for the reduction of C&D waste disposal by landfill by 50% in 2005 using 1995 figures.

Federal states, some cities and municipalities have begun developing their own specific ordinances that relate to for instance building demolition, waste prevention and separation. Another encouraging initiative was the signing of the Voluntary Agreement in 1996 by several industrial organizations. Its intention was to support the federal government to achieve its C&D waste targets. It contains the following:

- Information and advisory services to be made available to construction and demolition companies; and
- Research and development about avoidance of construction and demolition waste, separation and sorting of wastes and recovery measures, quality assurance for recycled materials and the promotion of applications for recycled materials.

3.9 Review of secondary construction materials markets

3.9.1 South Africa

3.9.1.1 Market status

Local markets for secondary construction materials have been around for a long time. However, the markets have largely been concentrated in certain regions of the country[46], they have been operating on an ad-hoc basis in the absence of a clear market development plan and they have largely been driven by business owners and the demand with no apparent lead or support from the government. Many low-income earners (and the homeless) have depended on secondary markets for the supply of affordable building materials for the provision of shelter for their families. There is also evidence of discerning high-income earners who buy certain distinguished building items of value from secondary markets for their own building needs[47].

Recent trends in secondary market development in South Africa show a steady increase in interest on the environmental, economic and social benefits of using innovative approaches to manage construction and demolition activity and the resulting waste. This is a result of a number of factors that include:

- The growing global and local debates on sustainable development and environmentally responsible construction;

[46] Mainly in and around the three metropoles of Johannesburg, Cape Town and Durban.
[47] Building materials or components with architectural or historical value.

- The recent developments in the waste management sector that have been driven by the Department of Environmental Affairs and Tourism in partnership with the Department of Water Affairs and Forestry;
- The need for construction industry regeneration;
- The growth in research (and lobbying) in the fields of sustainable construction and construction and demolition waste management;
- The need to create employment opportunities for the large proportion of South Africans who are unemployed; and
- The need for affordable building materials.

There are however certain constraints that currently inhibit the establishment of a viable secondary construction materials market. Discussions with construction industry players revealed that these constraints include:

- Project constraints on site e.g. a tight time schedule, a potential increase in labour costs due to the extra effort required in material recovery and space limitations for effective waste material separation and storage for reuse and recycling purposes.
- Current building removal and construction practices that are not suitable for secondary material recovery for reuse and recycling e.g. mass demolition and commingled waste storage on construction sites.
- Concerns relating to the guaranteed and continuous supply of good quality secondary construction materials. As secondary markets stand at the moment, there is no control of the source of waste material supply, the sources are scattered and the quantities are project dependent, which means that it is difficult to guarantee that upon demand, the required materials will be available and be of the right quality.
- Lenient legislation, which sometimes has "loopholes" and complications. Although municipalities such as the City of Cape Town have started to clamp down

on illegal dumping, it has been found to be generally cheaper to dump illegally (even when you get caught) than to dump at a landfill site. Also, the fact that waste legislation has, until recently, been scattered among various sectors meant that there was confusion with respect to responsibility, law enforcement and accountability.

- Lack of knowledge, misconceptions, low awareness levels, and a general fear of change. Many professionals and the general public seem to have a negative perception towards secondary materials. There is a general misconception that "secondary is synonymous with "inferior" and people seem comfortable to rather stick with the well known, tried and tested materials.

3.9.1.2 Market composition and size

Secondary construction materials markets consist of a combination of established and young markets. The supply chain is composed of raw secondary material feedstock suppliers, secondary industries and distribution outlets that supply end users. Of the materials that are used in construction, the materials in Table 16 have been found to be recovered for reuse and recycling in South Africa.

Table 16: Reusable and recyclable materials, secondary products and their applications

Material	Secondary Materials and Products	Typical Applications
Concrete	Recycled aggregates (various grades) Aggregate fines	Road construction Backfilling Landfill engineering Base for foundations Drainage Concrete applications
Bricks	Recycled aggregates Secondary bricks	Backfilling Landfill engineering Housing
Rubble (concrete, brick, masonry, ceramics, sand	Recycled aggregates Aggregate fines	Road construction Backfilling

etc.)		Landfill engineering
Timber	Structural timber Mulch Composting bulking agent Animal bedding Fuel	Housing Composting Energy Other uses
Asphalt	Recycled asphalt	Road surfacing Surfacing parking lots, tennis courts, driveways etc.
Metal	Recycled metal	Building components Machinery Tools Vehicle parts Other uses
Glass	Recycled glass Concrete reinforcement	Glass building products Other glass products Glass reinforced concrete
Plastic	Recycled plastic Concrete aggregate Concrete polymer	Plastic building products Composites Other plastic products Polymer concrete
Paper and Cardboard	Recycled paper Recycled cardboard	Paper Cardboard Other uses

Secondary construction materials markets have been steadily increasing in South Africa. A recent scan of secondary construction materials market role-players found that many demolishers had started incorporating a certain degree of innovation in the manner in which they undertake the demolition process as well as how they handle the resulting C&D waste. A noticeable proportion of the demolishers were starting to minimise the waste generated on site. A number of them were actually extending their business activities to include reuse and recycling. There is also evidence of established and emerging waste salvagers. Some of the salvagers have struck agreements with demolishers to be allowed the opportunity to salvage useful waste

materials on demolition sites before the waste is transported to landfill sites for final disposal. Notwithstanding this, there is still a high level of apathy and misconception of the implications of incorporating innovative C&D waste management and minimisation techniques to conventional building demolition.

Contractors on construction sites show slightly different behaviour. The big contractors that have recently refocused their attention to global markets have inevitably come across stringent requirements in other countries, particularly in Europe and North America. This has slowly made it imperative for contractors to incorporate innovation in construction and demolition processes as well as prioritise waste management and environmental responsibility. However, there is still a number of local contractors who claim that such efforts are not economical and require a lot of resources, while also highlighting the constraints described above as inhibiting factors. Many of the small and emerging contractors are so busy trying to survive that they do not foresee incorporating such activities into their daily operations. The Construction Industry Development Board (CIDB) has been tasked with the regeneration of the industry through providing strategic leadership, performance improvement and project and contractor registration. Early indications show commitment to a shift in paradigm from project delivery based on technical criteria to environmentally responsible sustainability criteria.

The highest proportion of secondary construction materials is from demolition activities. The recovered waste materials are either used on site (or elsewhere), sold to consumers directly by demolishers and salvagers, donated to the needy or sold to secondary material distribution outlets for subsequent resale to consumers. The

findings of the scan of secondary construction materials market role-players are shown in Table 17 and Figure 20.

Table 17: Summary of secondary construction materials market role-players

Role Players	Estimated number (Nationally)
Demolishers	26
Recyclers	80
Secondary material outlets	18
Waste collectors	>50
Landfill sites[48]	>500
Contractors[49]	>30 000

Please note that the figures indicated in Table 17 and Figure 20 are estimates and represent the role-players that the study was able to capture. There is evidence of numerous other small (and informal) industry role-players that are difficult to locate and thus quantify. In addition, constraints such as outdated contact details, closed down businesses and low response rates to enquiries resulted in the inability to find certain industry role-players. The author is aware of the CIDB's Register of Contractors initiative that is intended to capture all registered contactors that operate in South Africa's construction industry.

[48] The DWAF baseline study on disposal sites in 1998 found a total of 540 operating landfill sites and an estimated additional 15 000 small community landfill sites around the country.
[49] The estimate of the exact figure of contractors in South Africa is currently difficult to find, in 2001 the Government database had estimates of over 30 000 small and emerging contractors, several medium contractors and about 6 large contractors. The CIDB is currently completing the development of a register of contractors, which is expected to have accurate and current figures.

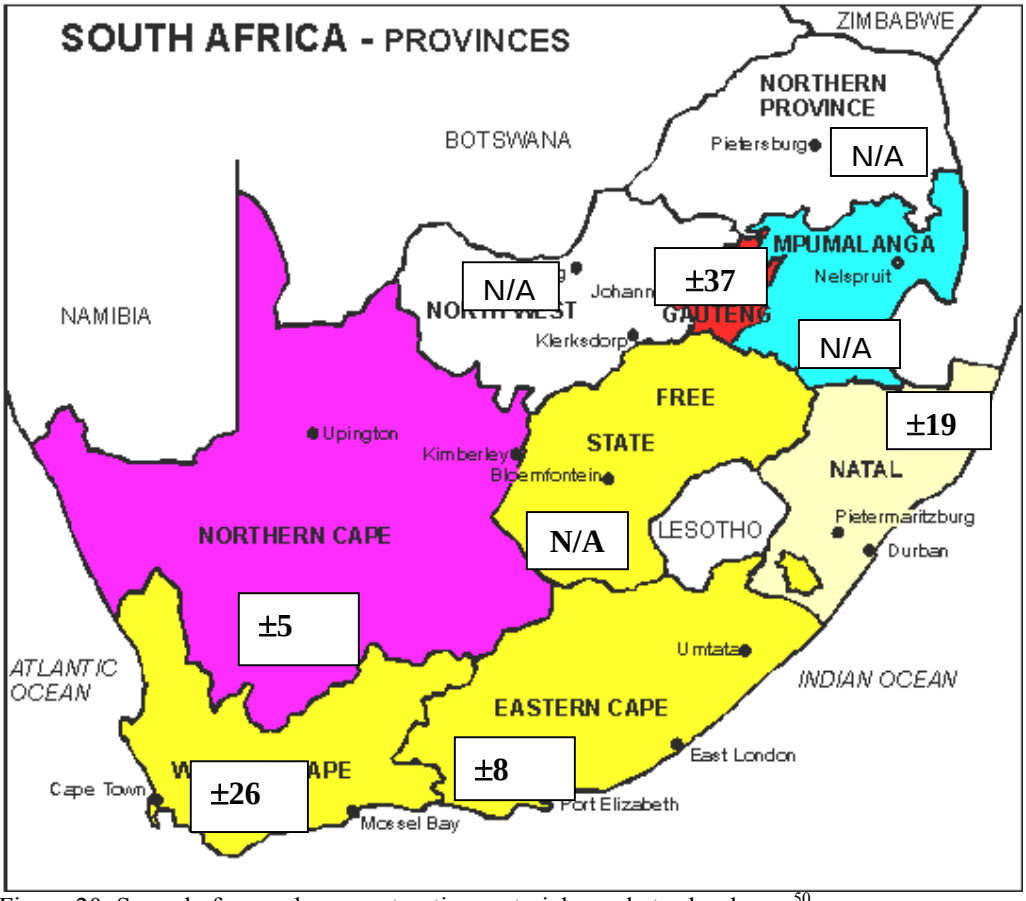

Figure 20: Spread of secondary construction materials market role-players[50]

Figure 20 gives a breakdown of the distribution of recyclers, demolishers and secondary construction material outlets only (contractors, waste collectors and landfill sites are **not** included). As indicated earlier, the major secondary construction materials market activity is concentrated around the metropoles of Johannesburg, Cape Town and Durban.

3.9.1.3 Reuse and recycling practice

Reuse

Construction and demolition waste reuse is an old practice. Industry players and the public have always salvaged useful waste material for reuse. This however has largely been an ad-hoc and uncoordinated activity that could be described as "cherry picking" and not part of a structured plan such as a waste management plan or building

[50] Makhabane, 2001.

deconstruction. Many of the country's low-income earners and the unemployed have used secondary materials to build their homes (including shacks). In addition, secondary material outlets have generally provided relief to consumers by supplying affordable building materials. Some of the examples of reuse applications of salvaged waste materials are given in Table 18.

Table 18: Applications of reusable materials

Category	Typical Application
In situ (and on other projects)	In other applications e.g. shuttering Backfilling Site levelling Landscaping etc.
Housing	Foundations Walls Roofing Fencing Paving etc.
Landfill engineering	Cover material Road construction Construction requirements etc.
Other	Garden rockeries Sound barriers Storm water drainage etc.

Recycling

Concrete, brick or rubble recycling

Cape Town has particularly made some progress in the recycling of building rubble. Malans Quarries, a building rubble recycler from Cape Town, has become a household name with an impressive track record of being involved in the large demolition/recycling ventures in the Cape and in supplying good quality recycled aggregates for road construction projects. At the first Construction and Demolition Waste Seminar hosted by the author in partnership with the City of Cape town and the

Western Cape branch of the Institute of Waste Management, Malans Quarries shared their experience in rubble recycling. Two encouraging things also happened at the seminar. Firstly, Spier Hotels, through their consultants Ove Arup, decided to embark on a trial testing process of Malans recycled aggregates in partnership with the University of Cape Town to determine a suitable blend of mix design that will enable the use of recycled aggregates in the construction of the Spier hotel in the Cape winelands. Secondly, the City of Cape Town struck an agreement with Malans Quarries to have them take over the municipality's building rubble sites for recycling purposes.

In Johannesburg, Recycle Tec, a recycling arm of Pilot Crushtec[51] resumed recycling activities after Wreckers stopped recycling operations due to poor market conditions a few years ago. Their exciting and compact Rubble Buster™ rubble-crushing machine was used on site during the expansion and remodelling of the Menlyn Park shopping mall in Pretoria. Although the market is not as developed as in the Cape, this project has demonstrated that there can be benefits to C&D waste minimisation on site.

In Durban, Concrete and Brick recyclers ran a big stationary concrete crushing plant that was quite established. The owner had developed a good relationship with the clients, which ensured good quality material supply. The business unfortunately closed down in 2000. There however is another rubble recycling activity that has been started in the region.

[51] Pilot Crushtec manufacture crushing and screening equipment for rubble recycling among other applications. They manufactured the famous "Rubble Buster".

Wood recycling

Wood recycling is a mature industry that has been in existence for a long period in South Africa. The availability of technology, industries and markets for primary timber products have enabled easier expansion of secondary timber material use. There are however newer timber recycling operations that are not as established as in other countries.

Metal recycling

Metal recycling is the most successful and most prevalent form of Recycling in South Africa (as is the case in other countries). The secondary markets have a well-defined and reliable supply pipeline with a network of scrap metal collectors, recyclers and product manufacturers all round the country. The main advantage of metal recycling is that the value addition process restores the scrap material to 100% of its original value and thus there are no suspicions of loss of quality.

Asphalt recycling

Asphalt recycling has become an integral part of the process of pavement construction in South Africa. It incorporates the removal of the old pavement surfacing layer and recycling in situ or at a recycling plant using either cold or hot processes to produce recycled asphalt suitable for reapplication in road construction projects.

Other recycling activities

Materials such as glass, plastic, paper and cardboard have mature non-construction related industries. These industries are found in most parts of the country and readily accept good quality secondary materials for reprocessing into products.

3.9.2 Other Countries

3.9.2.1 United states

Local markets for secondary materials have been growing steadily in the US. This is proven by the increase in building deconstruction and material salvage activities. Many new businesses have been formed to absorb salvaged materials. For instance, Happy Harry's Used Building Materials has expanded into a multi branch business in both Canada and the US[52]. Furthermore, business and other institutions involved in the material salvage area have formed partnerships and alliances to lobby for increased waste material salvage and reuse in construction. One example of such a partnership is the Used Building Materials Association (UBMA). Local markets, however are not large enough to absorb all the secondary material feedstock that is in supply. There are various reasons for this including a slow increase in local demand, the need for more education initiatives, the need for more incentives to buy recycled products and the subsidization of transport and associated costs.

The US secondary materials sector has been dominated by export markets when compared to internal markets. Concerns have thus been raised about the shipment of secondary material feedstock to overseas countries instead of local supply (the shipping of secondary feedstock is seen as a drawback to the US economy compared to its supply locally for industrial production of secondary products that can then be

[52] Macozoma, 2001.

exported). It has, however been acknowledged that this currently is the only solution because the local demand cannot absorb all secondary waste materials.

