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AN INVESTIGATION INTO THE MATERIAL EFFICIENCY PRACTICES OF UK MANUFACTURERS

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ABSTRACT

This thesis examines the Material Efficiency practices of manufacturing companies in the UK. The study was motivated by the increasing attention given by literature to sustainable strategies in general, with less attention being given to material resources which in turn contributes to the reduced supply of natural resources, persistent solid waste and toxicity. There is also a lack of insight about how the manufacturing industry is coping with pressures to reduce solid waste and better utilise materials as resources.

A critical literature review identifies Material Efficiency and related strategies and any issues of implementation. This academic perspective is supported by an exploratory study of Material Efficiency practices using multiple case studies and qualitative data collection and analysis. The participating companies selected were manufacturing companies that practice Material Efficiency and any related strategies.

It was found that manufacturers do practice Material Efficiency and related strategies although few of them use the names and constructs found in the literature. Most of the companies do practice the lowest strategy (e.g. Waste Minimisation) in the sustainable manufacturing hierarchy, while most companies struggle with developing the higher strategies such as Resource Efficiency and Eco-efficiency, in part due to measurement complexity. The investigation found a set of attributes in the difficulties, benefits and accelerators that affect manufacturers when implementing Material Efficiency strategies and also studied the factors that motivated the manufacturers to implement and to choose the strategies. It is found from this research that these attributes are interrelated and dependent on each company's context such as company's size, type of product, and type of materials used etc.

The findings describe real Material Efficiency practices as used inside the UK manufacturing industry, while comparing actual practice to what has been suggested in the literature. The study provides insight into how companies experience and practice Material Efficiency and other related sustainable manufacturing strategies.

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PUBLICATIONS

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LIST OF ABBREVIATIONS

CPET	:	Crystallized Polyethylene Terephthalate
EPSRC	:	Engineering and Physical Sciences Research Council
KPI	:	Key Performance Indicator
LCA	:	Life Cycle Analysis
OECD	:	Organisation for Economic and Development
PSS	:	Product Service Systems
SME	:	Small Medium Enterprise
UK	:	United Kingdom
US	:	United States
WEEE	:	Waste Electrical and Electronic Equipment Directive

1 INTRODUCTION

This thesis is the report of an exploratory study of Material Efficiency practices in UK industry. The study was based primarily upon interviewing practitioners in UK manufacturing industry and on literature mostly from UK and European academics and government agencies publications. This first chapter of the thesis presents the background of the study; gives an overview of the research aim and objectives and describes the scope of study. This chapter also presents a summary of the thesis structure.

1.1 Background to the Research

The pressures to reduce waste are increasing among developed countries including United Kingdom and other European countries due to several factors, especially increasing environmental awareness. The UK government has recognised that waste must be reduced beyond household waste recycling (House of Lords, 2008). Waste resulting from manufacturing, products and services offered together contributes to 24 percent of total waste arising in England, whereas household waste only amounts to about 9 percent (Defra, 2007). In manufacturing, effective use of materials is one possible component of a sustainable manufacturing strategy. There are many such strategies proposed in the literature and used in practice, with confusion over what they are, what the differences among them may be and how they can be used by practitioners in design and manufacturing to improve the sustainability of their products and processes. These strategies include Waste Minimisation, Resource Efficiency, Resource Productivity, Eco-efficiency, Pollution Prevention and many more. There are definitely distinctions and similarities between these strategies, but one thing they all have in common is that they strive to prevent waste or reduce waste by increasing natural resource productivity such as energy and materials. However, there is very little evidence that shows what type of strategies manufacturers actually use in industry. There are also many unanswered questions such as whether manufacturers are using the same strategies proposed in the literature and in professional reports, plus questions over what motivates manufacturing companies in UK to subscribe to these strategies and how they going about implementing it.

By drawing on company case studies through a series of interviews with key management personnel involved in sustainable strategies implementation, this thesis seeks to investigate the implementation of Material Efficiency strategies in UK manufacturing industry.

This thesis reports the findings of a PhD which commenced in year 2005 and finished in year 2009. This research is conducted in a new area with very little published academic research to date.

1.2 Research Aim and Objectives

This section details the research aim and research objectives on which the study will be based.

1.2.1 Research aim

The aim of this research is to establish an insight into Material Efficiency strategy as discussed in the literature and as practiced in the real world. By presenting this work, other researchers and practitioners can gain knowledge and understanding as this study will characterise and categorise strategies that fall under the Material Efficiency concept.

1.2.2 Research objectives

The objectives of this research are:

- Critically to review substantive literatures, company practices and other secondary resources in relation to:
    - the concept of Material Efficiency including its rationale, origins and attributes;
    - the rationale, origins and attributes of other related strategies similar to Material Efficiency;
    - related sustainability issues.
- To identify the key characteristics of different Material Efficiency strategies.
- To categorise Material Efficiency strategies.
- To validate key findings emerging from the study on companies' practices using experts' experiences and opinions.

1.3 The Scope of Study

Considerable research and attention by academics and government bodies has emphasised waste as an output of customer activity. More attention has been given lately to Resource Efficiency and to Waste Prevention or Minimisation but directed into either *"waste"* or *"resource"* or *"environmental impacts"*. There is a lack of emphasis

on *"material"* as a key resource (other than energy) and as the origin of all *"solid waste"*.

Thus the scope of this research project is to investigate Material Efficiency practices in one of the biggest producers of solid waste i.e. manufacturers.

This research will be conducted using a qualitative approach by conducting multiple case studies where one manufacturing company is equal to one case. The means of determining the unit of analysis will be described in the Research Methodology chapter. On determining the company as the unit of analysis, the data collection was done by interviewing several key personnel from management, each of which held job designations related to environment, design, material sourcing and/or sustainability.

The definition of Material Efficiency taken from several authors will be discussed in detail in Chapter 2 but as a preamble to assist in understanding, the author refers to Material Efficiency as the concept that aims to: (1) ***use less material*** (dematerialisation – through reuse/recycling, servicing, sharing and material substitution), (2) ***produce less waste*** (good and quality design so the product is reliable) (3) ***use less energy*** (to process the materials, to use the product and to treat the product during disposal (waste treatment)), (4) ***use less toxic material and produce less toxic waste*** and (5) ***cause less impact to the environment***.

Material Efficiency strategies have been used by manufacturing companies to minimise waste, maximise material usage (efficient use of material) and use environmentally benign material through:

- practicing these strategies in production;
- designing a product in such a way that supports those strategies in production;
- influencing suppliers to adopt these strategies;
- influencing and causing customers to support those strategies by using material efficient products.

Manufacturing industry can be classified as engineering (where raw materials such as steel or plastics are processed and assembled, with some purchased components, into a product) or processing (where raw materials are processed into a different form which is then sold on to another manufacturer or to the general public) (Burman, 1995).

1.4 Thesis Structure

This thesis is presented in eight chapters. The summary of each chapter is provided below.

Chapter 1 (Introduction)

The chapter forms an overview of the background to the research, research aim and objectives; and the research scope.

Chapter 2 (Literature Review)

The chapter reviews and analyses substantive and contextual literature in order to provide a clear view on the subject. The chapter also presents a critical review and analysis on the four significant Material Efficiency strategies to be able to show the research gaps. The final section of this chapter shows how the research propositions are designed to answer the research gaps.

Chapter 3 (Research Methodology)

The chapter presents the research design considerations. It starts by describing why and how the researcher chooses the research philosophy, research paradigms and research methods. In the research methods section the choices of research purpose, research strategy, data collection, data analysis and validation are explained. Techniques used in this study to enhance the research quality are discussed.

Chapter 4 (Case study evidences)

The chapter reports the within-case evidence from ten case studies within the main topics studied: the implementation experiences and the factors motivating the implementation of Material Efficiency strategies.

Chapter 5 (Cross-case analysis)

The chapter undertakes a cross-case analysis based on the themes discovered in chapter 4. This chapter reports how cross-case analysis has been done. The issues and concerns with qualitative data analysis have also been discussed in this chapter.

Chapter 6 (Validation)

The chapter presents the validation conducted on the results from cross-case analysis using secondary data. The findings from chapter 5 were confirmed or rejected to eliminate or add to findings.

Chapter 7 (Discussions)

The chapter presents research findings to the research questions and those that emerged during the literature and data analysis. Remarks on interesting data and research reflections also discussed.