Export markets are unfortunately characterised by demand and price swings that can raise or drop material prices, thus impacting on the economics of the recycling business. A speaker in a recycling conference held in Florida in 2001 indicated that the "market swings" form a seven-year cycle of peaks. Thus to be able to monitor this, companies may need a dedicated broker or consultant that understands market dynamics to help keep a company's bottom line positive.

Examples of US secondary material exports include:

- Metals – Metals are the largest and most established commodity of secondary material scrap exported from California. The main markets for US scrap metal are Korea, Japan, South Korea, China, India and Malaysia.
- Paper – Paper has successfully been exported to markets in China, Japan and South Korea. The markets result from the lack of forests in these countries.

3.9.2.2 United Kingdom

Secondary markets in the UK are also showing an upward trend. Excellent research work that is conducted by organisations such as DETR, the EA, the Institute of Demolition Engineers and the National Federation of Demolition Contractors and BRE is gradually solving one of the main barriers to market development i.e. lack of accurate and up to date information on C&D waste arisings and characteristics. The regulatory advances are also contributing to new trends of C&D waste end use. The EC report estimates that C&D waste crushers are in the region of 50-100 in the UK.

Timber recycling is increasing with new markets being sought in horticulture and energy recovery[53]. Chipboard manufacturers are now replacing virgin feedstock with 25% recycled wood fibre. However, markets are still constrained by factors such as the location and quality of C&D waste input. Other materials such as plastics, cardboard and paper from construction and demolition activities are currently not reaching the recycling sector. This is mainly due to current poor source control and the absence of separate collection systems.

3.9.2.3 The Netherlands

Secondary markets in the Netherlands have grown tremendously since the turning point in the Dutch regulatory environment i.e. the focus on sustainable resource use and construction practice. Much of the focus though has been into developing recycling markets when compared to reuse markets. Considering that the Netherlands only produces 85% of the aggregate that is needed by its construction industry, recycled aggregate markets are at an advantage of competing with import markets rather than domestic. The number of recycling plants is estimated to be around 120 with about 20 of these being located on construction sites and the remainder located on fixed recycling centres[54].

As indicated earlier, in excess of 90% of all the C&D waste that is generated is recycled. Less that 2% of the recycled aggregates find use in recycled aggregate concrete (RAC), however tests have been conducted and the potential is there. The

[53] McGrath *et al*, 2000.
[54] Symonds, 1999.

bulk of the aggregate is used for road layer construction i.e. in subbase, basecourse and asphalt is recycled for reuse in road surfacing. Half the wood from construction and demolition sites is recycled for secondary applications. The remainder of the materials are not recycled much and in cases where they are recycled, the information is not readily available.

3.9.2.4 Germany

There has been a growth in secondary markets in Germany. According to Schultmann[55] specialised operators that deal with used construction materials have increasingly been establishing new outlets. This can be attributed to the advances in the regulatory environment in Germany. In addition, market growth has also been stimulated by the introduction of web based C&D waste material exchanges both at national and regional level. Currently it is estimated that there are around 1000 C&D waste crushers in Germany.

As illustrated in figure 5, there is a good spread of secondary industries i.e. inert C&D waste recyclers, roof material recyclers, and plastic, metal, wood and glass recyclers among others. The spread however varies with region, but if the Upper Rhine valley is anything to go by, the market situation looks good.

[55] Schultmann and Rentz, 2000.

3.10 Lessons for South Africa

The following lessons can be drawn from experiences in other countries:

1. It is critical that consistency be achieved at least nationally (ultimately regionally and internationally) on the definition and classification of C&D waste. Current inconsistencies make it difficult to accurately account for waste generated, reused, recycled, disposed by landfill and dumped illegally.

2. There is an urgent need for accurate and up to date information on C&D waste arisings, its character and location. The absence of such information makes it difficult to measure the C&D waste problem, plan for C&D waste minimisation and secondary construction materials market development.

3. The countries reviewed in this study are different in their own right e.g. building systems and methods, however they have been found to exhibit similar trends with reference to C&D waste management, and the shift towards sustainable resource use and construction practice. For instance:
    - There is a gradual clamp-down on C&D waste disposal on landfill sites;
    - There is a shift towards improved site management and waste prioritisation with the focus on waste prevention, source control and separate waste collection;
    - Secondary markets are starting to play a pivotal role in the success of C&D waste minimisation; and

- Efforts are being directed towards awareness creation, partnership creation and information dissemination in addition to imposing legislation.

4. The composition of C&D waste is difficult to measure. It has been found to vary tremendously with the type of activity, construction /demolition method and material content. However, general observations can be made on typical waste types that can be expected from certain types of structures and construction activities. Waste composition is of particular importance when considering options for waste material end use.

5. With the exception of the Netherlands, waste disposal by landfill is still the most predominant form of C&D waste disposal, ranging between 55% and 85%. Current trends however show a move towards restricted landfill disposal (if not a complete ban).

6. Fiscal and regulatory instruments (e.g. landfill tax, spot fines for illegal dumping, tax exemptions, and landfill restrictions, ordinances on waste handling and transportation, and target setting) are making the environment more conducive to alternative waste handling options instead of landfill disposal. With proper monitoring in place, unwanted consequences such as illegal dumping and unlawful incineration can be avoided.

7. Information sharing is critical to the success of C&D waste minimisation. It has been shown that waste material exchanges stimulate secondary markets, while up to date waste information systems make C&D waste management more effective.

8. Government support is critical to the success of C&D waste prevention, management and minimisation programmes. This support can be financial, technical, regulatory and/or infrastructural.

9. While a degree of mandatory measures is necessary to ensure control, more can be achieved through partnerships and stakeholder involvement. There are many role-players in the life-cycle of C&D waste and they all need to contribute to sustainable construction.

10. Secondary markets have potential to create employment, change material consumption patterns, contribute to the economy and develop new markets that are based on RE's i.e. recovery, reuse, repair, remodelling, recycling and remanufacturing.

11. There is a need for continuous research into ways of improving the quality of secondary materials, their performance and their application in everyday operations**.**

CHAPTER 4: STRATEGIES FOR SUSTAINABLE C&D WASTE MANAGEMENT

4.1 Construction sites

Many developed countries have realised the need to modify tendering, contracting and construction site processes in order to ensure that waste prevention and management are prioritised on site. Recent innovations include the promotion of waste avoidance to prevent waste from being generated in site activities, the incorporation of waste specifications in tender documents, the inclusion of model waste management language in contract documents, the demand for waste management plans prior to commencement of construction and the promotion of the purchase and use of recycled content products.

4.1.1 Waste avoidance

Waste avoidance on construction sites focuses on activities that ensure that waste is not generated in the first place. It is by far the most economical approach to dealing with waste compared to minimisation and disposal. As described above, international discourse on waste management has changed from previous talk of "end-of-pipe" solutions to "cradle-to-grave" and recently to "cradle to cradle". Countries are embracing the notion of questioning the whole concept of waste, arguing that it is a man made by-product. Countries have begun setting zero waste targets for themselves and full-scale research is being conducted to look into more innovative ways of using waste materials. The concept of waste avoidance can be represented by three components viz. waste prevention, waste demand management and waste reduction. (See Table 19)

Table 19: Categories of waste avoidance[56]

Waste prevention	
Waste prevention concentrates on construction site practice that determines whether or not waste will be created prior to or during construction site activity.	
Areas of intervention	**Description**
Design	Design for waste reduction through e.g. doing more on site with less materials and designing buildings for easy disassembly of components and materials for reuse and recycling.
Operations	Ensuring clear communication of designs to the project team, maintaining equipment to prevent malfunctioning and reducing human error to avoid unnecessary waste through errors and redos.
Procurement	Engaging suppliers to encourage them to reduce the amount of packaging material they use when supplying building materials, to motivate for the use of reusable containers and to negotiate "take back" agreements for unused materials.
Demand management	
Waste demand management concentrates on construction site practices that rely on the human element, since many jobsite waste problems are a result of avoidable practices.	
Areas of intervention	**Description**
Material delivery	Ensuring that care is taken to protect building materials during the loading, transportation and off loading stages.
Material storage	Ensuring that building materials are stored safely in appropriate places upon delivery e.g. wood and gypsum drywall materials should be stored indoors to avoid damage by rain, and roof tiles should be stored away from the jobface to avoid damage.
Material use	Material sections need to be cut optimally to reduce the amount of off cuts and allow for the use of the remaining materials elsewhere on the jobsite.
Project team	It is essential that the contractor communicates with the crew, gets commitment from the crew, and trains them in order to reduce errors.
Waste reduction	
Waste reduction concentrates on construction site practices that determine the amount of generated waste that will ultimately be disposed by landfill.	
Area of intervention	**Description**
Separation at source	Providing receptacles and a collection system that enables selective

[56] Based on Macozoma, (Construction), 2002.

	and separate storage and/or disposal of reusable, recyclable and unwanted waste on site.
On site reuse	Allowing for the reuse of useful waste material on site before it enters the national waste stream.

4.1.2 Waste specifications

Clients are increasingly becoming vocal about the type of performance they expect from construction projects. Designers are experiencing more and more pressure from clients to introduce (innovative) measures to reduce wastage on the jobsite and ensure environmental buildings. This demand is a result of three factors viz. a need to reduce construction costs, a need to demonstrate environmental responsibility and a need to comply with local waste legislation and reduction goals[57].

One such measure that is beginning to find application in construction industries in developed countries is a waste specification. Waste specifications can be prepared by designers for inclusion in tender documents for specific projects. The specifications are written in model specification language to emphasise and prioritise waste avoidance and minimisation on construction sites. The specifications need to emphasise that the project is looking for alternative (and innovative) waste management techniques to conventional collection and disposal by landfill. Waste specifications address the following[58]:

- Use of waste reduction techniques during construction;
- Reuse of construction waste material on site;
- Recovery of construction waste material from site for resale and use elsewhere;
- Return of unused construction material to vendors for credit; and

[57] Triangle J Council of Governments, 1995.
[58] Based on Triangle J Council of Governments, 1995 and Vleck, 2001.

- Recycling of construction waste.

Designers can specify that contractors are expected to embrace and use innovative designs and construction materials. They will also be expected to implement waste prevention and minimisation strategies which include reducing packaging materials, returning unused materials to suppliers, developing waste management plans and promoting the reuse of useful waste materials on site. The contractors can also be required to investigate local secondary markets in order to decide which materials will be cost effective to recycle based on locally available recyclers and their fees. Shown below is an outline of the contents of a waste specification that was developed in North Carolina in the US.

Waste Spec: Model Waste Specifications for construction waste reduction, reuse and recycling, *By Triangle J Council of Governments, NC, USA, 1995.*

The specification looks at specific building materials and products, and construction processes and identifies opportunities for waste reduction, reuse and recycling. In addition it has a section that is meant to specifically deal with construction and demolition waste management. The contents of this section are:

Introduction: Construction waste management

Part 1 – General

Requirements included in this section

A. Waste Management Goals

B. Waste Management Plan

C. Management Plan Implementation

D. Special Programs

Part 2 – Products (not used)

Part 3 – Execution (not used)

4.1.3 Model contract language

Designers are beginning to realise the potential of using the legal status of a contract document to change the behaviour of contractors on site. Since a contract is binding the designers can use it to demand that waste management be prioritised on site, clearly outline all required actions and make provisions for the legal resolution of disputes resulting from breach of contract. The project contract provides the opportunity for the designer to stipulate that the contractor shall be expected to comply with project plans and goals as they relate to waste management. The contractors will be expected to ensure that their whole crew participates in waste management. The main/general contractor can be encouraged to delegate responsibility to sub-contractors in order to improve accountability and distribute liability between himself and his sub-contractors.

Various actions can be implemented on site to ensure that the issues highlighted above are achieved. Compliance with project goals and participation can for instance be achieved by giving clear instructions to all team members on what is expected of them, inserting penalty clauses for non-compliance and by offering incentives for achieving targets. Site waste management is generally effective if there is an individual with overall responsibility. A general contractor or waste management specialist can be appointed to manage the waste management portfolio, delegate

responsibility to relevant people and ensure commitment and accountability. Finally, it may be beneficial to distribute liability among sub-contractors for their specific wastes rather than have the general contractor being responsible. Such an approach will encourage sub-contractors to be responsible and more efficient since they will have a stake in the resulting gains or losses due to their waste practice. Shown below is a sample of waste management contract language.

Model Waste Management Contract Language, *Based on Washington State Plan as quoted by R Vleck, University of Florida, Florida, USA, 2001.*

I. Description

A. The owner desires that this project generate the least amount of waste possible and to ensure the generation of as little waste as possible due to error, poor planning, breakage, mishandling, etc.

B. Of the inevitable waste that is generated, as many of the waste materials as economically feasible shall be salvaged, reused or recycled. This is mandatory wherever practicable.

C. With these goals the contractor shall develop a waste management plan for this project.

II. Waste management

A. Plan

1. Required sections

Within fourteen working days after receipt of notice to proceed, or prior to waste removal on site, whichever occurs first, the contractor shall submit three copies of the draft waste management plan to the architect and owner: The plan should contain the following sections:

a) A list of each material proposed to be salvaged, reused, recycled and disposed of

b) *Estimated quantities for each waste stream*

c) *Separation requirements*

d) *On-site storage method for each waste stream*

e) *Transportation method for each waste stream*

f) *Destination of each waste stream*

g) *Estimated disposal fee or rebate of each material*

2. Materials

The list of materials should at a minimum, include:

a) *Cardboard, carpet, clean dimensional wood, site clearance, concrete, bricks and masonry, asphalt, metals, gypsum, excavation soil, glass, wood.*

3. Additional information

Include the names of each subcontractor who will transport non-hazardous or hazardous waste from the construction site and the name of the receiving facility that will accept waste for disposal.

B. Resources

A sample waste management plan and waste management plan forms are attached as part of this document. In addition, the contractor may request specific technical assistance or referrals from resources that include:

a) *A Recycling coordinator, Engineering and Architectural services, a sustainable buildings specialist, a solid waste management office or the department of environmental affairs.*

C. Review and Approval

The draft waste management plan will be submitted to the Architect for review and approval with one copy going to the owner. The Architect will check the following:

a) *That all materials that may be economically recycled are listed.*

b) *That the haulers, recyclers and waste disposal facilities that are listed cover general waste, recyclable waste and hazardous waste.*

Upon completion, the Architect submits his comments and when satisfied with the contractor's response, the plan is approved.

D. Reporting

The contractor shall submit monthly progress reports that summarise waste practice on site. The reports shall be submitted in a format acceptable to the owner and shall contain:

a) *Details of all materials that were salvaged, reused and recycled form the project*

b) *Details of all the materials that were disposed of in landfill sited from the project*

4.1.4 Waste management plans[59]

A waste management plan can be described as a construction project related plan that gives provisions for the prevention, separation, salvage, reuse, recycling and disposal of C&D waste. The ultimate goal of a waste management plan is to reduce the amount of C&D waste destined for landfill to an absolute minimum. A waste management plan encourages resource efficiency and helps internalise the environmental externalities related to building construction.

4.1.4.1 Elements of a waste management plan

A waste management plan does not have to be complicated in fact it need not even be a long document. It simply needs to be concise, comprehensive and practical for easy

[59] Based on Macozoma, (Construction), 2002.

interpretation and implementation on site. A good waste management plan will contain the following components:

- Goals;
- Waste audit;
- Waste disposal options;
- Waste handling requirements;
- Transportation requirements; and an
- Economic assessment.

4.1.4.1.1 Setting goals

Before conducting any detailed planning for waste management on site, the client team should make a commitment to waste prevention and waste redirection from landfill to reuse and recycling applications. This should be followed by realistic and quantitative targets for waste reduction. Realistic targets can be based on previous projects of similar nature, targets set by environmental rating systems that reward waste reduction with credit points and financial considerations (advised by market conditions).

4.1.4.1.2 Waste Audit

For the contractor to be able to determine the best approach to deal with jobsite waste, he needs to collect information relating to the waste that will be generated on site. This information will be useful for waste planning. Such information is generally required before the waste is actually generated on site although on site waste audits

can also be conducted to capture useful information for future projects and to update waste estimates for the current project.

A waste audit can basically be divided into two activities viz. a waste analysis and a waste assessment.

Waste analysis

A waste stream analysis will determine the types and quantities of waste that will be generated in the project. The analysis will also determine the stages of construction where specific wastes will be generated. There are two methods of conducting a waste stream analysis. The first involves collecting actual data from project sites to determine the types of materials being discarded. The second uses information from previous projects. Both methods characterise wastes that are generated on the jobsite, and can help identify suitable waste reduction options.

Collecting data from the jobsite during construction can take several forms. Information can be extracted from purchase records, waste bin inspections and detailed waste analyses of selected sample waste bins. (See figure 21) Secondary analysis from previous experience on the other hand includes extracting waste generation rates, using purchase records and using waste disposal records for similar projects. In cases where information is not readily available, other sources that can be used for quantity estimates include engineering estimates, and typical waste composition figures for construction sites.



Figure 21: Analysis of a waste bin[60]

Waste assessment

A waste assessment will use the information collected in the waste analysis to determine the site-specific waste characteristics. The assessment will help characterise waste by type, amount, method of generation and time of generation. It will also identify the construction activities that generate large quantities of waste. This information will inform the contractor on which waste reduction options he needs to focus his efforts.

Waste analysis and assessment information can be captured in a simple spreadsheet. It can be arranged in a manner that will easily show the types of envisaged waste materials; the expected quantities; recyclability; activity and time of generation; and a possible recycling option. (See Appendix A1 for a sample waste analysis and assessment sheet.)

[60] BRE, Smartwaste case studies, 2000.

4.1.4.2 Waste disposal options

Having assessed all the waste that will be generated on site, it is now possible to explore the various end-scenarios. It is useful to have knowledge of the types of materials that are reusable and recyclable, the conditions of acceptance in the respective markets, secondary market conditions in your area and the location and types of waste disposal sites. (See Table 20)

Table 20: Types of C&D waste materials

Waste material types	Description
Reusable materials	- Some materials can be accepted for reuse applications if they satisfy certain criteria, e.g. dimensions, level of contamination and quality. - Typical places to approach with reusable materials include suppliers, secondary material outlets and renovators. - If available, obtain a published list of locally accepted reusable materials. - Reusable waste can be sold at a site sale or auction. - Useful waste material can also be donated to charity organisation.
Recyclable materials	- Find a list of which materials are recycled in the locality of the project. - Locate the companies that recycle these waste materials. - Useful sources of such information include registers of recyclers, waste material exchanges and waste information systems that are either administered by government waste departments or by research institutions that specialise in waste management. - Sometimes unconventional methods of searching for information may yield the best results, particularly for the not so popular recyclable materials such as insulation material and carpet padding. - Establish market prices for specific waste materials.
Unwanted waste	- Accept that site activity will inevitably still generate a certain amount of unusable and unwanted waste that is good only for disposal by landfill. - Find out what types of waste disposal sites are there, i.e. municipal waste sites, C&D waste sites, garden and C&D waste sites etc. - Determine the requirements for acceptance e.g. commingled or clean separated waste. - Determine the location and distance to these sites. - Determine the tipping fees charged by each.

Hazardous waste	- Find out about all the relevant local regulations relating to the handling and disposal of hazardous waste. - Find local hazardous waste removal contractors. - Determine the location and distance to the designated hazardous waste disposal sites. - Determine the tipping fees charged by each.

4.1.4.3 Waste handling requirements

In order to have efficient waste management on the jobsite, consideration should be given to how the waste will be handled to maximise recovery. Since the most effective waste reduction strategy is source control, 100% participation from the construction crew is important. Before the crew can participate, it is important that they are made aware of the waste plan, they need to be trained on waste handling methods and they need to be involved in the process.

The project team needs to appoint an individual that will be responsible for the overall waste management activity. This can be the general contractor or a waste management specialist. This individual can appoint and train one or two waste management leaders that will be responsible for the day-to-day running of jobsite waste activities and feedback to the waste manager.

Some of the actions the waste team will have to take include the following:

- Decide on whether to implement a "time based" waste recycling system at the jobface or dedicate "a recycling centre" on site.
- In case of the former, plan the system and determine container sizes, number and location and coordinate details of container collection.
- In case of the latter, design and layout the recycling centre on site. (See Figure 22)
- Determine security, staff and facility requirements for the recycling centre.

- Clearly mark all items in the recycling centre to avoid confusion, contamination and abuse.
- Plan for the collection of waste from the jobface to the recycling centre.
- Ensure adequate and sufficient containers to allow for effective waste separation, storage, collection and transport to the recycling centre and to the final destination.
- Train the labour crew to distinguish between reusable and recyclable materials, how to avoid contamination and where to store reusables, recyclables and unwanted waste.
- Co-ordinate waste collection to avoid the collection of half-empty or overflowing containers.



Figure 22: A sample waste recycling centre

4.1.4.4 Transportation requirements

Consider options available to collect and transport reusable, recyclable and unwanted waste away from the construction site. There are four basic methods that can be used[61], namely:

[61] Construction works newsgram, http://splash.metrokc.gov/swd/bizprog/sus_build/newsgram6.htm.

- *Commercial hauling* - This method involves contracting with waste or recycling service providers to place collection containers on-site, collect and transport the full containers to waste or recycling facilities. This strategy works well on projects where large quantities of materials are generated, such as on demolition sites, big housing projects and on commercial projects. Some recyclers offer smaller waste containers or containers with several compartments for small-scale projects such as home improvements.
- *Self-hauling* - This method is often preferred for residential construction and remodelling. Recyclable materials are collected on-site in piles or temporary containers and taken to recycling facilities using the contractor's own vehicles. This method is effective for materials generated in small quantities.
- *Cleanup services* - A construction clean-up service that offers waste removal and recycling services all in one. The clean-up crew comes on-site and picks up recyclables and garbage that are collected in piles or containers. The materials are then taken to the most appropriate recycling or disposal facility. Such services can offer job-site recycling consultations as well.
- *Commingled recycling* – The last option in the order of preference, commingled recycling programs collect containers of mixed recyclables or mixed garbage and recyclables, and separate them at material recovery facilities. This option is convenient for cramped sites, but the cost saving is limited (high pre-recycling costs) and recycling rates may be lower than for other options.

When assessing the above options, it is important to contact local service providers in order to determine the sizes of their containers, and their rental and collection estimates.

4.1.4.5 Economic considerations

The above information will help in deciding which of the waste materials are economical to reuse and recycle and which are not. The main criteria that are used to decide between extended use applications and landfill disposal are the cost implications of each option and the anticipated returns. Landfill disposal generally depends on local tipping fees and the associated transport costs while extended use applications depend on recycling costs and market conditions.

The cost analysis can be conducted in a simple spreadsheet. (See Tables A2.1 and A2.2 in Appendix A2) For all the identified reusable and recyclable materials, use the estimated quantities (from the waste audit), container sizes and rental estimates (transportation requirements) and tipping fees/rebates (disposal options) to calculate the total cost of each possible option. Calculate the estimated disposal cost for all other unwanted wastes. For all the reusable and recyclable options, calculate the cost of landfilling the same amount of waste and compare with the above totals to determine the savings or additional costs.

The results of the cost analysis can be used in conjunction with the waste goals above to decide which materials to reuse, recycle and landfill. It may be cost effective to only recycle one or two of the waste materials generated by the project or it might be worthwhile to institute a full-fledged recycling program[62].

[62] Construction works newsgram, http://splash.metrokc.gov/swd/bizprog/sus_build/newsgram6.htm

4.1.5 Plan implementation

One key determining factor of the success of a waste management plan is its implementability. It is good to develop strategies that are guided by the ideals that we would like to reach in the construction industry, however at project level our contribution towards these ideals should be through achievable goals using practical methods. Furthermore, some plans may not be cost effective to implement. It may thus be better to begin on a small scale and increase the effort as the learning curve flattens out.

The actions described in Table 21 will be necessary when implementing a site waste management plan[63].

Table 21: Actions required for implementing a waste management plan[64]

Actions	Description
Appointment of waste manager	To ensure commitment, operational efficiency and accountability, the waste management function should be assigned to one individual. The waste manager should be given power to: - Select his waste team; - With the help of his team instruct, oversee, record and feedback on day-to-day waste practice; - Delegate responsibility to sub-contractors where necessary; and - Coordinate with suppliers, service providers and sub-contractors to prioritise waste prevention and salvage on site.
Distribution of information	The contractor must distribute the waste management plan to the client team, his crew and to all subcontractors that come to site. The contractor needs to communicate information relating to activities that might be a source of confusion, for example: - If applicable, how the "time-based" waste recycling system will work. - If applicable, identify the designated area for a

[63] Construction works newsgram, http://splash.metrokc.gov/swd/bizprog/sus_build/newsgram6.htm.
[64] Based on Construction works newsgram, http://splash.metrokc.gov/swd/bizprog/sus_build/newsgram6.htm.

	"recycling centre" on site and explain how it will work. - Give details of how day-to-day findings will be fed back into site activities to improve waste practice. - Describe what constitutes contamination and what steps will be taken to ensure it does not manifest itself on site.
Waste handling	The construction site should be clearly laid out with sufficient instructions for waste management. Provision should be made for easy and convenient jobface waste separation and storage; smooth and timely separate collection; and effective use of the recycling centre. The facilities dedicated for the waste program should be kept clean at all times. Finally, all hazardous waste should be treated as a separate waste stream, clearly marked and stored in isolation for collection.

4.1.6 Support[65]

4.1.6.1 Training and Information

In order for waste management to be successful on construction projects, it needs to be afforded the same priority and status as safety for instance. Its program can even be incorporated into the safety program, to simplify things. Either way, the waste program should have a strong element of training in order to allow for maximum participation from the contractors and their labour crews. Training can take the form of general awareness training for all members of the construction team and detailed waste management training for the selected waste team. Regular meetings need to be held to give feedback on progress, achievements and possibly to award outstanding performance. The construction site should have adequate signs and information relating to waste reduction goals, waste management procedures, who to contact for assistance, performance to date and outstanding achievers.

[65] Based on Construction works newsgram, http://splash.metrokc.gov/swd/bizprog/sus_build/newsgram6.htm and Macozoma, 2002.

4.1.6.2 Monitoring and evaluation

The waste team must select effective feedback mechanisms to make sure that problems are dealt with timeously, that processes can be improved while the project is running and to prevent the repetition of similar mistakes in future projects.

Some of the available approaches include:

- Day-to-day site inspection and data capture with overnight feedback to enable corrective action the next day.
- Ongoing monitoring of site activities with regular progress reports detailing quantities of generated waste, quantities redirected to extended use applications and quantities of unwanted waste. Along with these quantities, should come the associated expenses/income of each option. All expenses/income should be accompanied by proof e.g. receipts, invoices etc.
- Post project evaluation with details on project finances, successes and lessons learnt.

4.1.6.3 Education

The construction team will be in a better position to participate if it has knowledge on waste management and green construction. The contractor needs to organise a waste training program (a basic awareness course for all and a detailed waste management course for the waste team). As indicated earlier, it might be easier to incorporate such training into the safety-training program. The contractor can also mandate sub-contractors to train their crews in waste management by including clauses in contract documents.

4.1.6.4 Motivation

Education may equip the project team with the required knowledge to participate effectively in waste management, but can it guarantee participation? This is an obvious concern of any participative process. One mechanism that can be used to improve the chances of participation is motivation. Some of the motivational mechanisms that can be used include:

- Management style – the waste manager should always appear positive, full of courage and hope. Workers look up to management, particularly in times of change and new initiatives.
- Innovation – the contractor should implement things such as slogans, team building items such as stickers and uniform, and spotlights on outstanding team members.
- Sharing successes – the construction site should have signposts with information on achievements to date. The contractor should hold regular meetings to acknowledge team and individual effort.

Incentives – the contractor should organise inexpensive rewards such as caps and T-shirts, good parking spots and vouchers to deserving team members.

Note: Sample waste management plan template is included in Appendix A3.

4.2 Demolition sites

In view of the increasing environmental health and safety concerns that relate to conventional building demolition (i.e. increasing pressure from occupational health and safety practitioners), the associated financial and environmental costs of pollution and waste management (i.e. costs of conventional demolition and pressure from environmentalists), and increasingly stringent legislation, many demolition industries find themselves in a state of transition. There is a general shift, at least in developed countries, away from mass demolition techniques towards planned building disassembly (complete or partial) with the intent of recovering useful building materials for reuse and recycling. The technology of building disassembly is neither unique to the construction sector (e.g. its been successfully applied in the manufacturing sector), nor new (i.e. buildings have been stripped to recover useful building materials for a very long time). However, the technique has found a revival in the past decade under the term building deconstruction.

4.2.1 Building deconstruction[66]

Building deconstruction can be defined as a process of selectively and systematically dismantling buildings to reduce the amount of waste created and generate a supply of high value secondary materials that are suitable for reuse and recycling. Deconstruction can be conducted prior to traditional demolition, be an integral part of the demolition process or replace demolition as a preferred building removal technique. It can be viewed as a sustainable alternative to mass demolition that seeks

[66] Based on Macozoma, (Deconstruction), 2002.

to close the loop of material flow thereby contributing to resource efficiency in construction. The process of building deconstruction can be described as construction in reverse. The materials that were installed last are the first to go and so on. Whereas traditional mass demolition is a mechanical process, deconstruction is largely a labour intensive process. It is thus a great way to understand how buildings are constructed, how components are assembled and connected together and how the scheduling and sequencing of tasks on construction sites works. This presents a great opportunity for training labour for the construction industry.

There are two main types of building deconstruction viz. non-structural (also known as soft stripping) and structural deconstruction. Non-structural deconstruction refers to the removal of non-load bearing components of a building such as windows, doors, appliances, sanitary ware, cabinets and electric fixtures among others. This type of deconstruction can be accomplished with few tools, typical job safety considerations and unskilled labour. It will generally take anything between a few hours and a couple of days. Structural deconstruction on the other hand refers to the dismantling of the structural fabric of a building e.g. building frame, roof system and walls. It requires a range of tools, may require mechanical equipment and a mix of unskilled and skilled labour. It will generally take anything between a number of days and a few weeks. Structural deconstruction is affected more by environmental and occupational health and safety regulations than non-structural deconstruction.

4.2.1.1 Elements of building deconstruction

Since building deconstruction is a labour intensive activity, when compared to conventional demolition, it will be subject to stringent scrutiny with reference to e.g.

environmental health, worker safety and public safety issues. In order to successfully conduct a building deconstruction exercise, thorough feasibility analyses, and project planning and design should be conducted. The elements of building deconstruction are presented in Table 22.