Chapter 8 (Summary and Conclusions)

The chapter re-visits the aim and objectives, provides a summary of research process and research findings. The chapter presents the contributions to theoretical knowledge, research limitations and research opportunities for future research and the implications for practitioners.

2 LITERATURE REVIEW

This chapter aims to review substantive literature to provide a clear view of the concept of Material Efficiency, other similar strategies and its contextual background. As the research aims are to compare material efficiency practices in industries with what is written in literature, and also to provide an insight into the strategy, the literature review has been done extensively and critically by the researcher. At the beginning of this chapter the strategy of doing a literature search was explained, followed by the critical review on the subjects and lastly research propositions were presented.

2.1 Literature Search

The literature search strategy for this research was developed by first identifying the most relevant databases, conferences and journals and using key words (such as Material Efficiency, Sustainability, Waste Minimisation, Cleaner Production and Factor X). This generated many hundreds of potential papers whose abstracts were analysed and promising papers read. Snowballing using paper references, authors, conferences and journals generated a second long list. Many publications were found including theses, journal articles, conference proceedings, newsletters, books and government reports in the UK and abroad. Each new search brought more authors, journals, conferences and companies to the researcher's attention, as well as a growing set of potential keywords. It is clear that the topics of sustainable manufacturing and efficient use of materials have been described in many different ways over the last decades. Using the new keywords, new authors, new journals, etc, it was possible to search further. Based on title and/or abstract, all papers indicating the topic of material efficiency were collated, read through and their references added to the search. When new searches brought no new material, the initial searching was ended. Regular searches have been used since then to update with new material as it becomes available. The majority of the papers found did not relate directly to the topic of material efficiency and were discarded; the remainder formed a core set of some 130 papers which are used within this study.

Through the literature review and the authors' analysis four main strategies were chosen as representing the main body of knowledge. Where other labels existed for strategies they could reasonably be categorised within one of the four selected strategies. The researcher then sought for key characteristics noted as important by one or more papers, importance here was conceptualised as relating to the practice or success of sustainable manufacturing or strategy or to guidance for action (for example, importance claimed through novelty alone was ignored). These characteristics identified from the literature review formed the structure for a second reading of each paper, seeking evidence of comment against the key characteristics. Characteristics that generated low or no data

were then discarded, followed by analysis of each characteristic across the four previously identified strategies which improved the detailed understanding of each characteristic. Further analysis studied all papers related to a single characteristic for any pattern that could elaborate on similarities or differences between the four strategies. Finally all the papers related to each strategy were re-visited to throw light on the relative importance of each characteristic to that strategy. The academic papers used are international in source, while the policy documents relate primarily to European Union and UK situations.

2.2 Contextual Literatures

In this section, the background on environmental issues and its history were covered. The scope of this section does not allow an extensive review on this literature. However the evidence gathered from what is happening especially on waste issues and materials scarcity from the available literature signalled very strong evidence and was used to support the decision to conduct the research.

2.2.1 Wastes and resources scarcity

Centuries ago, when natural resources were abundant and labour was scarce, industries strived to find ways to increase labour efficiency through introducing diverse manufacturing strategies and technologies. Strategies ranged from job flexibility, shift-work, time-and-motion study and mass production to lean production, while technologies ranged from machine tools, engines, and automated devices to robots and automated lines; all these were designed and used to increase labour productivity in order to meet customer demand. Machines needed to be faster, cheaper, more reliable and always available. More recently, the theme of 'doing more with less', normally meaning less labour effort per unit of production, was re-directed away from increasing batch sizes, hence improving machine utilisation, toward the revolutionary approach of 'lean' production, which emphasised making what was needed when asked for by the customer. While the lean concept attracted initial concern over its impact on decreasing machine utilisation, the many benefits of improved lead times, lower inventory etc, has shown the value of this radical re-think.

That radical re-thinking of the system of manufacturing may be occurring once more, propelled by a changing world where energy and materials are becoming less abundant and labour more abundant. Environmental changes, globalisation and access to cheap labour through cheap transport are altering this balance. This literature is particularly concerned with materials and how manufacturing may be changing in response to increasing scarcity of materials. While a strategy of using less material has an obvious and direct economic efficiency of paying less per product, it also helps to make a manufacturer more robust to supply shortages and contributes positively to the limits placed on humanity by the physical limits of the planet - noting that human resources

are renewable for as long as natural resources remain available but not the other way around.

Efforts made by researchers from as early as the 1960's promoted 'pollution prevention' (Dales, 1968) and the IPAT equation [the multiplicative contribution of population (P), affluence (A) and technology (T) to environmental impact (I)] (Commoner, 1972; Ehrlich and Holdren, 1971; Holdren and Ehrlich, 1974 as cited by Fischer-Kowalski and Amman, 2001). In 1987, the Brundtland report popularised the concept of sustainable development which it defined as *"meets the needs of the present without compromising the ability for future generations to meet their own needs"*. However, it was not until the wakeup call in 1992 at the Earth Summit in Rio de Janeiro when nations met to discuss problems due to pollution that they agreed to the need for actions toward sustainable development. Whilst no agreements between nations were reached at the summit on the issue of pollution, the consensus on there being limits to what we could put into nature (in the form of pollution), as well as what we could take out of nature (in the form of raw materials), did result in industries and organisations starting to work towards practicing sustainable material/resource strategies such as Resource Efficiency, Eco-efficiency and Sustainable Development. This also has made governments more active in imposing regulations and rules related to waste management and pollution.

For industry, a widely-used and basic strategy to increasing the efficiency with which we use available resources is to concentrate efforts on recovery of products or materials at the end of their useful life (which includes re-use, re-manufacturing, re-cycling and energy recovery and is termed the waste hierarchy (Jackson, 1996)). Sometimes referred to under the generic name of re-cycling, the effectiveness of these strategies in tackling waste and pollution problems is questioned in the literature. Schmidt-Bleek (1995) pointed out that less than 20% of all materials originally moved (disturbed and extracted) end up in products and infrastructure. This makes the overall recycling capacity very limited. In the worst case scenario highlighted by Lovins (2003) they suggest that from the 100% of natural capital extracted to make a product in the United States, commonly only 7% of materials become products that we end users see or use, meaning 93% becomes waste within industrial processes (this includes extractive and manufacturing waste). Out of the 7%, 1% becomes durable and 6% becomes waste from customer first use. Going further, of these 1% consumer durables, only 0.02% is recycled or re-manufactured and the balance of 0.98% becomes persistent waste from disposal (typically landfill). It is argued that waste recovery activities often concentrate on the 7% of waste that occurs after use; being a small percentage of the natural resources extracted it is obvious that waste recovery should also be focused earlier in resource flows within the industrialised supply chain. This view puts emphasis on the role of the production system rather than the waste management system, and this

literature seeks to explore published strategies that are proposed to mitigate against these lost material resources.

There are many techniques and concepts that are proposed to support a move generally towards sustainable development (see Maxwell *et al,* 2006) and specifically towards sustainable manufacturing (such as local manufacturing, low carbon manufacturing, low temperature processing, etc) but the researchers focus here on those published strategies which are reported to tackle the issue of resource use and waste in the industrial system, namely Waste Minimisation; Material Efficiency; Resource Efficiency and Eco-efficiency. There are similarities and distinctions between these strategies, but one thing they have in common is that they strive to prevent and reduce waste by increasing natural resource productivity. Given that these concepts are now reaching into industrial practice it is a concern that a proliferation of terms, definitions, tools, explanations and scope could act to confuse practitioners and so delay implementation of sensible industrial strategies to do more with less. This literature seeks to structure, compare and contrast the four identified primary strategies of Waste Minimisation; Material Efficiency; Resource Efficiency and Eco-efficiency. Given the variety of terms and ideas presented in literature and other media, the quality of debate and learning among and between practitioners and researchers may be negatively impacted. The issue of common language, clear definitions and scope, and shared mental models are regular themes in the literature on change management and knowledge management (for example, Moss Kanter (2001) and Senge (2006)). This literature seeks to juxtapose the primary strategies to enable a more precise debate; it is not the intention to select or propose one strategy as 'superior'.

2.2.2 Materials

For thousands of years, humans used materials in making things to help everyday life become easier. For these thousands of years have humans used traditional materials (e.g. bronze, stones, gold) to produce things. As civilisations advanced, humans consumed more materials. As technology got more advanced and as materials became scarce, humans used more complex combination of materials. This increase in material consumption with complex materials combinations contributes to greater environmental damage.