Table 22: Elements of building deconstruction

Element	Description
Site assessment - Physical assessment - Environmental assessment	The physical assessment entails the development of an inventory of what the building is made of. This will help determine the extent to which a building can be deconstructed. There are two methods that are used to identify the materials used in the building, which layer they are on and how they are secured to the structure i.e. a visual inspection and an invasive inspection. The invasive inspection is useful particularly to identify hidden layers e.g. toxic substances such as asbestos containing materials and lead paint that need to be removed from a building, according to regulations, prior to deconstruction (environmental assessment). Other potential problems that can be identified include underground fuel tanks, electrical transformers etc.
Building removal permit	Deconstruction, like demolition, is a building removal process and thus regulations require that a formal notification of intent to remove a building be given. In order to obtain approval the electrical power should be disconnected, all gas and sewer lines must be capped, hazardous materials must be removed and a site inspection by the building authority must be arranged.
Site conditions - Security - Site safety	Deconstruction planning should ensure that the workers and the public are protected at all times, that the salvaged useful waste materials are secure on site and that equipment is safely stored at the end of every working day. In addition, workers need to be protected from potential operational hazards such as falling from elevated work platforms, fire, exposure to hazardous substances and building collapse.
Labour - Insurance - Wages - Training	Since building deconstruction is a labour intensive activity, labour related issues need special attention. The workers need to be protected from physical and environmental hazards e.g. through the use of protective equipment (hard hats, eye protection etc), provision should be made for compensation in the event of an accident and workers should be remunerated according to prevailing wage rates. Workers also need to be trained in construction trades, understand construction vocabulary and be able to effectively use tools and facilities on a construction site.

Building disassembly (removal of) - Fixtures - The roof - Walls - Floor - Other features e.g. stairs	The process of deconstruction is simply 'construction in reverse'. The materials that were installed last in the building are the first to go and so on. Throughout the stripping process, the structural integrity of the building should be monitored to prevent the building from collapsing on its own. When structural components are stripped, it is advisable to erect scaffolding to ensure stability, worker access, mobility and safety. In addition, some building sections may need bracing to maintain rigidity. It is suggested that wherever possible, elevated building components e.g. the roof be brought down to ground level for stripping. This is because it is safer and quicker to work on the ground. The stripping of fixtures and the roof are typically done with hand tools. Floors can be stripped with hand tools or mechanical equipment depending on the type. Walls usually require a combination of hand tools and mechanical equipment. Special attention will need to be given to features such as stairs and basements before selecting tools, taking into account the site conditions.
Processing and materials handling - Fixtures - The roof - Walls - Floor	Material removal from a building needs to be coordinated with material processing and material storage to avoid pile-ups, blockages, double handling and potential hazards on site. The site layout should allow the stripping and processing (i.e. de-nailing, cleaning, sorting, sizing, bundling and stacking) of different types of materials in separate locations without conflict. All recyclable materials should have a designated route that does not interfere with materials salvaged for reuse.
Salvaged materials management - Reuse - Resale - Donation to charity	There are three basic types of salvaged building materials viz. low value materials of relatively poor quality that cost in the range of 10-25% of virgin materials, good quality materials that can readily substitute virgin materials costing 50-85% of virgin material cost and high value materials whose value may equal or exceed virgin material costs (100%+) based on quality, scarcity etc. There are several ways of handling salvaged building materials. The owner can store salvaged building materials for future use on the same site or on other projects. This would save the client procurement costs related to acquiring new materials. Alternatively, the owner can donate the salvaged materials to charity if no use can be found for them. Another option is to sell salvaged materials and generate income from them.



Figure 23: The process of building deconstruction, US.[67]



Figure 24: Processing of recovered timber, Turkey.



Figure 25: Storage of recovered materials, Turkey[68].



Figure 26: Processing of recovered steel reinforcement, Turkey.

[67] US deconstruction photographs appear courtesy of the University of Florida.
[68] Turkish photographs appear courtesy of Dr Eliaz-Ozkan ST, Middle East Technical University.

4.2.1.2 Important considerations for successful building deconstruction

Feasibility of deconstruction

The feasibility of building deconstruction refers to the assessment of the conditions under which the disassembly of buildings to maximise material salvage for reuse and recycling purposes is likely to be successful. The feasibility of deconstruction can be determined using two main criteria viz. the physical potential and economic potential of a given area. The assessment of an area for deconstruction potential depends on the availability of baseline information about the prevailing conditions in that area. Useful sources of information include public housing authorities, building authorities, statistical services, finance and revenue services, health departments and existing secondary material businesses.

There are a variety of factors that influence the feasibility of building deconstruction. These factors present both the opportunities and the barriers to deconstruction. Many of the factors will vary in different areas, but some commonalities can be drawn on a broad scale. Some examples of the factors that influence the feasibility of building deconstruction include the availability of buildings to be deconstructed, the physical condition of the buildings, local construction activity and practice, the local economy, secondary markets, prevailing policy, labour issues, environmental concerns, tipping fees, time constraints, government support, prevailing codes and specifications, and public perceptions of secondary materials.

Design for deconstruction

Design for deconstruction (DFD) refers to the design of a building with the intent to manage its end-of-life more efficiently. The process is intended to ensure the easy disassembly of buildings in order to reduce waste generation and maximise the recovery of high value secondary building components and materials for reuse and recycling. This innovative approach encourages designers to incorporate DFD principles at the design stage of construction projects to ensure that the subsequent stages of remodelling, repair and building removal are conducted efficiently (DFD views end-of-life scenarios for building systems, products and services in a holistic manner that includes both asset management and building removal processes). This approach reinforces the need to consider the life cycle of a building as presented in the model for sustainable construction.

The main elements to consider when designing for deconstruction are:

- Using the model for sustainable construction as a guide during design i.e. superimposing sustainability principles to the traditional life cycle analysis model.
- Designing for flexibility through balancing durability and adaptability, and using the concept of building layers to view buildings i.e. designing buildings in such a way as to isolate the core structure from the skin, the services and the interior.
- Using principles of design for deconstruction (See Appendix A4)
- Selecting the right materials for building components (See Appendix A5)

4.2.2 Waste material salvage

The salvaging of different useful waste materials has varying degrees of benefit, requires varying levels of effort and can be cost effective or costly thus justifying a decision to salvage or not. The most common type of material salvaging is the soft stripping of fixtures inside and on the building face e.g. sanitary ware and sun shades. This type of material salvaging requires less effort and is much safer, but may not carry much value depending on what is being salvaged. On the other hand, structural deconstruction comprises the salvaging of the structural elements of a building. This activity requires a longer period of time, has serious safety implications. It often involves the recovery of high value building materials that need care to prevent damage e.g. roof trusses, steel beams and columns, wooden floors, walls etc.



Figure 27: Salvaged sanitary ware and tiles, Turkey.



Figure 28: Salvaged windows, metal roof sheetings and fenestration, Turkey.



Figure 29: Salvaged columns, US.

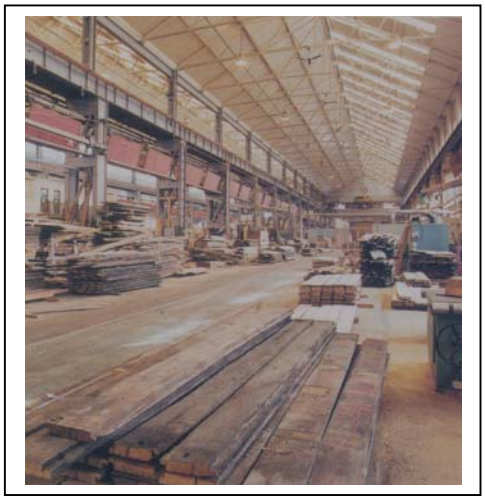

Figure 30: Salvaged structural timber, UK.

A decision to recover a specific building component/material from a building will depend on a number of factors e.g.:

- The amount of effort required to recover the material (recovery cost);
- The condition (quality) of the material;
- The perceived value (potential revenue) of the material;
- The status of secondary markets (demand, availability and perceptions) in the locality of the building; and
- Prevailing regulations, standards and specifications on the use of secondary materials

Based on the above, the contractor can decide to conduct partial deconstruction to salvage certain building materials or undertake complete deconstruction and salvage all building materials.

If a decision is made to salvage secondary building materials, the benefits will include the creation of an alternative material resource pool for construction needs (as an alternative to virgin materials). This will ease the burden on virgin materials and contribute to preserving exhaustible natural resources. Where applicable, the use of secondary materials on site will save costs relating to waste disposal and new material procurement for construction purposes. Furthermore, the salvaging of secondary materials will help preserve the embodied energy contained in these materials.

4.3 Implications for waste management

The introduction of such innovations to construction and demolition activities will have a tremendous impact on C&D waste generation and its management. Since for

both cases the techniques are based on improved source control and material separation for reuse and recycling, they will result in a reduction in the amount of C&D waste that is generated in the first place. In the case of the waste that is generated, the techniques will maximise opportunities for the redirection of useful C&D waste away from the waste stream that is destined for landfill into extended use applications i.e. reuse and recycling. In addition to saving waste disposal costs, this will delay the costs of closure and rehabilitation of existing landfills and also delay the costs of developing new landfill sites. Source control of waste will also help curb illegal dumping, which will save municipalities millions per annum in clean-up costs.

Perhaps the most important implications are environmental, even though they tend to be overlooked most of the time. Reduced illegal dumping will free up green spaces in urban areas and reduce environmental degradation. The delay of developing new landfill sites will preserve land. The energy contained in secondary materials will be preserved if such material is put into extended use. Finally the use of secondary materials will close the materials loop in the life cycle of construction thereby contributing to resource efficiency in construction.

CHAPTER 5: SURVEY – CONSTRUCTION INDUSTRY C&D WASTE MANAGEMENT PRACTICE

5.1 Introduction

A survey of the construction industry was conducted in order to get a better understanding of the level of uptake and application of "sustainable construction" principles in day-to-day construction, demolition and renovation activities. The survey was intended to complement the information gathered during the review of South Africa's C&D waste practice, as discussed in Chapter 3. The intention was to determine how construction industry activities are carried out and how the waste that is generated is managed. This survey was not intended to immediately influence current operations, but rather to observe current practice. The findings of the survey reinforce the findings of the C&D waste practice review and will enable recommendations to be made to construction industry practitioners on measures that can be put in place to ensure compliance with sustainable construction principles and ensure increased secondary construction material usage.

5.2 Survey questionnaire

The survey questionnaire used was designed with the intention of getting feedback in seven (7) main areas i.e.:

- Construction activities – to understand the types of construction activities that are undertaken by construction companies. This section also asked about the concept of sustainable construction to determine general awareness.
- Waste management – to determine the amount of waste that is generated on site and how such waste is managed.
- Environmental issues – to determine awareness of the environmental implications of construction activities.

- Economics of reuse, recycling and secondary markets – to assess the perceived cost implications of undertaking waste minimisation strategies such as reuse and recycling.
- Regulations, standards and specifications – to determine the construction industry's opinion of the role of regulations, standards and specifications in promoting or inhibiting waste minimisation and secondary materials markets.
- Role of Government – to determine industry expectations of the role Government should play in stimulating secondary construction materials markets.
- Public awareness and perceptions – to check the construction's level of understanding of consumers and how consumer perceptions are likely to affect their decision to adopt sustainable construction practices.

The survey questionnaire is attached as Appendix A6.

5.3 Response rate

Table 23 gives a summary of the survey conducted, providing details on the construction and demolition companies covered by the survey and the response rate obtained.

Table 23: Survey response rate

Companies	**Questionnaires sent**	**% of total**
Construction Companies	137	94%
Demolition Companies	8	6%
Companies		**Responses Received**
Total	145	14
Response Rate		10%
% Response in Construction		9%
% Response in Demolition		14%

The response rate obtained was generally poor at an average of 10%. It is however not a great concern to the author that the response rate was this low for two reasons:

- Firstly, the selected contractors vary from the conventional big construction industry players to a large number of middle and small contractors. Many of the small contractors, as is the case in other countries, are relatively young in the industry and very small in size and they generally focus on survival and hence do not dedicate much time and resources to sustainable construction or similar industry level matters. On the other extreme, general apathy could explain the lack of responses from established contractors. As in other countries, this is believed to be because of the perceived benefit of engaging in initiatives of this nature.
- Secondly the low response rate could be a good indicator of the level of uptake and application of sustainable construction and waste minimisation in the South African industry. Judging by the responses that were received, there indeed are low levels of absorption of these emerging global trends and huge gains can be achieved by rolling out the proposed framework.

5.4 Findings

5.4.1 Construction activities

The respondents generally indicated that they use a variety of construction materials in both the demolition and construction activities. Many respondents use both mechanical and labour intensive construction and demolition methods. Depending on the size of company, mechanical equipment would be heavy plant for large companies and small plant for small and emerging companies.

Waste generated on site seems on average to be in the range of 3-10% of material procured with limited outliers in the bottom end of 0-1% and at the top end at 30%. Training (internal or outsourced) is generally provided for skilled personnel at foreman level or higher and a tertiary qualification is required as a minimum at entry level. Unskilled and semi-skilled labour generally has no entrance qualification requirement, with training ranging from onsite training to no training at all.

There is generally little knowledge of sustainable construction, with relatively few companies that conduct in house research into international trends in construction industry performance improvement.

5.4.2 Waste management activities

The respondents generate a wide range of waste materials on site depending on the project type. Typical wastes indicated include concrete, brick, asphalt, mortar, masonry and clear spoil. Methods used for waste storage on site include a combination of commingled disposal receptacles, separate recycling receptacles and dedicated stockpiling on site. Similarly generated waste is collected by a combination of contractors themselves, municipal waste services, private waste collectors and emerging waste contractors for disposal at either municipal or private disposal sites.

The staff of the respondents are generally aware of waste management requirements and practice some form of waste management and recovery for recycling. Only three respondents indicated ever having tried to implement a formal waste management or minimisation programme on site. For these the benefits were clearly evident in terms

of waste reduction, hence disposal cost reduction. There is clear awareness of the environmental impact of such waste management or minimisation, however the social impact is not well understood.

Waste generated by the respondents varies from 1ton per month to 40 000 tons per month. This depends on two issues mainly, i.e. the size of company and the size of project. There understandably will be more interest and keenness to experiment with waste minimisation at the high end of generation, as the potential savings will be more. However, if waste recovery also happens at landfill sites, the small waste generators can incrementally make significant impact.

Only three respondents indicated that their companies conduct research into international trends in waste management and minimisation.

5.4.3 Environmental issues

The respondents indicated awareness of the potential environmental impacts of their construction industry activities and expressed confidence that their activities were in compliance with relevant regulatory requirements. Only two respondents indicated that their companies do not have an environmental policy.

Staff is generally knowledgeable in environmental issues and requirements, and for the ones where it is applicable, training is provided to staff for handling hazardous waste. One respondent indicated that the services of a specialist are procured to handle hazardous waste. Apart from hazardous waste training, 38% of the respondents indicated that their staff is not trained in environmental processes and requirements.

5.4.4 Economics of reuse, recycling and secondary markets

The majority of respondents were of the opinion that the biggest cost components of reuse and recycling were transportation and processing. Transportation includes both the transport of material feedstock to reprocessing plants and the distribution of secondary materials and products to end markets, while processing costs include the cost of plant, labour and the sorting of materials to improve quality.

Many respondents seem to have tried the reuse and recycling option, and although not at a macro scale, they also seem to have conducted some form of cost benefit analysis. The general observation is that if waste is separated on site and reused in situ, the benefits are higher due to cost savings e.g. avoided disposal costs and virgin material acquisition costs. A concern was raised with the challenge of sometimes being far from recycling facilities and/or end markets for secondary materials, as this tended to increase the costs of this option.

About 63% of the respondents indicated that there is a perception that reuse and recycling is more expensive than waste disposal. The respondents generally could not come up with comprehensive suggestions on how the cost of reuse and recycling can be reduced. Some respondents did however make good suggestions such as using mobile recycling plants to be able to set up at the source of waste, recycling close to end markets, creating secondary markets and reviewing regulatory mechanisms.

5.4.5 Regulations standards and specifications

This area was the least known by the respondents. Those that had the knowledge seemed somewhat aware of recent construction industry improvement and waste regulation developments. Generally there is a feeling that engineers and government tend to hinder the use of secondary materials and should embrace these materials more. In addition, the respondents indicated that what is required to further create a conducive atmosphere for secondary material use was a review of construction specifications and the introduction of incentives and punitive measures in waste regulations to increase waste recovery instead of disposal.

5.4.6 Role of Government

Generally the respondents felt that Government has a role to play in promoting secondary construction materials. There was a fairly balanced split between the respondents who felt that government should or shouldn't use punitive measures such as tax and surcharge pricing to force people to use secondary materials. There was however unanimity in the suggestion for government to use incentives to encourage the use of secondary materials.

Many felt that Government should lead the process through awareness creation and demonstration. It was also felt that the private sector has a role to play in promoting secondary materials, providing the environment is conducive and business prospects are high.

5.4.7 Public awareness and perceptions

About 75% of the respondents agree that “secondary materials” are perceived to be synonymous with “inferior materials”, albeit for different reasons. Some think this is due to engineers who are used to conventional specifications, not embracing recent developments, while others think it is a result of limited knowledge and comfort with tried and tested materials.

It was generally agreed that changing the perception of the public with respect to secondary materials can be achieved through a combination of mandatory secondary material use, awareness and education, government partnership with communities and market forces.

On average, respondents indicated that secondary materials should cost in the range of 50-80% of virgin materials in order to have meaningful costs savings and profit prospects. This was seen to be a lever to swaying public perception towards acceptance of secondary materials. There was also reference to the need for secondary materials to at the worst be equal to virgin materials, however the most important observation made was that the cost of using secondary materials should be viewed at its broadest sense i.e. comparing it not only to the purchase price of virgin materials but also to the disposal cost component waste generated on site.

It was generally felt that the South African public is not fully knowledgeable about sustainable development and that more awareness needed to be created. One respondent however pointed out that knowledge does not necessarily imply use,

stating that while awareness was increased through debate on the subject, increased use would come with skill in the use of secondary materials.

5.5 Summary

In summary the following observations can be made:

- Sustainable construction and waste minimisation are not being absorbed sufficiently by the construction industry in South Africa. Reasons for this are broad and vary, but are generally a result of a combination of insufficient regulatory interventions, low levels of awareness and education, underdeveloped secondary markets, negative perceptions, limited incentives etc.
- There are varying opinions about the exact role that government should play in promoting sustainable construction and secondary material use. Stakeholders seem to think that some degree of regulation is necessary, but are quick to advise against total control, preferring increased adoption of free market principles.
- The private sector role in promoting sustainable construction and the creation of viable secondary materials markets is not well defined or understood. Stakeholders seem to think that the private sector will only be able to enter once the environment is conducive, with clear profit making potential. The critical role that the private sector can play in changing public perception, creating demand for secondary materials and guaranteeing secondary material supply is not generally realised.
- The economics of reuse and recycling vs. virgin materials and waste disposal have yet to be thoroughly unpacked. The many hidden costs of virgin material use and waste disposal are often not considered when conducting cost benefit analyses, and hence the perception that reuse and recycling are expensive still persists.

- There is a steady but definite penetration of sustainable construction and waste minimisation in the South African construction industry, what is needed is the elevation of its profile and its acceleration to ensure that South Africa does not lag behind international development trends in this regard.

CHAPTER 6: PROPOSED FRAMEWORK FOR DEVELOPING A SELF-SUSTAINING SECONDARY CONSTRUCTION MATERIALS MARKET IN SOUTH AFRICA

6.1 Introduction

As described above, South Africa has yet to exploit the full potential of secondary materials. The construction and waste management industries have been shown to lag behind international best practice in terms of introducing measures that will ensure sustainability in the consumption of resources and the preservation of the environment. As observed in the review of other countries, sustainable construction and waste minimisation are emerging as the preferred models for promoting/ensuring sustainability in construction and waste management processes respectively.

In order to successfully establish and sustain a formal secondary construction materials market, South Africa needs to develop a comprehensive market development strategy and plan. Such a strategy and plan need to involve and integrate all stakeholders and activities that form part of the construction and waste management industries. The market development strategy and plan need to cover the entire life cycle of construction materials in order to comply with the model for sustainable construction.

6.2 Status of materials flow in construction

Material flow in construction has conventionally followed a linear pattern from extraction through to disposal. Each of the various stages of the material flow diagram would then generally have cross cutting implications such as energy, waste, resources, finances and the environmental impact. See Figure 31.

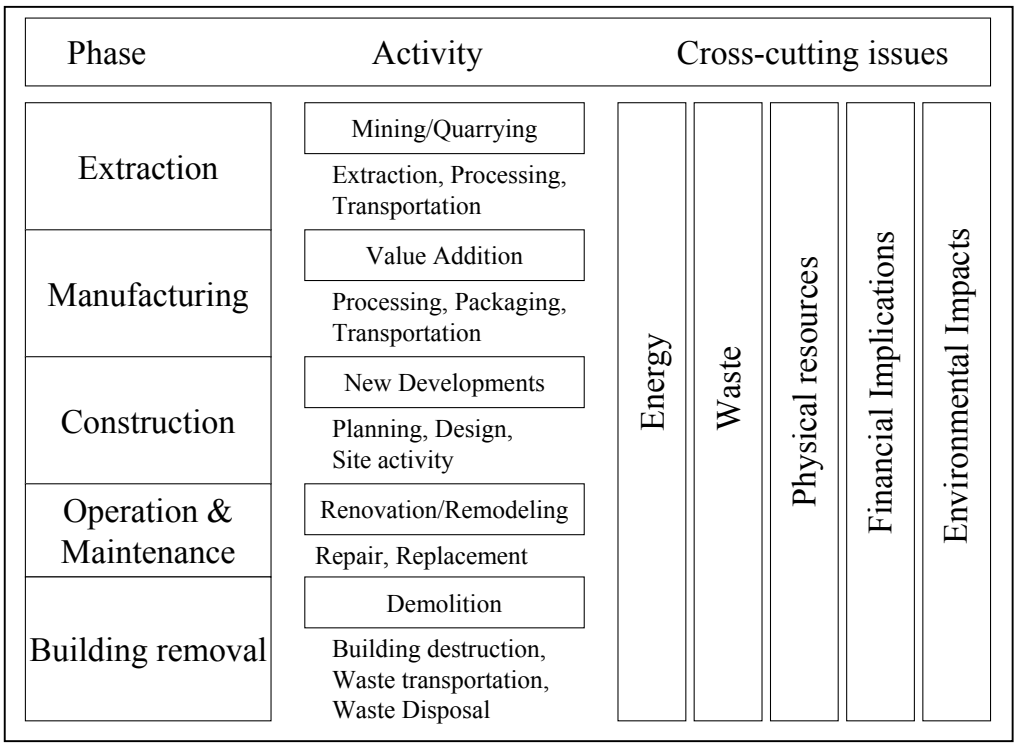

Figure 31: Conventional flow of materials in construction

The following inefficiencies have been observed in relation to construction and demolition practice and the conventional flow of building materials throughout the lifetime of a building.

Virgin material extraction

- Extracting more and using less due to resource availability and artificially cheap land;
- High energy consumption rates;
- Toxic emissions to the environment;
- Disturbance of ecosystems and sometimes (if not often) no rehabilitation;
- Waste generation and irresponsible disposal.

Manufacturing of materials and products

- High energy consumption rates;

- Emissions to the environment;
- Generation of general and toxic waste by-products;
- Use of packaging materials that end up as waste;

Construction

- Material procurement errors;
- Poor material handling practice;
- Human error;
- Lack of waste management planning.

Operation and Maintenance

- Poor energy performance of buildings;
- Renovation without planning for material recovery and secondary material use;
- Lack of building adaptability to different user needs over time.

Demolition

- Lack of building flexibility to enable different use;
- Lack of design for deconstruction that prevents material and component recovery;
- Demolition without planning for material recovery, reuse and recycling;
- The loss of embodied energy that is contained in materials.

To address the above shortcomings of conventional material flow in construction, a paradigm shift is required. This shift involves the redefinition of materials flow through a building in order to ensure a closed loop pattern of material consumption that creates raw material feedstock from potential waste material thus reducing raw material dependency, reducing waste generation and generating secondary construction material supply and demand. See Figure 32.

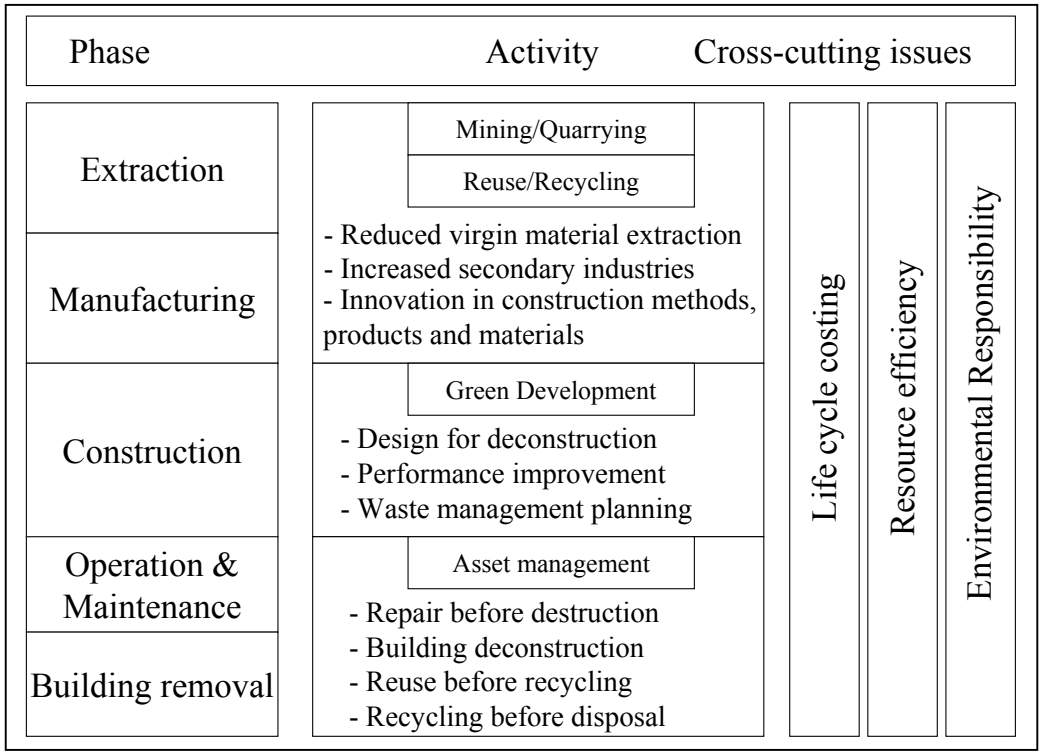

Figure 32: Revised life cycle of materials in building construction (towards sustainable construction)

As shown in figure 32, the revised life cycle of materials in construction is based on the concept of "resource efficiency". Such an approach can ensure that:

- The "materials flow" loop is closed to ensure that waste materials become resource pools for future construction material needs;
- Dependency on virgin materials is reduced;
- Innovative construction materials are developed and used increasingly in construction;
- A new economy is created based on construction material recovery, repair, remanufacturing, reuse and recycling;
- New job markets and new revenue streams are created;
- New consumption patterns emerge.

6.3 Establishing a secondary construction materials market

Developing a secondary construction materials market is dependent on the availability of information relating to commodities that are available to provide raw material feedstock for secondary markets. This information is essential for ensuring that sufficient material supply will be available for secondary markets. In addition, secondary markets rely on information dissemination and awareness creation among the public in order to promote secondary materials and create the necessary demand. Furthermore, material supply and market demand will need to be supported by a good network of secondary material infrastructure, which comprises waste recovery facilities, waste recycling facilities and secondary material retail outlets. Figure 33 provides a flow chart of the necessary elements of a comprehensive secondary construction materials market development strategy and plan.

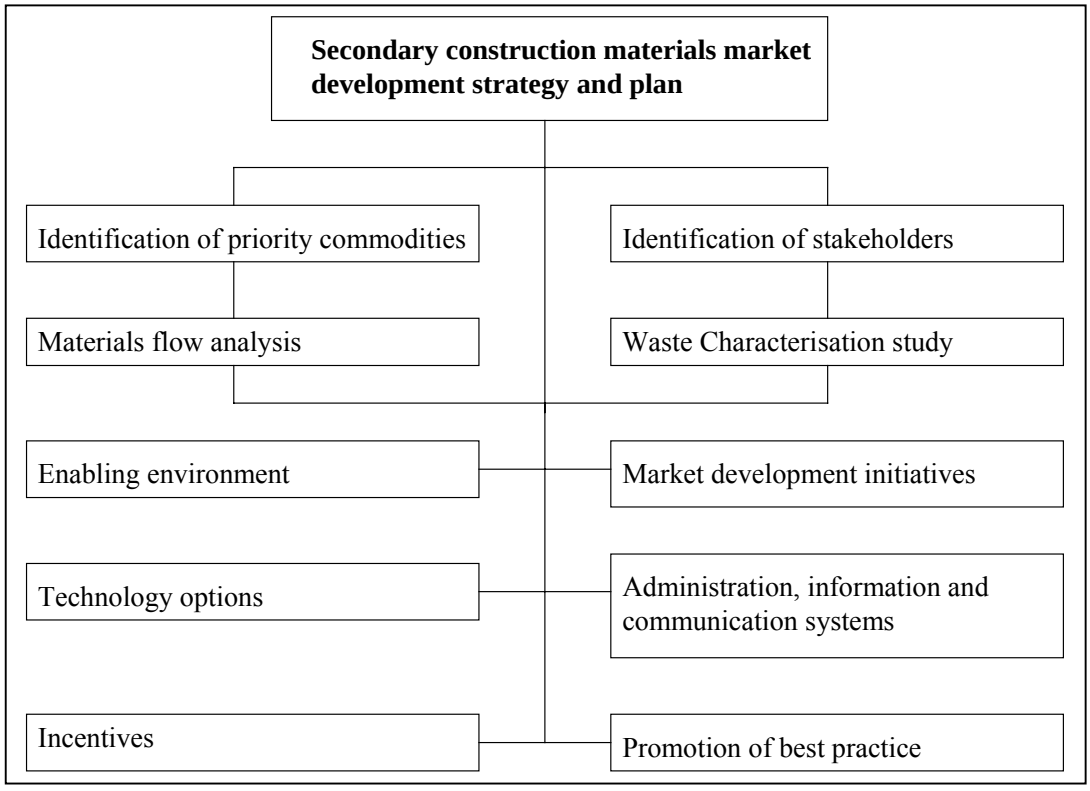

Figure 33: Flow diagram for the development of a secondary construction materials market

6.3.1 Identification of priority commodities

Many materials that are used in construction, demolition and renovation activities can be reused and/or recycled into secondary products for extended application in construction processes. However, the amount of effort involved in the recovery and restoration of value in waste materials varies according to for instance the stage at which the waste materials were recovered, the amount of processing required to restore the material's value and the proximity of materials to end markets. Thus when overall waste minimisation targets are set for an area, careful consideration has to be made to determine component contributions of each material type to the overall target.

Naturally, only the biggest contributors would justify investment into infrastructure and systems for recovery, recycling and distribution. For demonstration purposes, in 1990 the California Integrated Waste Management Board (CIWMB) set a target of 50% waste reduction through diversion from waste disposal to recovery for reuse and recycling by 2000[69]. In order to achieve this target, the CIWMB defined its secondary market capacity goal to be 25 million tons per annum (MTPA). By 1995, the CIWMB had managed to achieve a diversion rate of 12 MTPA. In order to ensure that the remaining 13 MTPA was achieved in the remaining 5 years, the CIWMB developed a market development plan that identified the potential contribution of the various waste materials (see Table 24). From this, a priority list of waste materials/commodities was identified.