'For many materials, the rate of use in society now vastly exceeds anything generally encountered in natural eco-systems. As stability is largely a rate determined characteristic, it is to be expected that many of these materials uses are unsustainable.'
(Chadwick, 1998: p. 28)

The Netherlands Environmental Assessment Agency of the Dutch National Institute for Public Health and the Environment (RIVM) distinguishes the following problems related to materials (van der Voet *et al,* 2003: p. 10):

- Climate change
- Waste production
- Acidification
- Loss of biodiversity
- Toxicity and external risks
- Depletion of resources
- Landscape degradation

Ashby (1992) suggested that *'materials contribute to environmental damage at three points of their life-cycle: in their production, in the use of products made of them, and in the disposal of these products'*. There are patterns in material consumption in industrial countries; it is observed that each material will have its peak reduction of uses. This does however not mean that there is a reduction of materials consumption as a whole, rather a reduction of one material because of an increase in other materials usage. Also, this is something to do with *'dematerialisation'* and *'transmaterialisation'* concepts which will be discussed below.

2.2.3 Dematerialisation

The concept of dematerialization refers to the decline of material use per unit of service output (De Bruyn, 1998). Dematerialisation is often mentioned as a strategy or as an indicator in the framework of sustainable development. Dematerialisation can be broadly defined as the reduction of the throughput of materials and energy required to service economic functions (Norgate *et al,* 2007). It can be measured on different geographical scale levels like nations, regions and cities but also within different sectors of industry, households and in products (von Weizsäcker *et al*, 1997).

However, a preferable view is that the demand decline being observed can be more aptly explained by transmaterialisation. Transmaterialisation implies a recurring industrial transformation in the way that economic societies use materials, a process that has occurred regularly or cyclically throughout history. Instead of a once-and-for-all declination of the intensity of use of certain materials, transmaterialisation concept suggests instead that the demand for materials experiences phases of old and lower quality materials linked to mature industries undergoing replacement by higher-quality or technologically more advanced materials (Labys, 2002).

2.3 Defining and Analysing the Four Strategies

The four strategies were chosen because they are the most commonly represented in academic and practitioner literature and are self-reported to act at the level of manufacturing strategies; terms used by single authors were ignored as were terms which were assessed to be tools or to be of a limited scope or to be phrases to capture all other strategies (such as: material selection techniques, design for dis-assembly and green manufacturing). Each strategy appeared to have its own audience: Waste Minimisation is more commonly used in the UK, Resource Efficiency is popular among UK authorities and especially in the literature, Eco-efficiency is popular world-wide and especially in Europe (where Resource Efficiency is less common), and Material Efficiency is emerging as a related strategy.

Through the literature review and the researcher's analysis four main strategies were chosen as representing the main body of knowledge. Where other labels existed for strategies they could reasonably be categorised within one of the four selected strategies. The researcher then sought key characteristics noted as important by one or more papers, importance here was conceptualised as relating to sustainable manufacturing or strategy or guidance for action (for example, importance claimed through novelty alone was ignored). These characteristics identified from the literature review formed the structure for a second reading of each paper, seeking evidence of comment against the key characteristic. Characteristics that generated low or no data were then discarded, followed by analysis of each characteristic across the four previously identified strategies which improved the detailed understanding of each characteristic.

At this point the characteristics were then fixed and a table (Table 2.6 at section 2.5) created of the characteristics and all relevant papers, categorised under the four strategies (17 characteristics were identified, ranging from *'system boundaries'* through *'data availability'* to *'measurement & target'*). Further analysis studied all papers related to a single characteristic for any pattern that could elaborate on similarities or differences between the four strategies. Finally all the papers related to each strategy were re-visited to throw light on the relative importance of each characteristic to that strategy. The academic papers used are international in source, while the policy documents relate primarily to European Union and UK situations. This literature now explains a variety of perspectives on that literature, beginning with explanations on what each strategy is.

Each strategy chosen is analysed and discussed based on a comprehensive literature review which includes; background, selected definitions, advantages and limitations and also issues and critics.

2.3.1 Waste Minimisation

In physicochemical expression, Waste Minimisation is frequently mentioned in sustainability strategies. Committing to minimise waste is recognised as desirable in managing resources. Waste Minimisation is described as **the reduction of waste** at source, recognising that is cheaper not to produce waste in the first place. Waste Minimisation covers activities aimed at reducing wastes from: raw material and ingredient use; product loss; water consumption and effluent generation; paper and packaging; factory and office consumables; energy consumption; all other solid, liquid and gaseous wastes; and wasted effort (Department of the Environment, 1998).

The waste hierarchy provides a framework within which the most desirable waste management options are set out. Waste management policy in the UK is created with reference to the Waste Directive of European Council (75/442/EEC) published in 1975 amended by 91/156/EEC (1991), 91/692/EEC (1991) and commission decision 96/350/EC (1996), with further development through national directives such as recently published new Waste Directive of European Council 2006 (2006/12/EC) and the Waste Strategy for England 2007 (DEFRA, 2007). This sets out the requirements for countries in managing their waste. The hierarchy of waste management principles has been agreed by European Council Directive, 1991 as: waste prevention; recovery; and then safe disposal. In the UK, the present national strategy in dealing with waste is based upon a hierarchy of preferred options (Phillips *et al*, 1999) described as: Reduction (previously known as waste minimisation), reuse, recovery [including recycling, composting and energy recovery] and disposal [landfill and incineration without energy recovery]. Waste Minimisation is now being referred to as an out-dated option compared to waste prevention [waste prevention, recovery and safe disposal] (House of Lords, 2008; Kirkpatrick, as cited in (Pongrácz *et al*, 2004)). Although there are different versions of the waste hierarchy it is widely accepted that waste minimisation, reduction or prevention is the first priority, while recycling has a higher priority than incineration and land filling has the lowest priority (Moberg *et al*, 2005).

The primary definition of Waste Minimisation used in UK is *'the reduction in quantity and hazardousness of waste produced at source'* (OECD, 1998). In this definition, re-use, recycling and recovery are not included. Although this Waste Minimisation definition is only confined to hazardous related waste, the Waste Minimisation Act 1998 states that Waste Minimisation is a top priority of UK government in managing waste. Waste Minimisation is claimed as the top priority of the waste management hierarchy but it is not being prioritised or given the necessary support by the UK authorities (according to the House of Commons All Party Environmental Audit Committee, 5th Report, Waste-Audit, as cited in Hawkins and Shaw, 2004; Read *et al*, 1998). Selected definitions referring to these ideas in literature, including those commonly used by organisations in the UK are listed in table 2.1.

The term Waste Minimisation can be argued to be the clearest among the four strategies, emphasising the reduction of the worst types of polluting waste. However some authors do refer to Waste Minimisation as a different version of waste prevention, indicating the level of challenge in creating a common language for the emerging fields of sustainable manufacturing and sustainable engineering. The term Waste Minimisation is preferred and used in the U.K. while in the U.S, the term 'waste minimization' is most often replaced by 'pollution prevention' (Levin, 1990; Freeman *et al*, 1992). Waste Minimisation, due to its simple and direct goal of minimising waste has been seen as a first step for organisations implementing a broader and more sophisticated environmental strategy (Clelland *et al*, 2000). Van Weenen (1990) grouped the terms *waste prevention, waste avoidance, waste reduction, waste minimisation, pollution reduction, pollution prevention* and *recycling* as similar in terms of strategies. All these strategies are concerned with waste (cause) and pollution (problems or effect), although using different names they have the same underlying aim of minimising impact on the environment from human activities.

Pongrácz (2002) pointed out that although Waste Minimisation is not yet considered equally everywhere because many activities of Waste Prevention are concentrated in 'on-site recycling' activities (recovery, or diversion of waste from landfill). Thus Pongrácz suggested that Waste Minimisation includes four rather different options:

Using less material to produce the product, so that when it is thrown away, there is less waste created.

- Creating durable products.
- Waste evasion: the effort to avoid waste creation.
- Substitution: by using less harmful substances

The first three options suggested by Pongrácz are broader than most other authors offer for Waste Minimisation and are considered by the researcher to indicate the level of definition confusion in this field. The three options are not considered part of Waste Minimisation in this literature and can be more commonly found among the techniques referenced in papers related to the three strategies discussed in later sections.

Author(s)	**Waste Minimisation**
U.S Environment Protection Agency (EPA) (1986)	As the reduction, to the extent feasible, of hazardous waste that is generated or subsequently treated, sorted or disposed. It includes any source reduction or recycling activity undertaken by a generator that results in either (1) the reduction of total volume or quantity of hazardous waste, or (2) the reduction of toxicity of hazardous waste, or both, so long as such reduction is consistent with the goal of minimizing recent and future threats to human health and the environment.
Bates & Philips (1998)	Waste minimisation is the reduction of waste at source, recognising that is cheaper not to produce waste in the first place.
The UK Chartered Institution of wastes (formerly IWM), 1996 (as cited in Read and Philips, 1998)	Prevention and/or reducing the generation of waste, improving the quality of waste generated, including reduction of hazard and encouraging re-use, recycling and recovery.
OECD working definition on waste minimisation agreed at Berlin Workshop 1996 (Riemer & Kristoffersen, as cited in Pongrácz *et al*, 2004))	According to which it encompasses these three elements in the following order or priority: ▪ preventing and/or reducing the generation of waste at source; ▪ improving the quality of the waste generated, such as reducing the hazard; and ▪ encouraging re-use, recycling and recovery.
European Topic Center on Waste (ETC/W) (Riemer & Kristoffersen, as cited in Pongrácz et a,. 2004))	Waste minimization/cleaner production is only related to preventive measures. Waste minimization includes: ▪ Waste prevention i.e. reduction of waste by application of more efficient production technologies; ▪ Internal recycling of production waste. ▪ Source-oriented improvement of waste quality, e.g. substitution of hazardous substances; ▪ Re-use of products or parts of products, for the same purpose.
The UK Environment Agency, 1997 (as cited in Phillips *et al*. 1998))	Describes waste minimisation as: The reduction at source, by understanding and changing processes to reduce and prevent waste. This is also known as process or resource efficiency. Waste minimisation also includes the substitution of less environmentally harmful materials in the production process.

Table 2.1 Selected definitions of Waste Minimisation

Measurements and indicators for assessing success in Waste Minimisation are direct in nature as many of them are based on recovery and recycling targets (Hanssen *et al*, 2003). In the UK, where businesses are going to be increasingly responsible for the waste they produce, Waste Minimisation is proposed as the best way for companies to reduce their impact on the environment (Cheeseman and Phillips, 2001) and to cut cost associated with waste. Based on the definitions listed in table 2.1, most authors agreed that waste should be prevented at source rather than after the waste is brought into existence; while congruent with the concept of Waste Minimisation the need to reduce waste at source emphasises the role of prior decisions (such as product and process design) which is commonly viewed by the relevant papers as outside the scope of Waste Minimisation.

2.3.2 Material Efficiency

Efficiency is the ratio of an output to the input of any system. Thus, Material Efficiency can be stated as **the ratio of the output of products to the input of raw materials**. Worrell *et al* (1997) explained Material Efficiency as analogous to Energy Efficiency where Material Efficiency improvement is described as reducing the consumption of primary material without substantially affecting the service or function of a product. In a broader definition this is expanded by Worrell *et al* as *'reducing the consumption of primary materials without affecting the level of human activities qualitatively'*. Similarly to Worrell *et al*, Peck and Chipman (2007) defined Material Efficiency parallel to Energy Efficiency definition. All selected definitions on Material Efficiency are listed in table 2.2 below.

Author(s)	**Material Efficiency**
Worrell *et al* (1997)	The definition of material efficiency as 'the amount of primary material that is needed to fulfil a specific function'. Material efficiency improvement allows the same function to be fulfilled but with a reduced amount of material.
Glossary of EEA (EEA, 2006)	Material productivity is an indicator of the output on value added generated per unit of material used.
Peck and Chipman (2007)	Material efficiency in industrial production is defined as the amount of a particular material needed to produce a particular product.

Table 2.2 Selected definitions of Material Efficiency

Von Weizsäcker *et al* (1998) in their book ***Factor four: Doubling Wealth, Halving Resource Use*** suggested that we could use resources at least four times as effectively as we currently do. Hawken *et al* (1999) in their book ***Natural Capitalism: the Next Industrial Revolution*** suggests that we will observe the birth of a new type of industrial

revolution which emphasises the use of resources efficiently including material resources. Young *et al* (1994) suggested the need for an efficient material economy as the next efficiency revolution, claiming that it will require more than technological improvements alone, and calls for a shift of culture and ethics. Material Efficiency as explained here is echoed in later sections and can be said to be a core element of other sustainability strategies such as Resource Efficiency and Eco-efficiency.

In the literature, the researcher found relatively few studies on Material Efficiency or Material Productivity; most studies mentioning Material Efficiency do so as part of other strategies such as Energy Efficiency, Resource Efficiency and Eco-efficiency. The closest concept to Material Efficiency is dematerialisation. The concept of dematerialisation is presented as being concerned with the reduction of the quantity of material used to achieve a functional performance, which can be contrasted with the concept of Material Efficiency introduced by Worrell (1995) which is concerned with the maximum usage of input material. To achieve Material Efficiency, it is clear that dematerialisation should be practiced, as well as other actions. Some definitions of dematerialisation are shown in table 2.3 below.

Author(s)	**Dematerialisation**
van der Voet *et al* (2004)	Dematerialisation as the reduction of the throughput of materials in human societies.
De Bruyn (1998)	The concept of dematerialization refers to the decline of material use per unit of service output.
Herman *et al* (1990)	… the word dematerialisation is often broadly used to characterize the decline over time in weight of the material used in industrial end products.
Wernick *et al* (1996)	More broadly, dematerialization refers to the absolute or relative reduction in the quantity of materials required to serve economic functions
Bernardini and Galli (1993)	…as the reduction of raw material (energy band material) intensity of economic activities, measured as the ratio of material (or energy) consumption in physical terms to gross domestic product (GDP) in deflated constant terms.

Table 2.3 Selected definitions of Dematerialisation

Material Efficiency and Energy Efficiency are always linked together, firstly as similar concepts applied to different objects – material and energy, and secondly it is commonly argued that actions to reduce one resource will also reduce the other. Improvement in Material Efficiency typically saves energy in not producing and transporting that material; while improvement in Energy Efficiency reduces the consumption of materials and other primary resources (Worrell, 1995; Worrell *et al*,

1997; Lilja, 2009a and 2009b). Again it is argued that Material Efficiency is a core strategy in all sustainable strategies. Energy Efficiency is a field attracting much research (see Hanley *et al*, 2009; Worrell *et al*, 2009; Vera and Langlois, 2007 and Herring, 2006), while less attention is given to Material Efficiency as a strategy. The researcher argues that there is a need to study Material Efficiency as a whole and in depth, including upstream and downstream material flows that include everything from material extraction to landfill and from production up to national level, an argument that is explored in more depth in the House of Lords (2008). Material Efficiency problems, if tackled intensively, have a great potential to contribute to sustainability and can make it easier for other strategies, such as Resource Efficiency and Eco-efficiency, to be executed successfully. Material Efficiency as a strategy is argued to benefit from having a very clear measure of performance (material out versus material into the system), which makes it easier to implement in practice.

The definition of Material Efficiency by Worrell (1997) however is limited in scope due to his prior concerns with increasing Energy Efficiency through improving Material Efficiency. The definition and concept of Material Efficiency by Peck and Chipman (2007) are much better but only suggested an improvement of three components of Materials Efficiency: light weighting in the production process; waste reduction in the production process; and recycling of materials in the production-consumption cycle. A thorough study should be conducted on Material Efficiency that covers issues of a material's toxicity and environmental impacts. The strategy for achieving sustainability by reducing the amount of material alone could be ineffective because a smaller amount of material used is not necessarily safer in terms of its toxicity and its environmental impacts compared to larger amounts of other types of material. Different materials give different environmental impacts (Weaver *et al*, 1996; Pearce, 2001). Therefore, the toxicity and not only conversion efficiency and recyclability of the material should be prioritised due to its great influence on the environment. Thorough investigations on varying material impacts are often missing in Resource Efficiency and Eco-efficiency strategies, leading to Geiser (2002) arguing that we have spent several decades focusing on the consequences of materials use but not addressing the materials directly. Realising this, currently there is increasing effort in promoting Material Efficiency and the efficient use of materials as part of resource efficiency improvement in developed countries such as in Germany (Meyer *et al*, 2007), Australia (Schliephake, 2009) and Finland (Halme *et al*, 2007; Lilja, 2009a and 2009b).