[69] California Integrated Waste Management Board (CIWMB), 1996.

Table 24: CIWMB Market Capacity Goals

Material	2000 Market Capacity Goal (MTPA)*	Comment
Paper	9.8	Priority
Inerts (building rubble)	4.7	Priority
Compostibles and Mulches	6.3	Priority
Urban Wood	1.5	Priority
Ferrous Scrap	1.6	Established market
Plastics	0.4	Priority
Glass	0.6	
Tyres	0.2	Priority
Total**	25.0	

*Includes materials diverted for recycling, composting and energy recovery
**The total figure includes other materials not listed in the table

The paper, inerts, compostibles and wood were selected due to their large contribution to the waste stream, while plastics and tyres were selected due to their special collection and threat they pose to the environment. Further work was conducted to identify opportunities that are presented by the different materials as further justification for prioritisation e.g. areas of possible application; possible markets and revenue streams; reusability and recyclability etc.

6.3.2 Identification of stakeholders

It is important to identify and involve all stakeholders that contribute to material consumption and waste generation in construction processes; as well as stakeholders that can enable the development of a sustainable secondary construction materials market. These will need to be lobbied in order to promote partnership in market development. Some of the stakeholders to be involved in this process are listed in Table 25.

Table 25: C&D waste stakeholders and their areas of influence

Stakeholders	Contribution
Designers	Design for waste reduction and recovery for reuse and recycling
Building owners	Advocacy for "green" building practice
Demolishers	Alternative technologies and source control
Contractors	Waste management planning
Consultants	Client support in green construction
Waste collectors	Waste recovery and separate collection
Landfill sites	Stockpiling of useful C&D waste
Salvagers	Waste recovery
Secondary material shops	Supply of good quality secondary materials
Recyclers	Supply of good quality recycled materials and products
Local authorities	Approval and support of secondary industries
Funding agencies	Sponsorship of research and pilot projects
NGOs	Advice and support
Research (Universities and Research bodies)	Innovation, investigations, tests and decision support
Standards generating bodies	Testing and recognition of innovations
Communities	Involvement and demand for secondary materials and products

6.3.3 Materials flow analysis

South Africa will need to conduct a material flow analysis in order to understand the quantities, condition and composition of materials through the various stages of a building's life cycle (See Figure 31). This knowledge will enable informed decision making on the areas that need to be targeted in order to ensure that priority materials will be diverted to reuse and recycling in sufficient quantities at the lowest reprocessing cost. See Figure 34.

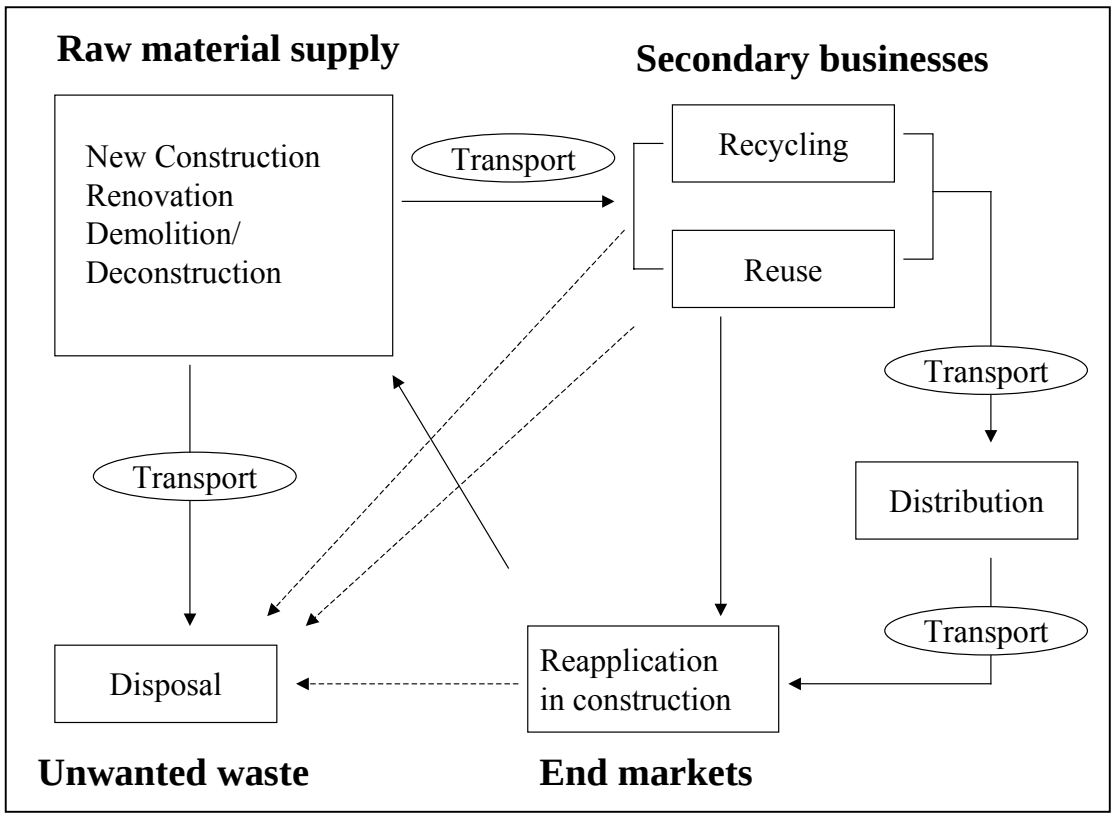

Figure 34: Secondary material diversion to reuse and recycling

6.3.4 Waste characterisation study

As per the observations made in the study of C&D waste practice in South Africa and the lessons learnt from other countries, it is imperative that South Africa commissions a waste characterisation study in order to determine the properties of C&D waste that is generated in construction, demolition and renovation sites. For instance:

- The quantities generated;
- How it is stored;
- Its composition at various stages;
- Where it is disposed of;
- How much is currently being diverted to reuse and recycling applications;

- The size of reuse and recycling markets;
- The cost and revenue streams; and
- The regulatory environment governing the management of C&D waste.

Such a study will be very instrumental in informing the authorities on the main waste streams that South Africa should focus attention on in terms of disposal control, and the promotion of reuse and recycling. This should be a full-scale study at national level, providing both a national picture as well as providing the requisite regional status detail.

6.3.5 Enabling environment

The review of countries such as the United States, the Netherlands and Germany indicate that Government can play a critical role in promoting the creation of viable secondary construction materials markets. Interventions ranging from regulatory, financial, demonstrations and awareness campaigns have had varying degrees of success in the various countries and South Africa can learn valuable lessons from each of these cases in order to implement a comprehensive government intervention locally.

For instance, the following interventions can be considered:

- Regulatory interventions such as the banning of the disposal of useful C&D waste in landfill sites, i.e. the Netherlands case, can provide a strong swing towards the redirection of waste to reuse and recycling operations. Secondly, illegal dumping must be outlawed and its profile elevated to a serious crime in order to deter people from using it as a preferred option. By the very nature of regulatory

interventions, there will be a strong reliance on Government's ability to enforce any such legislation that is introduced.

- Financial interventions such as the introduction of a landfill tax i.e. the United States case, has been shown to have a threshold beyond which a definite change from landfill disposal to reuse and recycling happens. In addition, government can introduce legislation, i.e. the California case, where demolition contractors are charged a fee per ton (deposit), which is refundable if the demolisher can prove a recycling rate of 50% or more generated waste material.

- Government led demonstration projects, as in the United States, can go a long way to convincing communities and the construction industry that waste material recovery and reapplication is not only environmentally sound but can also be economical. This approach can also be useful during the research phase in order to determine further information in the area of sustainable construction.

- A partnership between Government and the private sector can also play an instrumental role in accelerating change in the perception of secondary construction materials by communities and the broader construction industry. Awareness campaigns can amplify the value of opting for secondary construction materials instead of virgin materials. Since this subject spans across many sectors such as public works, transport, environmental affairs and energy, various Ministries and industries can find a role to play in such awareness campaigns.

6.3.6 Market development initiatives

The current underdeveloped state of secondary construction materials markets is due to relative industry inexperience in the domain of reusable and recycled materials. This is a consequence of a number of factors that include manufacturer specifications; consumer preferences and perceptions; perceived and actual material feedstock and product quality; and policy and regulatory frameworks that impact (often negatively) on the supply and demand of secondary construction materials.

The state of California in the Untied States developed a market development plan that included the following elements:

Recycled materials development zones

These are industrial business districts, which receive focused government and financial sector support in order to;

- Promote recycling market development;
- Cluster recycled product development industry segments such as recovered materials, manufacturers and distributors in order to reduce input costs
- Facilitate micro-lending packages from both government and financial institutions, and
- Provide a central and easily accessible business support service to secondary material businesses within the recycled materials development zone.

Secondary material infrastructure development

The provision of secondary material infrastructure will support the development of recycled materials development zones in order to ensure that the demand for

secondary materials and products will be met by the supply. It has been observed that secondary materials sometimes suffer the uncertainty of availability due to factors such as limited projects, varying material composition and distant sources. This intervention will ensure the establishment of waste stockpile and sorting facilities in strategic locations to supply waste reuse projects and recycled product manufacturers. In addition, this will also include infrastructure for recycled waste distribution in order to bring recycled materials within reach of end markets.

Buy recycled materials programmes

These programmes are intended to elevate the profile of reusable and recycled materials. The focus of such programmes is two-fold, i.e. to dispel the perception that the term "secondary" is synonymous with the term "inferior" in relation to secondary materials through demonstrations and to prove that it can be economical to opt for secondary materials instead of virgin materials from a lifecycle perspective.

6.3.7 Technology options

Construction and demolition technology options need to be investigated in order to maximise the potential for sustainable construction and waste minimisation. Guided by the model for sustainable construction and the waste hierarchy, as discussed in Chapter 1, technologies should be investigated for applicability in specific situations. For instance:

- When buildings are constructed, renovated and/or due for removal, consideration should be given to deconstructability (i.e. the ability to dismantle instead of demolishing).

- Construction technologies and construction materials will have a direct impact on the recoverability and usefulness of recovered materials. For instance rigid construction limits the dismantling of buildings and the use of composite materials and materials with hazardous substances usually rules out any form of waste recovery.
- Depending on the applicable conditions, when embarking on a demolition project consideration should be given to the most important objective e.g. rapid removal and construction or job creation and material recovery. This will inform the selection of an appropriate demolition method and technology e.g. implosion, mechanical mass demolition, or labour intensive dismantling.
- Waste generation and recovery processes will usually determine the quality of secondary materials produced, thus careful planning is required before waste is generated. Waste separation, storage and processing technologies are key to maximising the quality of the final product.

6.3.8 Administration, information and communication systems

As stated elsewhere "if it cannot be measured, it cannot be managed", thus authorities and the construction industry need to set-up information systems that will be able to capture information on construction material sourcing, processing, use and disposal. This information is important for identifying the potential for resource conservation through building and component reuse, product reuse, and waste material reuse and recycling. At macro level this information will allow for resource efficiency master planning, while ensuring detailed site management and waste management planning at project level.

Information dissemination is very important in the drive to increase public awareness, educate communities and the construction industry and in changing the perception of practitioners that might be reluctant to change due to comfort with tried and tested material. The use of internet based waste material exchanges in the United States, Germany and the United Kingdom has enabled the linking of secondary material producers with end users, providing choice for the latter in terms of material type and quality to suit their building requirements. Such facilities also enable competition that helps reduce the cost of secondary materials for the consumer.

6.3.9 Incentives

The promotion of sustainable construction needs to be comprehensive in nature, incorporating both the "carrot and stick" incentive approaches. Once more, the review of best practice in this regard in countries such as the Netherlands, Germany, The United States and the United Kingdom reveals a number of useful instruments that South Africa can adopt as incentives. For instance:

- Marginal costing which will ensure direct user payment in line with the rate of consumption (as opposed to a flat fee payment structure). Waste disposal at landfills to be determined per ton and per type of material, including discount fees for recyclable materials per type.
- Tax relief for the conversion and reuse of obsolete yet structurally sound buildings instead of complete demolition.

- Targeted support to reusable and recycled material industries, incorporating a broad range of products including micro-loan finance, business development support, material supply and product distribution support etc.
- Focus on employment creation through labour intensive building deconstruction instead of mass demolition. Where appropriate, this would yield more jobs per project, ensuring that the construction industry increases its job creation levels.
- The introduction of a rating system that gives preference to building, civil engineering and demolition contractors that use "green building" practices.

6.3.10 Promotion of best practice

Government and the private sector should lead the process of promoting the use of secondary construction materials market through practical demonstration. Initiatives that have been shown to work in other countries include:

- Sponsorship of demonstration projects to help further research in C&D waste management and waste recovery.
- Donation of buildings for showcasing the potential of building deconstruction and site waste minimisation.
- Documentation of projects to increase literature and disseminate information on sustainable construction and C&D waste minimisation.
- Identification of large housing settlements, apartment buildings, offices or old military bases for deconstruction, renovation and adaptation for different use - applying the principles of sustainable construction in executing the works.

6.4 Ensuring successful implementation of the proposed framework

The framework proposed above contains a significant amount of work that has hitherto not been conducted in South Africa. For the proposed framework to be successful, it will require a suitable champion to lead the process and coordinate the various activities with the identified stakeholders. Also fundamental to success will be the communication among the various stakeholders. The review and benchmarking of South Africa's construction and demolition waste practice with developed countries including the United States, United Kingdom, Germany and the Netherlands has shed light particularly in two areas i.e. the gap areas in relation to South Africa's current practice and the possibilities presented by sustainable construction and waste minimisation in the quest to balance the economic, social and environmental impacts of development.

Lessons from elsewhere have shown that the proposed framework can be championed by either Government or the private sector. However, in both cases it has been found that both the public and private sectors have a significant role to play. It will thus be useful to create a steering committee that can comprise both the public and private sectors in South Africa. The steering committee will be expected to provide guidance on the roll out of the proposed framework. It is however important to note that, even with a steering committee, a single champion is necessary to ensure direct accountability for the process. A detailed institutional structure must be developed to clearly define the roles and capacities of the various identified stakeholders and to enable proper assignment of functions in accordance with the proposed framework. Funding issues will inevitably need to be addressed during this process, but this should be done after the completion of preliminary processes such as the setting up of

institutional arrangements, the identification of a champion and domain leaders, and the definition of scope and activities to be executed. This is preferred, as funding challenges generally tend to constrain proper planning.

A comprehensive secondary construction materials market development strategy and plan will need to be developed first in order to guide all interventions to be made. This is important to ensure coherence in the roll-out of activities, and it will also give guidance on the scheduling of activities as informed by agreed targets. The various stakeholders involved will have various roles and contribute at various stages of plan roll out, however where necessary and appropriate stakeholders should provide leadership in order to ensure broad buy in by the public e.g. demonstration projects, awareness campaigns, and the funding of research. Of equal importance will be the commissioning of monitoring and evaluation processes in order to track progress, communicate results and determine alignment with the overall goals of sustainable construction and waste minimisation.

CHAPTER 7: CONTRIBUTION OF RESEARCH PROJECT AND FURTHER WORK

7.1 Research report

As explained in the context, this research project was not intended to question or advance the theoretical basis for promotion of the concept of sustainable construction. It was however intended to continue from the author's previous contributions to the areas of sustainable construction and C&D waste minimisation by proposing a framework that can be used by South Africa to create a viable secondary construction materials market, which will be a valuable tool to ensuring the absorption of sustainable construction by the construction industry.