2.3.3 Resource Efficiency

Resource Efficiency is actively being promoting by the UK government as part of its government policy for sustainable development (Foxon, 2000). Resource Efficiency is the strategy that **strives for the efficient use, reduction of flow and consumption of resources drawn from nature** (Schmidt-Bleek, 1996). Resource Efficiency, also called Resource Productivity, has received much attention recently because it is focused on

managing resources as a whole rather than being limited to one stage of the resources' life, such as Waste Minimisation and pollution prevention which centred the focus on waste *(cause)* and its polluting effect. The strategy of Resource Efficiency defines itself as being concerned with the wider scope of impacts on the environment including reducing the generation of waste, using fewer resources and using resources, production processes and extracting processes that have less impact towards the environment. Schmidt-Bleek (1996) points out that resource extraction is the most significant cause, since all materials taken into an economy end up sooner or later as emissions and wastes. Thus reducing the costs of environmental damage requires both bringing down emissions and reducing the flow of resources drawn from nature.

Resource Productivity and Resource Efficiency are among the terms used and are often proposed as specific indicators of the efficiency of the entire economy (OECD as cited in (EEA, Ed: Moll and Gee, 1998)). Emphasising national resources consumed versus economic value added can give a very rough calculation of conversion efficiency at the level of the nation state, but is seen as more challenging for single businesses or manufacturers. While the measurement of Resource Efficiency and Resource Productivity is presented at the Nation level the concepts are still advocated as pertinent and useful to industrial organisations. The researcher's analysis (seen in 2.6) shows that many authors consider the ability to easily and accurately measure something as being important in operationalising the concept or strategy into practice, which the concept of Resource Efficiency finds difficult. Some of the authors or organisations are selective in their terminology and use either Resource Efficiency (e.g. Foxon, 2000; Wuppertal Institute, 2002) or Resource Productivity (e.g. Pearce, 2001; Schmidt-Bleek, 1995), while some refer to both Resource Efficiency and Resource Productivity and sometimes use them interchangeably (e.g. Commission of the European Communities 2003, Hawken *et al*, 2000; von Weizsäcker *et al*, 1997) and yet others use both terms and do differentiate between them (e.g. Dahlström and Ekins, 2005). Refer to table 2.4 for definitions of Resource Efficiency and Resource Productivity.

Among the authors who promote a Resource Efficiency strategy for industry are those promoting Factor X: Amory Lovins and his co-authors in Factor 4 (von Weizsäcker *et al*, 1997) and Natural Capitalism (Hawken *et al*, 2000) plus Schmidt-Bleek with Factor 10 with its MIPS and ecological rucksacks as measurement tools (Schmidt-Bleek, 1996). Factor X is a quantitative goal for Resource Productivity and also Eco-efficiency (Reijnders, 1998). Lovins and co-authors in their book ***Factor four: Doubling Wealth, Halving Resource Use*** suggested that we could use resources at least four times as effectively as we do now. Hawken in his book ***Natural Capitalism: the Next Industrial Revolution*** envisions a new industrial revolution by combining the principle of radical resource productivity improvements with principles of bio-mimicry (reducing waste through closing cycles), encouraging a services and flow economy and increasing in natural capital. Schdmit-Bleek suggested a Factor 10 level of Resource Efficiency

improvement is both necessary and attainable for industrialised countries if sustainability is to be reached. He suggested that within one generation, nations can achieve a tenfold increase in the efficiency with which they use energy, natural resources and other materials.

Author(s)	**Resource Efficiency**
UK policy (Environmental agency, R & D technical report, 2004) (as cited in Thomas and Iles, 2004)	At a national policy level, resource efficiency and resource productivity can be defined as the efficiency with which energy and materials are used throughout the economy, i.e. the value added per unit of resource input. At the installation level this means 'making more with same quantity of raw materials'.
Commission of the European Communities (Commission of the European Communities 2003)	Resource efficiency or resource productivity can be defined as the efficiency with which we use energy and materials throughout the economy, i.e. the value added per unit of resource input.
Cabinet Office, UK, (2001)	Resource productivity measures the efficiency of the economy in generating added value from the use of natural resources.
Pearce (2001)	Suggested the ratio of 'output' (Y) to natural resource 'input' (R). Where is Y could be GNP and R may be materials or energy input.

Table 2.4 Selected definitions of Resource Efficiency

The European Environment Agency pointed to differences between the Factor 4 and Factor 10 concepts; suggesting that Factor 10 addresses absolute use of nature, where global use of nature should be halved and that the use of or access to natural resources should be distributed equally all over the world. Meanwhile, Factor 4 addresses the relative concepts of Eco-efficiency or Resource Productivity, with assumptions that global use should be halved and at the same time, global welfare should be doubled (EEA, Ed: Moll and Gee 1998). Some authors commented that achieving Factor 10 is much more challenging by comparison with Factor 4 and would require very significant technological innovation to implement (Moffat *et al*, 2001; Reijnders, 1998; Hawkins and Shaw, 2004).

Pearce (2001) suggested a variety of means for making natural resource use more efficient through:

- Reducing the wasteful use of resources
- Adopting technological change which raises the efficiency of a given unit of resources.

- Substituting other inputs, such as labour, for natural resources, so that output stays the same but resource use is reduced.
- Recycling materials so that that the 'same' unit of resources is used several times.
- Substituting one resource for another. If the focus is on environmental pollution, one tonne of one material may be less polluting than one tonne of another.

There are several calculation methods proposed for measuring Resource Efficiency. An example of Resource Efficiency calculation at national level is dividing the total economic activity of a country (expressed in GDP) by the total energy use or total material use (Commission of the European Communities 2003; Bringezu, 1993). The Material Intensity per Unit Service (or function) (MIPS) was proposed by Schdmit-Bleek in 1992 as an initial measure of Resource Efficiency of product and services. He suggested that Resource Productivity is the inverse of MIPS (Schmidt-Bleek 1995).

MIPS = Material Input per Service Unit = MI/S

Resource Productivity = Service or Function Delivered/Material Used = Reciprocal of MIPS = S/MI

Dahlström and Ekins (2005) have sought to elaborate on the two related strategies and have differentiated between the meaning of Resource Efficiency and Resource Productivity. Resource Efficiency was defined as a basic ratio of two resource variables of the same kind; that is, the ratio is dimensionless. Resource Productivity is not dimensionless and introduces economic output as a purposeful objective, assessing the amount of natural resource input needed to achieve a level of economic activity.

. Resource Efficiency:

M_o/M_i = material efficiency

E_o/E_i = energy efficiency

Resource Productivity

Y_o/M_i = material productivity

Y_o/E_i = energy productivity

Where M_o is material output, M_i is material input, E_o is energy output, E_i is energy input and Y_o is economic output (the welfare output is seen to be measured by economic output).

Moffatt *et al* (2001) listed several more Resource Efficiency measurements: 1) Factor 10 and Factor 4 (including MIPS and Rucksacks); 2) Environmental space; 3) Ecological Footprints; 4) Human Appropriated Net Primary Production (HANPP); 5) Assimilative Capacity; 6) Asset Balances for Environmental Capital; 7) Safe Minimum Standards; 8) Cost-effectiveness in pollution control; 9) Comparing resource utilisation rates with economic optima; and 10) "Y/e" measure.

A criticism of Resource Efficiency is that although the strategy may be technologically possible, it requires economic and political action (such as incentives and regulatory regimes) (Hawkins and Shaw 2004, Pearce 2001, Foxon 2000, Reijnders 1998). This makes Resource Efficiency difficult to implement as a single organisation and acts as a barrier to its practicality for industry. The report by the Commission of European Communities (2003, p. 9) commented that the system boundary covered by Resource Efficiency is still limited.

> *'…the given definition of resource efficiency deals solely with the use to which resources are put. This implies that it does not consider the way resources are extracted or harvested (upstream of the economic activity) nor how they are disposed to air, water and soil (downstream of the economic activity). In order to fully understand the environmental implications of resource use, it is necessary to include both upstream and downstream activities (including the use of infrastructure, transport, dispersive losses, etc.)'*

2.3.4 Eco-efficiency

The strategy of Eco-efficiency is explained as having the business link to sustainability (DeSimone and Popoff, 1997). The concept of Eco-efficiency was used by Schaltegger and Sturm in 1990 (Schaltegger and Burrit, 2000). The strategy is concerned with increasing economic development whilst aiming to lower environmental impact, and is not a new strategy since it has been around since 1970s (Côté *et al*, 2006; Ehrenfeld, 2005). The concept was mainly popularised at the United Nations Conference on Environment and Development (UNCED) summit in Rio in 1992 through Changing Course, the book written by Stephen Schmidheiny and published by BCSD (since 1995, called the World Business Council for Sustainable Development (WBCSD)). WBCSD then took up the strategy and launched it world-wide and has since marketed Eco-efficiency as its central business strategy for bringing about corporate progress towards sustainability and has helped it become adopted by numerous companies, firstly in Europe and Latin America, then in other countries (WBCSD 2000a). The WBCSD describes Eco-efficiency as '*being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality to life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity*'. More definitions by various authors are listed in table 2.5 for reference.

The 'efficiency' measures in Eco-efficiency are said to hold more than one perspective. *"The cross-efficiency between the economic and the ecological dimension - economic-ecological efficiency – is the ratio between the changes in value in environmental impact added and economic value added. Economic –ecological efficiency is often referred to as eco-efficiency"* (Schaltegger and Burrit, 2000: p. 51). Schaltegger and Burrit proposed the following equation for measuring Eco-efficiency;

$$\text{Eco-efficiency} = \frac{\text{Value added}}{\text{Environmental impact added}}$$

WBCSD represents Eco-efficiency as a ratio of **'**Product or Service Value' over 'Environmental Influence', and argues that Eco-efficiency brings together the two eco-dimensions of economy and ecology to relate product or service value to environmental influence (WBCSD 2000a).

Based on the above equation, Eco-efficiency is improved by reducing the environmental impact while maintaining or increasing the monetary value added. Due to its greater scope, this strategy is argued to appeal to higher levels of management and government in policy and decision-making. Similar to the Resource Efficiency strategy, Factor X is among the Eco-efficiency goals. Thus MIPS calculations for Factor 10 appear in measurements of Resource Productivity and in Eco-efficiency. Resource Productivity can also be included as one of a set of Eco-efficiency indicators. WBCSD outlined two types of indicators that are suited to measure Eco-efficiency at a business level, being ***generally applicable*** indicators which can be used by virtually all businesses and ***business specific indicators*** which are likely to be individually defined from one to another business or sector. For a list of generally applicable and business specific indicators proposed by WBCSD, see WBCSD (2000b). Eco-efficiency at the product level is defined as product value per unit of environmental impact (Kobayashi *et al*, 2005). For examples of Eco-efficiency analysis at product level see Walsh and Singh, 2009; Oikawa *et al* (2005), Park *et al* (2005), Kobayashi *et al* (2005) and Aoe (2003),. Other than product level Eco-efficiency is also adopted to measure services, strategies, tactics and policies. For examples of eco-efficiency analysis used to evaluate operation see Scholz and Wiek (2005), to evaluate services see Korhonen and Luptacik (2004) and to evaluate tactics see Suh *et al* (2005). For the highest level of measurement, see Seppälä *et al* (2005) which listed four types of indicators that can be used to measure Eco-efficiency at macro-economy level such as at regional level. Huppes and Ishikawa (2005 and 2009) suggested that Eco-efficiency is capable of measuring both macro and micro economy level actions for sustainability.

Author(s)	**Eco-efficiency**
Stephen Schmidheiny, Chairman of the Business Council for Sustainable Development, 1992 (as cited in WBCSD, 2000a).	Coined the term "eco-efficiency" to describe ever more useful goods and services while continuously reducing resource consumption and pollution.
The World Business Council for Sustainable Development (2000a)	Eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality to life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity.
President Council on Sustainable Development. Eco-efficiency Task Force Report (1996)	Eco-efficiency can be broadly defined as the production, delivery, and use of competitively priced goods and services, coupled with the achievements of environmental and social goals.
Welford (1997)	Improvement in "eco-efficiency" is defined as "adding maximum value with minimum resource use and minimum pollution".

Table 2.5 Selected definitions of Eco-efficiency

While Eco-efficiency is a popular concept, evidenced by the frequency of citation, many authors voice concerns over the Eco-Efficiency strategy. As the definition (refer to table 2.5) from WBCSD suggests, Eco-Efficiency will be achieved when competitively priced goods or services can satisfy human needs and bring quality of life, while reducing ecological impacts and resources intensity throughout the life cycle, to a level at least in line with the earth's estimated capacity. From the Eco-efficiency measurement and list of indicators proposed by WBCSD, there is no means for society to determine that Eco-efficiency can satisfy human needs, quality of life, reduce ecological impact and far more to guarantee that earth's carrying capacity would not be exceeded (Ehrenfeld, 2005). It is not clear how earth's carrying capacity can be related to the practical measurement of Eco-efficiency. Ehrenfeld noted that '*…carrying capacity simply does not enter the economic calculus'*. It is still possible for the earth's carrying capacity be exceeded although Eco-efficiency has been implemented widely.

To deal with this challenge of having meaningful measures at the level of an individual organisation, while recognising impacts on the wider world, a measurement of Eco-efficiency is proposed by WBCSD which is very much limited to the boundaries of a single company. Warhurst (2002) comments that Eco-Efficiency '*…only includes indicators for quantity and value of company products and does not consider indicators of product use downstream in the supply chain'*. Hukinnen (2001) pointed out that '*…by*

expressing environmental impact simply in terms of mass consumption of natural resources, eco-efficiency creates the illusion that environmental impacts are universally commensurable, regardless of where the impact takes place, and can, therefore, be managed through globally applicable governance systems'. Ehrenfeld (2005) has joined the argument on measurement of Eco-efficiency, stating that, as with other environmental management systems, Eco-efficiency has a problem with quantification when both the numerator and denominator are problematic. It is hard enough to measure its numerator as measuring product and service value have qualitative equations in it, and the denominator is a greater challenge as measuring environmental impacts is far more complicated. Most researchers are using LCA (Michelsen *et al*, 2006, Park *et al*, 2007, Kicherer *et al*, 2007) or LCIA in assessing environmental impacts but LCA and LCIAs are problematic in their own right (Amini *et al*, 2007; Ayres, 1995). It is argued that Eco-efficiency indicators proposed by WBCSD can dangerously show false Eco-efficiency positives due to relative measurements being used where sometimes increases in Eco-efficiency may not necessarily mean improved Eco-effectiveness (Braungart, 2007; Day, Dyllick and Hockerts; Gray and Bebbington; Stahlmann and Clausen; and Ullman, as cited in Figge and Hahn, 2004). The Eco-efficiency ratio achieved could give a false indication due to several reasons. Among the reasons is that Eco-efficiency fails to differentiate between kinds of material (Hukkinen, 2001) and its impact towards environment; and the resource scarcity, waste and energy used increase even when the Eco-efficiency improves (Holm and Englund, 2009; Strandbakken, 2009 and; Korhonen and Seager, 2008). Another problem with Eco-efficiency is that no single approach has been developed to measure and report the Eco-efficiency (Park *et al*, 2007). Although WBCSD have proposed a standard framework to measure Eco-efficiency, in real practice companies especially Japanese companies, actively develop their own Eco-efficiency indicators to evaluate their business segments, subsidiaries, processes and products (Burritt and Saka, 2006). It is also suggested that its broader aim and relative measurement can make Eco-efficiency an implicit and general goal (Ehrenfeld, 2005; McDonough and Braungart, 1998; Honkasalo, 2001).

2.4 Comparison and Discussions

This section describes various characteristics of each strategy, enabling more direct comparisons to be made across a broad literature. The aim is not to identify the superior strategy but to improve understanding.

2.4.1 Challenges in making comparisons

The broader the strategies, the more complex the measurements involved. Indicators used in measurement should have a metric or combination of metrics that reflect the real state of the product or processes as defined by the strategy. Some strategies have clear definitions but have measurements that do not cover all the areas as defined. Effective measurements and indicators are important for operational success, and should be

understandable, implying the correct situation and based on accessible data. Problems arise when products or processes achieve a good score while not meeting the aim of the strategy. For example making packaging lighter but using more toxic and more scarce materials would 'improve' a Waste Minimisation score. Thus it is important to have set of indicators that are feasible to measure and which can be acted upon, for *'what gets measured gets improved'*. Difficulties in measurement can lead to difficulties in communicating the strategy.