The research project has looked at South Africa's current practice in relation to construction and demolition waste management on construction, demolition and renovation sites as well as waste disposal sites. The study has also reviewed South Africa's secondary construction materials market from waste diversion and recovery to material reuse and recycling. In order to get an appreciation of where South Africa is in this area globally, it was benchmarked against the United States, United Kingdom, Germany and the Netherlands, which are among the leading countries in the areas of sustainable construction, and construction and demolition waste management. This benchmarking revealed a lag in South Africa's current practice in this area, but more importantly provided valuable lessons that South Africa can use to accelerate the penetration of the principles of sustainable construction in the construction industry.

As intended, the research project finally proposes a framework that can be adopted by South Africa to develop a self-sustaining secondary construction materials market,

which can prove to be a valuable tool for ensuring the absorption of sustainable construction principles in construction activities. The framework emphasises that construction should be viewed from a life cycle perspective, and that understanding materials flow throughout the life cycle of buildings will enable informed decision making on where interventions should be made to recover materials for reuse and recycling, thus minimising waste generation and extending material life.

7.2 Further research work

There are various areas that require further work in order to complement the work conducted in this study. Until now, work in the area of sustainable construction with particular emphasis on construction and demolition waste and the secondary construction materials market in South Africa has been of a regional or local nature with no national level studies. The author's previous studies found reuse and recycling activity in selected parts of South Africa with no proper coordination and limited Government involvement or cooperation.

Some of the areas that need further research in order to promote the absorption of sustainable construction in South Africa's construction industry include:

- Further research on the properties, scope of application, generation and supply of recycled aggregates;
- Review and modification of construction specifications to accommodate secondary construction materials recovered from construction, demolition and renovation activities;

- Investigation of the feasibility of adopting building deconstruction as a preferred technology for building removal ahead of demolition in South Africa;
- Benchmarking of South Africa's construction and demolition practice against developing countries to compare the rates of absorption of the principles of sustainable construction, C&D waste minimisation and the state of secondary construction materials markets. Such a study will yield one of two things, either valuable lessons for South Africa or useful information for other developing countries.
- Detailed construction and demolition site assessments using some of the methods proposed in this study to assess waste generation and develop waste specifications and waste management plans;
- Initiation of demonstration projects to showcase the potential economic, social and environmental benefits of applying sustainable construction principles against similar projects that use conventional methods.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

- Construction industries have been found to contribute significantly to the amount of waste that is generated by countries across the globe, and South Africa is no exception.

- Many countries are concerned about construction industry inefficiencies and diminishing landfill disposal capacity, and are thus embarking on approaches that will ensure resource conservation through sustainable practices. The latest international trends for construction industries in this regard include "sustainable construction" and "C&D waste minimisation".

- The concepts - sustainable construction and waste minimisation, are not being absorbed in the desired rate by the construction industry in South Africa. Reasons for this vary, but are generally a result of a combination of insufficient regulatory interventions, low levels of awareness and education, underdeveloped secondary markets, negative perceptions, limited incentives etc.

- It is critical that consistency be achieved at least nationally (ultimately regionally and internationally) on the definition and classification of C&D waste. Current inconsistencies make it difficult to accurately account for waste generated, reused, recycled, disposed by landfill and dumped illegally.

- There is an urgent need for accurate and up to date information on C&D waste arisings, its character and location. The absence of such information makes it

difficult to measure the C&D waste problem, plan for C&D waste minimisation and secondary construction materials market development.

- The countries reviewed in this study are different in their own right e.g. building systems and methods, however they have been found to exhibit similar trends with reference to C&D waste management, and the shift towards sustainable resource use and construction practice. For instance:
    - There is a gradual clamp-down on C&D waste disposal on landfill sites;
    - There is a shift towards improved site management and waste prioritisation with the focus on waste prevention, source control and separate waste collection;
    - Secondary markets are starting to play a pivotal role in the success of C&D waste minimisation; and
    - Efforts are being directed towards awareness creation, partnership creation and information dissemination in addition to imposing legislation.

- The composition of C&D waste is difficult to measure. It has been found to vary tremendously with the type of activity, construction /demolition method and material content. However, general observations can be made on typical waste types that can be expected from certain types of structures and construction activities. Waste composition is of particular importance when considering options for waste material end use.

- With the exception of the Netherlands, waste disposal at landfill sites is still the most predominant form of C&D waste disposal, ranging between 55% and 85%.

Current trends however show a move towards restricted landfill disposal, if not a complete ban (this does not include acceptable landfill practice such as backfilling etc.).

- Fiscal and regulatory instruments (e.g. landfill tax, spot fines for illegal dumping, tax exemptions, and landfill restrictions, ordinances on waste handling and transportation, and target setting) are making the environment more conducive to alternative waste handling options instead of landfill disposal. With proper monitoring in place, unwanted consequences such as illegal dumping and unlawful incineration can be avoided.

- Information sharing is critical to the success of C&D waste minimisation. It has been shown that waste material exchanges stimulate secondary markets, while up to date waste information systems make C&D waste management more effective.

- While a degree of mandatory measures is necessary to ensure control, more can be achieved through partnerships and stakeholder involvement. There are many role-players in the life-cycle of C&D waste and they all need to contribute to sustainable construction.

- Secondary markets have potential to create employment, change material consumption patterns, contribute to the economy and develop new markets that are based on RE's i.e. recovery, reuse, repair, remodelling, recycling and remanufacturing.

- There are varying opinions about the exact role that government should play in promoting sustainable construction and secondary material use. Stakeholders seem to think that some degree of regulation is necessary, but are quick to advise against total control, preferring increased adoption of free market principles.

- The private sector role in promoting sustainable construction and the creation of viable secondary materials markets is not well defined or understood. Stakeholders seem to think that the private sector will only be able to enter once the environment is conducive, with clear profit making potential. The critical role the private sector can play in changing public perception, creating demand for secondary materials and guaranteeing secondary material supply is generally not realised.

- The economics of reuse and recycling vs. virgin materials and waste disposal have yet to be thoroughly unpacked. The many hidden costs of virgin material use and waste disposal are often not considered when conducting cost benefit analyses, and hence the perception that reuse and recycling are expensive still persists.

- There is a steady but definite penetration of sustainable construction and waste minimisation in the South African construction industry, what is needed is the elevation of its profile and its acceleration to ensure that South Africa does not lag behind international development trends in this regard.

- As with other countries that have been through the process of adopting the principles of sustainable construction to improve construction industry performance in terms of resource conservation, energy efficiency, and waste

minimisation, South Africa needs to have a realistic market development plan that will be implemented over the medium term, with realistic targets and timeframes. Sustainable construction is relatively new, there are many lessons to be learn and necessary actions will be slow, needing long lead times in certain areas. Of significance will be the need to collect information and plan before embarking on programmes.

- There is a need for continuous research into ways of improving the quality of secondary materials, their performance and their application in everyday operations.

Recommendations

Based on the findings of this study**,** it is recommended that the following interventions be considered in order to improve construction industry performance and ensure proper C&D waste management, thus enabling South Africa's development to be more sustainable.

C&D waste management:

- Undertake a study to characterise C&D waste in South Africa;
- Improve administrative systems for capturing information relating to C&D waste;
- Implement legislative instruments to support the prevention and redirection of C&D waste from disposal to extended use applications (i.e. reuse and recycling);
- Focus on education, partnerships and the involvement of stakeholders in C&D waste management; and

- Promote, support, plan and showcase C&D waste prevention, reduction, recovery, reuse and recycling.

Construction industry:

- Promote the application of the waste hierarchy in dealing with waste produced on construction, demolition and renovation sites i.e. waste avoidance before minimisation, then treatment before disposal;
- Develop waste specifications to ensure that waste management planning is part of tender specifications;
- Develop model contract language for waste management to ensure that waste management on site will be legally binding;
- Insist on the inclusion of waste management plans in tender documents;
- Promote building deconstruction as a preferred option to mass demolition, and ensure that its principles are applied throughout the lifecycles of buildings.
- Promote waste recovery for reuse and recycling in accordance with waste hierarchy before waste disposal at demolition sites.

Regulatory environment:

- The promulgation of the impending sectoral waste act;
- Increase tipping fees at landfill sites;
- Impose high taxes on raw material purchase;
- Prohibit the disposal of C&D waste in landfill sites;
- Tighten by-laws on illegal dumping;
- Introduce punitive measures for non-compliance; and
- Mandate the development of environmental management policies and programs.

Secondary market development:

- Develop a market development plan to establish a C&D waste sector through the establishment of a self-sustaining secondary construction materials market.
- Move away from prescriptive specifications to performance-based specifications. The latter details only the performance aspects of a particular material and not its composition. This will encourage innovation and give opportunity to the use of secondary construction materials.
- Ensure that there is ongoing research and development on the types and methods of material testing in order to ensure that all materials are tested on merit and duly accommodated by specifications where appropriate. Acknowledging the nature of standards, if well performing innovative materials were not used in pilot projects on a trial basis, we probably would not be using good materials like Pulverised Fuel Ash (PFA) and Ground Granulated Blast Furnace Slag (GGBS) today.
- Embark on awareness campaigns to influence public perceptions on secondary materials. This will help increase the demand.
- Embark on aggressive support of programmes and projects that improve C&D waste management. One approach to achieving this can be through government partnerships with the private sector. Examples include the sponsorship, documentation and showcasing of demonstration projects, the promotion of buy-recycled programmes and leading by example.
- Establish Recycled Material Development Zones (RMDZs) for the identification, set-up and support of secondary material businesses (industrial and SMMEs).
- Maintain a balance in the dedication of effort and investment of resources into the supply of raw secondary feedstock, the establishment of secondary industries and

distribution infrastructure, and the development of end-markets for secondary materials and products.

REFERENCES

1. Barnard D, *Environmental law for all*, Impact Books, Pretoria, 1999.

2. BRE Smartwaste case studies:*Reducing construction waste,* http://:www.bre.co.uk , 2002.

3. California Integrated Waste Management Board, *C&D Market development plan 1996*, http://www.ciwmb.ca.gov/ConDemo/

4. *Construction site waste: A new profit centre*, http://oikos.com/esb/46/sitewaste.html 1996.
5. Construction Works News Gram, http://splash.metrokc.gov/swd/bizprog/sus_build/newsgram6.htm (logged on in 2001)

6. Craven DJ, Okraglik HM and Eilenberg IM, *Construction Waste and a New Design Methodology,* proceedings of the First International Conference on Sustainable Construction, CIB Task Group 16, Tampa, Florida, USA, November 1994.

7. CSIR, *The situation of waste management and pollution control in South Africa*, prepared for the Department of Environment Affairs, Pretoria, February 1999.

8. Du Plessis C, *The meaning and definition of sustainable development in the built environment,* CSIR Building and Construction Technology, Maters Thesis submission, University of Pretoria, Pretoria, South Africa, November, 1998.

9. DWAF, *Disposal sites for hazardous and general waste in South Africa*, Report number W.5.0, Pretoria, 1998.

10. Ekanayake LL and Ofori G, *Construction material waste source evaluation*, Proceedings of the 2nd Southern African Conference on Sustainable Development in the Built Environment, Pretoria, South Africa, August, 2000.

11. Franklin Associates. *Characterization of Municipal Solid Waste in the United States,* Prepared for US Environmental Protection Agency, Washington, DC, June 1998.

12. Hobbs G and Hurley J, Deconstruction and the Reuse of Construction Materials, Building Research Establishment, proceedings of the Deconstruction and Materials Reuse: Technology, Economic and Policy meeting of the CIB Task Group 39 on Deconstruction, CIB Publication no. 266, United Kingdom, 2001.

13. Kasai Y, Rosseau E and Lindsell P, *Outline of various demolition methods and their evaluations,* 1998.

14. Kibert Charles J and Chini Abdol R, *Deconstruction as an essential component of sustainable construction*, Centre for Construction and Environment, University of Florida, Florida, USA, 2000.

15. Kibert Charles J, *Establishing Principles and a Model for Sustainable Construction,* proceedings of the First International Conference on Sustainable Construction, CIB Task Group 16, Tampa, Florida, USA, November 1994.

16. McDonald B and Smithers M, *Implementing a waste management plan during the construction phase of a project: a case study,* Australia, 1996.

17. Macozoma DS, *Building deconstruction*, CIB Publication, February 2002.

18. Macozoma DS, *Construction site waste management and minimisation*, CIB Publication, February 2002.

19. Macozoma DS, *Review of the US Secondary Construction Materials Market: Any Lessons for South Africa and Other Developing Countries*, CIB Publication, December 2001.

20. Makhabane M, *Register of secondary construction materials role-players,* CSIR Building and Construction Technology, 2001.

21. McGrath C, Fletcher SL and Bowles HM, *UK Deconstruction Report,* Building Research Establishment, School of architecture, Sheffield University and Telford Institute of Environmental Systems, University of Salford, prepared for the country status report of the CIB Task Group 39 on Deconstruction, CIB Publication no. 252, United Kingdom, 2000.

22. Pietersen HS and Fraay ALA, *Performance of concrete with recycled aggregates,* Proceedings of the CIB World Building Congress, Gavle, Sweden, 1998.

23. Schultmann F and Rentz O, *The State of Deconstruction in Germany*, French-German Institute for Environmental Research (DFIU), University of Karlsruhe, prepared for the country status report of the CIB Task Group 39 on Deconstruction, CIB Publication no. 252 Germany, 2000.

24. Symonds, *Construction and Demolition Waste Management Practices, and their Economic Impacts*, Report to DGXI European Commission, by Symonds in association with ARGUS, COWI and PRC Bouwcentrum, February 1999.

25. Te Dorsthorst B and Kowalczyk T, Reuse of Apartment Buildings: A Case Study, Delft University of Technology, proceedings of the Deconstruction and Materials Reuse: Technology, Economic and Policy meeting of the CIB Task Group 39 on Deconstruction, CIB Publication no. 266, Netherlands, 2001.

26. Te Dorsthorst B, Kowalczyk T, Van Dijk K and Boedianto P, *State of the Art Deconstruction in the Netherlands*, Delft University of Technology, prepared for the country status report of the CIB Task Group 39 on Deconstruction, CIB Publication no. 252, Netherlands, 2000.

27. Triangle J Council of Governments, *Waste Spec: Model specifications for construction waste reduction, reuse and recycling* (Research Triangle Park, NC: July 1995).

28. Vleck RE, *Advanced Constrution and Demolition Waste Management for Florida Builders,* prepared for submission for a Master of Building Construction degree, ME

Rinker School of Building Construction, University of Florida, Gainesville, Florida, June 2001.

APPENDIX

A1. WASTE ANALYSIS AND ASSESSMENT

Adopted from: CIB Fellowship Publication

Title: *Construction Site Waste Management and Minimisation,* by Macozoma DS, CSIR Building and Construction Technology, February 2002.