2.5 Comparing the Strategies

There is no doubt that all the strategies compared can contribute to sustainable development. They are all practiced in a variety of industries and some of them implemented under different names. But how much each of them is facilitating action towards sustainability and how effective they are remains debateable. As shown in table 2.6, they have various similarities and differences. Criteria chosen to compare the strategies are divided into: Definition, Scope, Practicality and Compatibility as described below:

a) Definition – What is the strategy and its aim.

Type – The clarity of the definition. Is the strategy clear (concrete) versus ambiguous and is it testable versus complex (philosophical)?

Orientation – What is the strategy defined around? Is it defined around Goal, Action or its Measurement? e.g. the definition of waste minimisation stating 'reduction of waste at source' shows that strategy is defined around its goal to reduce waste at source.

Focus - What is the definition centred on? Is it on *cause* (e.g. resources and material) or *effect* (e.g. pollution, emissions and waste).

Main goal – What is the priority goal that practitioners are expected to deliver against, extracted from the strategy's definition.

b) Scope – What is included in the strategy.

System boundaries – The horizontal limit of ***'elements'*** (e.g. waste, material or resources) flows that the strategy is intended to influence.

Influence over externalities- – Does the strategy influence externalities? Note: Externalities arise when actions by producers or consumers cause unintended effects on others. Externalities could be positive or negative.

Level usually used – What level the strategy is usually used at, as cited in the literature, e.g. Product/Process/Company/Regional/ National.

Depth of issues to be tackled to achieve goal – the depth of investigation needed on the ***'element'*** which the strategy is intended to cover.

Concerns - which dimensions of sustainability that are covered e.g. ecology, economy, and/or social.

Utility being assessed – the 'output' which is expected or desired when practicing the strategy.

c) Practicality – How difficult or easy the strategy is to implement.

Measurement and target – How simple or difficult the measurement would be to use in practice. Qualitative and quantitative aspects of strategies can contribute to levels of difficulty in setting targets and measuring against them.

Indicator effectiveness – How well does the measure indicate effectiveness (that a better score is a better outcome and indicates the direction of improvement).

Technical Feasibility – The ease of implementing the strategy and achieving its goal.

Data Availability – The availability and cost effectiveness of obtaining and processing the data to measure and manage progress.

Ease of communication – How easy it is for the strategy and its indicators to be understood by the stakeholders.

Does it guide action – How well does the strategy provide a clear guide to generate actions for change.

d) Compatibility

Between goal and measurement - Does the measurement cover the dimensions, scope and system boundaries stated by the definition.

As can be seen in table 2.6; using the criteria chosen as a comparison tool, the researcher concluded that Waste Minimisation is the most direct and simple of the strategies. Its goal is to reduce waste in order to save money and reduce pollution. The definition of Waste Minimisation is around its goal and focused on minimising waste, using the waste hierarchy to remove waste at source as a preference. Due to its simplicity, it is somewhat limited in scope although it can be implemented at various levels of a company. In terms of practicality, and due to the quantitative nature of its utility assessment, it makes the measurement relatively easy to implement. Data collection is usually available inside the company. The Waste Minimisation strategy can be a very effective strategy in reducing waste to landfill if every waste producer practices it and is committed to the strategy. There are few externalities to deal with,

and this makes the strategy meaningful to individual manufacturers; unfortunately singular action may not impact an entire supply chain and have limited effect on the amount of waste produced by the whole system. The strategy is attractive to companies as it helps reduce cost. Waste Minimisation activities are often a first step taken by industry in response to the call for sustainability. Waste Minimisation activities are also priorities in other sustainable strategies. Thus, efforts to implement a Waste Minimisation strategy can be a first step towards implementing bigger and more complex sustainable manufacturing strategies by manufacturing companies.

Table 2.6 Comparison of four main sustainable manufacturing strategies

Criteria / Concepts		Waste Minimisation	Material Efficiency	Resource Efficiency	Eco-efficiency
Definition	*Types*	Concrete - *1,2*	Concrete	Concrete	Philosophical -*3,4,5,6*
	Orientation	Goal oriented	Action oriented	Action oriented - 7	Measurement oriented
	Focus	Effect-waste -*1*	Cause- material	Cause- resources	Cause/effect – Resources/pollution
	Main goal	Reduce waste and pollution Reduce cost-*1,6*	Efficient use of resources (both material and energy) Reduce waste and pollution -9	Efficient use of resources Reduce waste and pollution	Efficient use of resources, Reduce waste and pollution, Quality of life Earth carrying capacity - *10*
Scope	*Systems Boundaries*	Limited -downstream	Upstream-downstream -9	1)Do not cover upstream and downstream activities -*7* 2) Cover upstream and down stream by measuring MIPS - *11*	Claimed to cover upstream-downstream by addressing all stages of product life-cycle -*12,14* - but seen as debateable- *13*
	Influence Externalities	Limited	Yes	Yes	Yes - supposedly big influence - *15*
	Level usually used	Process-*16*, Company-*17* and National	Process, Product-*9*	Product, Company and National -*18*	Product ,Company and National *3,4,5*
	Depth of issues to be tackled to achieved goal	Relatively easy	Potentially difficult	Difficult	Very difficult -*3,4,5*
	Concerns (e.g economy, ecology, social)	Limited	Limited -*19*	Broad	Broad -*3,4,5*
	Utility Assess	Weight, volume, cost	Functionality/services	Unit of value added	Unit of value added – *10,20*
Practicality	*Measurement and* *Target*	Direct/simple 1,21 Quantitative - *1*,8	Potentially complicated Quantitative	Complicated Qualitative Quantitative - *22*	Complicated -*3* Quantitative *22,23,24* and Qualitative
	Indicator Effectiveness	Yes	Potentially difficult	Difficult	Very Difficult - *27*
	Technical Feasibility	Yes	Potentially difficult	Difficult- 22,25,26,27,28	Difficult - *31*
	Data Availability	Easy - *1*	Potentially yes	Difficult	Difficult
	Easy of Communication	Yes	Potentially yes	Potentially yes	Difficult
	Does it guide actions	Yes	Potentially yes	Potentially yes	Debateable- 3,4,27,28,30
Compatibility	*Between goal and measurement*	Yes	Potentially yes	Potentially yes	No – difficult to determine on earth's carrying capacity- *3*,Limited -*4*,Does not effectively address the issue of toxicity - *31*

Note: Below is the list of authors referred by the table 2.6

Authors: (1) Bates and Philips, 1998 (2) Clelland *et al*, 2000 (3) Ehrenfeld, 2005 (4) McDonough and Braungart, 1998 (5) Honkasolo, 2001 (6) Korhonen, 2007 (7) Commission of European communities, 2003 (8) Cheeseman and Philips, 2001 (9) Worrell, 1997 (10) WBCSD, 2000a (11) Schmidt-Bleek, 1995 (12) Mosovosky *et al*, 2000 (13) Warhurst, 2002 (14) Michelsen *et al*. 2005 (15) Ekins, 2005 (16) Gottberg *et al*, 2006 (17) King and Lenox, 2002 (18) Cramer and van Lochem, 2001 (19) Worrell, 1994 (20) OECD, 1997 (21) Hanssen *et al*, 2003 (22) Reijnders, 1998 (23) Warhurst, 2002 (24) Park *et al*, 2007 (25) Hawkins and Shaw, 2004 (26) Pearce, 2001 (27) Foxon, 2000 (28) Figge and Hahn, 2004 (29) Huesemann, 2004 (30) Jansen, 2003 (31) Braungart *et al*, 2007.

Among the four strategies, Material Efficiency is given less attention in the literature although it is referred to in all the other strategies. The concept, compared to others, is more inclusive of upstream and downstream processes (and impacts), while it remains quite direct and relatively easy to measure and turn into action. Material Efficiency has the potential to reduce impact on the environment by using material efficiently upstream and downstream of factory material flows. The strategy is defined around its aim to achieve efficiency in material use.

Resource Efficiency is concerned with productivity of natural resources. This strategy has been viewed from multiple disciplinary perspectives: what is efficient, value adding and effective from one view is not necessarily viewed the same by others. Resource Efficiency embraces broader dimensions, while the reduced depth the strategy covers also contributes to difficulties in operationalising the strategy into effective action, nevertheless it remains attractive to policy makers. Utility assessment is based on a *Unit of value added per unit resource input* which is very difficult to measure because value added is qualitative and differs from one customer to another. Difficulty in measurement impacts on the utility of the indicator for sustainable manufacturing practice. Resource Efficiency does allow for the inclusion of energy inputs, while choosing not to embrace toxicity, earth carrying capacity or social dimensions. This makes it a good tool to indicate and monitor the consumption of a national or regional economy. Due to the movement of resources around the globe resulting from global manufacturing, it is, however, problematic to gaining a true indication of national Resource Efficiency (for example, do you become more Resource Efficient simply by deciding to buy a component from overseas rather than make in-house?).