Table A1: Sample waste analysis and assessment sheet

Waste Audit Information				
(Insert project specific information e.g. project name, main contractor, main sub-contractors, date etc.)				
Waste analysis and assessment sheet				
Container Type*	**Description**	**Volume (m3)**	**Weight (Tons)**	**% Full**
Unwanted waste				
Reusable metal				
Reusable wood				
Reusable drywall				
Reusable plastic				
Reusable bricks				
Wood recycling				
Metal recycling				
Cardboard recycling				
Drywall recycling				
Rubble recycling				
Comments				
* If there is more than one type of each container, add them to the list.				
(This analysis will give an indication of the type and amount of C&D waste that is generated on site per day/hour/week and this can be used to give a projected figure of expected waste quantities)				
(Indicate which of the containers will be used in a detailed waste audit)				

Container type	**Unwanted waste**		**Unwanted waste**		**Reuse containers**		**Recycling containers**	
Waste materials	**Reusables**		**Recyclables**		**Contamination**		**Contamination**	
	Vol/Tons*	**%**	**Vol/Tons**	**%**	**Vol/Tons**	**%**	**Vol/Tons**	**%**
Metal								
Wood								
Gypsum								
Concrete								
Bricks								
Masonry								
Asphalt								
Masonry								
Cardboard								
Total misplaced								
Comments								
* Give quantities in terms of volume or tonnage								
(This information will give indication of the type of materials that are generated in large quantities on site, where they are disposed of and where focus should be made)								
(Describe possible reuse and recycling options)								

A2. WORKSHEETS FOR WASTE ANALYSIS AND RECYCLING ANALYSIS

Adopted from: The King County Website

Title: *Construction Works News Gram*,

http://splash.metrokc.gov/swd/bizprog/sus_build/newsgram6.htm

And from: NAHB Research Centre Publication

Title: *Construction waste management handbook: Homestead Habitat for Humanity Jordan Commons*, prepared by the NAHB Research Centre for Homestead Habitat for Humanity, USA, May 1996.

A2.1 Waste Analysis Worksheet

Table A2.1: Sample worksheet for waste analysis

Project Waste Analysis Worksheet

Material	Quantity	Recyclable? Reusable?	Possible Recycling Method

A2.2 Recycling Economics Worksheet

Table A2.2: Sample worksheet for waste recycling and disposal

Waste Material	Q'ty (Tons)	Requirements (Container rental or self-haul)	Contact (Potential service provider)	Recycling Rate (-) Cost (+) Premium	Disposal Rate R/ton or R/m3	Cost (-) / Premium (+) Recycling (R)	Cost Disposal (R)	Net Premium - Recycling (R)
Metals								
Wood Reuse								
Wood Recycle								
Cardboard								
Drywall								
Recyclable Containers (all aluminium)								
Unrecoverable Construction Waste								
MSW Disposal								
TOTAL								

A3: SAMPLE WASTE MANAGEMENT PLAN

Name of Project	
Location	
Starting date	
Short Description	
Main Contractor	
Responsibility for waste	

A3.1 Description

- This project shall generate the least amount of waste possible by properly planning material procurement (ordering, transportation and delivery), ensuring proper material handling and storage to reduce the avoidable generation of wastage (i.e. broken and damaged materials) and reusing potential waste materials on site wherever possible. Of the inevitable waste that is generated, as many of the waste materials as economically feasible shall be recovered and sorted for donation, reuse elsewhere or stored separately for recycling.
- Table A3 below identifies all the waste materials that will be generated on this project. It gives a breakdown of the waste materials by type and quantity. It also describes the end-of-life option selected for each material and the associated handling procedures.
- Waste avoidance is given first priority, followed by waste minimisation. These shall be discussed at the beginning of every safety meeting (or waste management meeting where it exists). As each new subcontractor comes on site, the "waste manager" or "recycling coordinator" will present him/her with a copy of the waste management plan and provide a tour of the waste management areas on site, including the recycling centre if applicable. The subcontractor will be expected to ensure that all of his/her crewmembers comply with the waste management plan.

All waste containers will be clearly labelled (i.e. unwanted waste, and specific reusable and recyclable waste).

- The construction site shall be clearly signposted with information relating to waste management including directions to waste containers and the recycling centre, waste collection intervals, waste management targets and progress on site, acceptable and unacceptable site waste practice and outstanding performers among others.

A3.2 Waste management plan

Table A3: Waste management plan

Material	Qty	End-of-life option	Handling procedure
Demolition (in cases where an existing structure had to be removed)			
E.g. Concrete	100 tons	Recycled – concrete crusher and reused as fill	Break up and store separately
New Construction			
E.g. Clean wood scrap	30 tons	Reused on site and recycled by wood recycler (Name?)	Clean and store in clean wood container

A4. PRINCIPLES OF DESIGN FOR DECONSTRUCTION AND THE HIERARCHY OF RECYCLING

Adopted from: TG39 CIB Publication 266 – Deconstruction and Material Salvage: Technology, Economic and Policy

Title: *Developing an Inclusive Model for Design for Deconstruction,* by Crowther Philip, Queensland University of Technology, Australia, in proceedings of the CIB Task Group 39 Meeting, Wellington, New Zealand, April 2001.

Table A4 is arranged in a matrix format to show the relevance of each of the principles to the available options in the hierarchy of end-of-life scenarios for building removal.

Table A4: Principles of design for deconstruction and the Hierarchy of Recycling

Legend – level of relevance: ■ highly relevant ▪ relevant · not normally relevant					
No.	**Principle**	**Material recycling**	**Component remanufacture**	**Component reuse**	**Building relocation**
1	Use recycled and recyclable materials	■	■	·	·
2	Minimise the different types of materials	■	■	·	·
3	Avoid toxic and hazardous materials	■	■	·	·
4	Make inseparable assemblies from the same materials	■	■	·	·
5	Avoid secondary finishes to materials	■	■	·	·
6	Provide identification of material types	■	■	·	·
7	Minimise the number of different types of materials	·	▪	■	■
8	Use mechanical not chemical	·	■	■	■

	connections				
9	Use an open building system not a closed one	·	·	■	▪
10	Use modular design	·	·	■	▪
11	Design to use common tools and equipment, avoid specialist plant	·	▪	■	■
12	Separate the structure from the cladding for parallel disassembly	·	·	■	▪
13	Provide access to all parts and connection points	▪	▪	■	■
14	Make components sized to suit the means of handling	·	▪	■	■
15	Provide a means of handling and locating	·	·	■	■
16	Provide realistic tolerances for assembly and disassembly	·	·	■	■
17	Use a minimum number of connectors	·	▪	■	■
18	Use a minimum number of different types of connectors	·	▪	■	■
19	Design joints and components to withstand repeated use	·	·	■	■
20	Allow for parallel disassembly	▪	▪	■	▪
21	Provide identification of different component type	·	▪	■	▪
22	Use a standard structural grid for set outs	·	·	·	■
23	Use prefabrication and mass production	·	·	■	■
24	Use lightweight materials and	■	■	■	■

	components				
25	Identify points of disassembly	·	▪	■	■
26	Provide spare parts and on site storage for during disassembly	·	·	·	■
27	Sustain all information of components and materials	·	·	■	■

A5. MATERIAL CONSIDERATIONS

Adopted from: CIB Fellowship Publication

Title: *Building Deconstruction,* by Macozoma DS, CSIR Building and Construction Technology, South Africa, December 2001.

Table A5: Building component considerations for design for deconstruction.

Component	Elements	Materials	Comment
Foundation and floor	Foundation Floor bed Floor finish	Concrete Timber Ceramics Carpets	Concrete – cannot be reused immediately, but can be recycled into secondary materials Timber – can be reused immediately and recycled into various products Ceramics – durable, cannot be reused immediately, but can be recycled Carpets – recyclable, but process complicated, small market
Walls	Frame Siding Wall finish	Timber Steel Concrete Brick Gypsum drywall	Timber *as above* Steel – needs extra care if immediate reuse is considered, most recycled material Concrete *as above* Brick – high reuse potential, can be recycled into secondary materials Gypsum drywall – highest percentage of generated construction waste, recyclable if not contaminated, small market
Roof	Frame Sheeting Ceiling	Timber Metal Asphalt Concrete Polymers Gypsum	Timber – *as above* Metal – durable, costly initially but cheaper in long term, most recycled category of materials, established secondary market Asphalt – affordable, not reusable initially, can be recycled to road materials depending on prevailing policy Concrete *as above* Polymers – usually composite, not reusable or recyclable Gypsum *as above*

A6. SURVEY QUESTIONNAIRE

SURVEY QUESTIONNAIRE – SOUTH AFRICAN EXPERIENCE WITH SUSTAINABLE CONSTRUCTION AND SECONDARY CONSTRUCTION MATERIALS

By Skhumbuzo D Macozoma
Towards a degree of Master of Science in Engineering
University of the Witwatersrand
July-August 2004 and August – September 2005

A6.1 Section A: Definitions

Sustainable Construction

Sustainable construction is an integrative and holistic process, which aims to incorporate the principles of sustainable development into construction processes in order to ensure harmony between the natural and built environments. It signals a paradigm shift by adding the new sustainability criteria of environmental preservation, reduced energy consumption, reduced resource consumption and human development to the traditional performance criteria of time, cost and quality.

Construction and Demolition (C&D) Waste

Construction and demolition waste means non-hazardous waste resulting from the construction, remodelling, repair and demolition of structures. Structures include both residential and non-residential buildings, public works projects such as roads, bridges, piers and dams. It also results from natural disasters such as earthquakes and

tornadoes. C&D waste includes but is not limited to concrete, bricks, masonry, ceramics, metals, plastic, paper, cardboard, gypsum drywall, timber, insulation, asphalt, glass, carpeting, roofing, site clearance, excavation material and site sweepings. Some wastes are not included in the definition of C&D waste because of their nature. These include paints and other liquid wastes, asbestos and other hazardous wastes, putrescible waste, tires, appliances and containers with residue

Secondary Construction Materials

Materials that are used in construction and renovation processes, which are sourced from one or more of the following areas i.e. existing buildings; recovered building sections, components and materials; building fixtures; recovered waste materials; and recycled waste materials.

Recovery

The process of salvaging building sections, components and materials; and the redirection of waste materials away from disposal to extended use applications such as reuse and recycling. The salvaging useful materials from waste can be conducted using mechanical or labour intensive methods depending on factors such as the type of C&D waste; the level of contamination; the type of contamination; the size of waste particles; and the safety of the salvagers.

Reuse

Reuse means the recovery of useful building sections, components and materials; and the recovery of useful materials from the waste stream for immediate use (either on site or elsewhere) as secondary materials.

Recycling

Recycling means the reprocessing of salvaged useful materials that cannot be put into direct reuse to produce secondary materials and products.

Secondary Materials Outlets

Retail facilities for the resale of secondary building materials to consumers for construction and renovation purposes.

A6.2 Section B: General Information

Name of Company:

Address:

Name of person completing the questionnaire:

Position in Company:

Date:

A6.3 Section C: Construction Activities

1. What area of construction activity does your company operate in?

Construction ☐
Demolition ☐
Renovation ☐
Combination ☐
Other ☐

2. Which profession are you in?

Contractor ☐
Consultant ☐
Recycler ☐
Other ☐

3. What type of building materials do you predominantly prescribe/use?

Brick and mortar ☐
Concrete ☐
Timber ☐
Steel ☐
Plastics ☐
Composite materials ☐
Combination ☐
Other ☐

4. What construction/demolition/renovation method do you use?

a) Demolition

Mechanical demolition ☐
Labour intensive demolition ☐
Implosion ☐
Other ☐

b) Construction

Mechanical construction – small plant ☐
Mechanical construction – heavy industrial plant ☐
Labour intensive construction ☐
Other ☐

c) Renovation
Combination

Other

5. What is the minimum qualification required for your construction or demolition team?

6. What training does your construction/demolition team undertake to be adequately skilled for the job?

7. What percentage of construction materials end up as waste due to procurement error, wastage, incorrect dimensions, off cuts, human error, redos etc.

8. Are you aware of the concept of sustainable construction?

9. Does your company conduct research into the latest international trends in construction industry performance improvement? If yes; in which area?

a) Construction/demolition/renovation processes

b) Construction/demolition/renovation methods

c) Construction materials

A6.4 Section D: Waste Management Activities

1.What kind of C&D waste do you generate in your activities?

2. What kind of waste management system to you use on your Construction/demolition/renovation sites?
Commingled waste disposal in a waste skip

Separate waste disposal in designated, material specific waste receptacles

Stockpiling at designated area on site

Other

3. Who provides the waste management service for you?

Municipality ☐

Private waste contractor ☐

Emerging waste contractor ☐

Other ☐

4. Where is your waste disposed of?

Municipal landfill site ☐

Private landfill site ☐

Recycling facility ☐

In situ ☐

Illegal dump ☐

Combination ☐

Other ☐

5. How much C&D waste do you generate per project (please indicate minimum and maximum or average) in tons per day/month?

6. Does your staff know about waste management and are they required to know by your company?

7. Does you staff understand the need to:

a) Minimise waste and

b) The options available to achieve this i.e. reduction, separation, reuse and recycling

8. Have you ever implemented a formal waste management or minimisation programme on site? If yes:

a) What was the intention?

b) How much waste reduction did you achieve?

c) How much waste, by type, did you separate for reuse?

d) How much waste, by type, did you separate for recycling?

e) Please describe the system you used?

9. Based on your experience, what is your perception of waste minimisation in terms of:
a) Costs

b) Environmental impact

c) Social development

10. Does your company conduct research into the latest international trends in waste management and waste minimisation?

A6.5 Section E: Environmental Issues

1. Are you aware of the possible environmental impacts of your construction/demolition/renovation processes, methods, materials?

2. Do you ensure that your C&D waste is disposed of in an environmentally friendly manner? If yes, please explain.

3. Are your construction/ demolition/renovation safe and compliant with OHS, environmental and labour relations regulatory requirements; and quality standards?

4. Does you company have an environmental policy?

5. Is your staff:
a) Aware of environmental issues and requirements?

b) Trained in environmental processes?

c) Aware of hazardous materials and how to handle them?

A6.6 Section F: Economics of Reuse, Recycling and Secondary Markets

1. What do you think are the major cost components of reuse and recycling? Please explain.

2. Have you ever taken a cost benefit analysis for waste disposal vs. waste reuse and recycling for your company? If yes, please explain.

3. If you were to embark on a recycling initiative, what do you think are the enabling mechanisms that would need to be in place for your initiative to succeed? Please explain.

4. Would you say that there is a perception that waste reuse and recycling is more expensive than waste disposal? Please explain

5. In your perception, how can the costs of waste reuse and recycling be reduced?

A6.7 Section G: Regulations, Standards and Specifications

1. Are you aware of construction industry regeneration processes in South Africa e.g. legislation, the CIDB, review of specifications etc.? Please explain.

2. Are you aware of the evolution and current state of waste legislation in South Africa?

3. What do you think is still required in the construction industry to create an enabling environment for secondary construction material use?

4. What do you think is still required in waste legislation to create an enabling environment for C&D waste recovery, reuse and recycling?

5. Do you think standards and specifications enable or hinder secondary construction materials markets? Please explain.

A6.8 Section H: Role of Government

1. In your opinion, what is government's role in promoting secondary construction materials markets, reuse, recycling and the use of secondary products?

2. Do you think punitive measures such as taxing, surcharge pricing and criminal procedures will assist in achieving sustainable construction, waste minimisation and secondary markets? Please explain.

3. Do you think incentives are a better approach? Please explain.

4. If government embarked on aggressive awareness creation and the promotion of partnerships in the construction and waste sectors, would that have significant benefits in establishing secondary markets?

5. Does it make a difference if government support is in the form of legislation, money, communication, demonstration projects etc.? If yes, please explain.

6. Is there a role for the private sector in promoting secondary markets? Please explain?

A6.9 Section I: Public Awareness and Perceptions

1. Would you agree that the public assumes that "secondary materials" is synonymous with "inferior building materials" and that buying secondary materials would result in building defects etc.? If yes, what do you think is the cause of this?

2. What mechanism do you think may positively influence public perceptions?

Mandatory secondary material use ☐

Awareness and education ☐

Government partnership with communities ☐

Market forces and material prices ☐

Combination or other ☐

Please explain your choice above.

3. What would you say should be the price of secondary materials in comparison to virgin materials and why?

4. Do you think the South African public is conscious about sustainable development? If yes, what is the level of commitment? If no, what needs to be done to change this?

5. Will the public level of awareness and perception affect your company's decision to recover, reuse and recycle building materials into secondary materials?