Eco-efficiency is the broadest of the four dominant sustainable manufacturing strategies identified, and incorporates many more dimensions than the previous three. Although Resource Efficiency and Eco-efficiency have similarities, Eco-efficiency is further extended to address *"earth carrying capacity"* and quality of life. While this works to include concerns that the other strategies fail to encompass, these two dimensions

cannot be measured directly thus making the measurement and management of Eco-efficiency difficult and its effectiveness debateable. The current use of Eco-efficiency is largely supported by the World Business Council on Sustainable Development, who recognise its value in explaining the broad interactions between a business and the planet and its people. The WBCSD also recognises that a single measure is incapable of capturing the richness of the concept of Eco-efficiency and it provides a set of possible measures for business to select from, in the hope that the measures can guide action. In practice, the relative measurement used by Eco-efficiency is problematic because its indicator can be manipulated and can give false indications. The goal is broad, tends to be general and elusive, lacks depth and is limited in implementation. For example the measurement proposed by WBCSD does not easily include upstream and downstream activities; which are of the utmost importance. The Eco-efficiency measurement is used as set of indicators but the literature is sparse on the achievement of manufacturers in using these to become more sustainable.

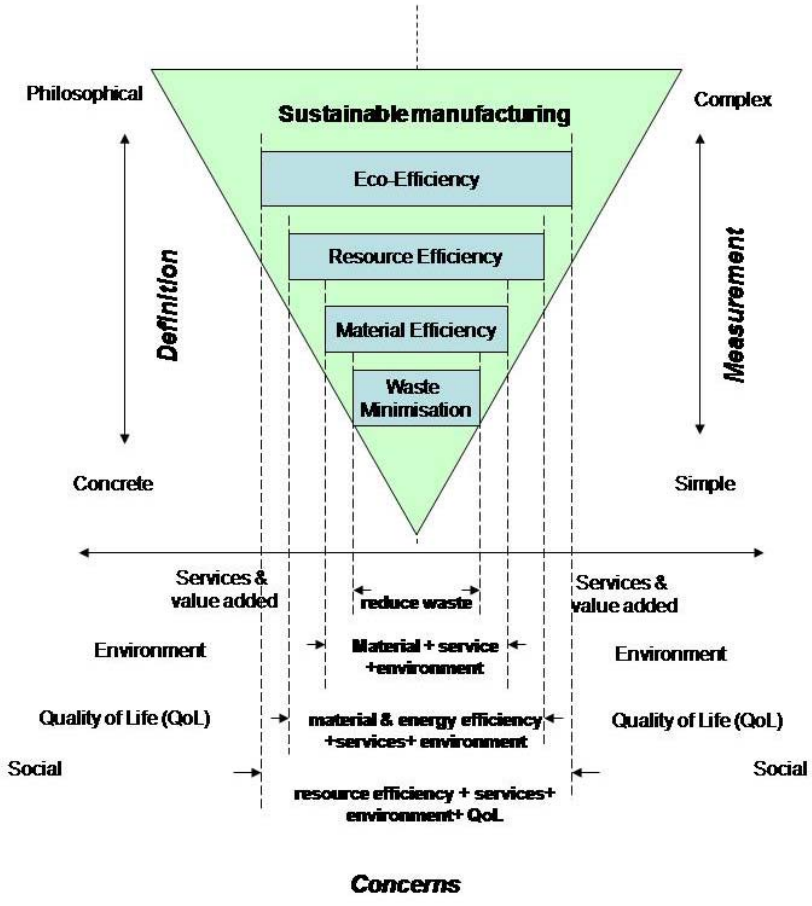

Figure 2.1 The hierarchy of sustainable manufacturing strategy

Figure 2.1 shows the relative scope of these sustainable manufacturing strategies and suggests a hierarchy between them. The more concrete the strategy the simpler the measurement and, therefore, the management of its implementation. The figure shows the simplest strategy is only concerned with reducing waste, which is a narrow view of sustainable resource use in manufacturing. However the more dimensions of sustainable resource use that are embraced, the more difficult it becomes to measure and the more philosophical the definition becomes.

2.6 The Importance of Material Efficiency Strategy

All four strategies discussed are contributing to sustainability which has the same goal to reduce waste (effect) and to achieve better utilisation or to reduce resources (cause). Although their definitions have different orientations; emphasis either on cause or effect; and their debates differ around choosing the ratio of productivity or efficiency to achieve effectiveness, these concepts are aiming for the same goal. From a simpler strategy, such as waste minimisation which is direct but easy to achieve, to Eco-efficiency which embraces more dimensions but poses greater challenges to implement and measure; the importance is not how many percent the efficiency achieved; the importance is the percentage achieved heading the right way (positive improvement). In other words, how effective the concept is.

Research on current literature shows that there is an increasing awareness of the scarcity of natural resources. There is a lot of effort that has been made by researchers to minimise waste and to increase Resource Efficiency but these efforts are unequal; energy efficiency gets greater attention compared to Material Efficiency. Although material efficiency is covered by Resources Efficiency and Eco-efficiency strategies, it is mostly concerned with how to reduce material quantity. Addressing material quantity will not solve all problems caused by materials. There is a need for thorough studies on Material Efficiency as the variety and complexity of material makes it difficult to address its environmental impact, i.e. holistic study.

2.7 Concluding Remarks for Literature Review

This literature chapter has presented a review and comparison of the four most popular sustainable manufacturing strategies mentioned in the academics' and practitioners' literature. These strategies range from the simple strategy of Waste Minimisation, which is direct and easy to achieve, to Eco-efficiency, which embraces many more concerns but poses challenges to implement and measure. A sustainable manufacturing resource strategy hierarchy in Figure 2.1 shows that the lower the strategy in the hierarchy the more concrete the definition is and the higher the strategy in hierarchy, the more philosophical the definition becomes. The lower strategy also has simpler measurements compared to the higher strategy. The concern at the lowest level of the hierarchy is to reduce waste, the highest level concern being to improve social, economic and

environmental sustainability. The literature emphasised various characteristics of a successful sustainable manufacturing strategy – for example, that an excellent strategy would have a clear definition, that the scope of the strategy would have clear and appropriate boundaries that handled externalities appropriately, that the strategy was practicable to implement, including having dimensions that were amenable to measurement, and being easy to understand and communicate, and that the goals of the strategy were compatible with the measurements used. Some seventeen characteristics were observed in the literature and a comparison of the four primary sustainable manufacturing strategies was undertaken using the characteristics; such a comprehensive comparison not being available in the existing literature.

Each of the four strategies of Waste Minimisation, Material Efficiency, Resource Efficiency and Eco-efficiency has different performance against each characteristic, with no strategy being superior. It is concluded through this research that Waste Minimisation is much simpler in definition and measurements but limited in coverage compared to Eco-efficiency which is the most philosophical and complex in measurements due to its intent to cover wider concerns. However, the data suggests that all these strategies are currently contributing to sustainable manufacturing and overall sustainability. The similarity is that all of them are aiming for sustainability, whether the goal is to reduce waste and to achieve better utilisation or to reduce resources. The differences between the strategies are various, but it is argued that the four strategies form a continuum from the simplest, most easily adopted, but narrow strategy of Waste Minimisation, through Material Efficiency then Resource Efficiency to Eco-efficiency. The existence of intermediate strategies, operating between the four, is possible, but the literature does not point to them, and the researcher argues that this is due to the challenge of measurement and its impact on definition and scope – the four strategies have emerged as those that have some compatibility between the definition and its measurement – by including a new variable the previous strategy is changed into a new one, and with few variables there are few strategies.

To choose among the four, practitioners from different manufacturing backgrounds may prefer different strategies. There is no evidence that specific strategies suit a specific manufacturing situation or product or process or sector. Those practitioners who prefer simpler measurement and visible achievement might choose Waste Minimisation or even Material Efficiency. For those who are willing to deal with a broad scope of causes and effects that potentially go beyond their own production plant boundaries, the concepts, tools and measures of Material Efficiency and Resources Efficiency strategies may be useful and appropriate, while generalists who would like to include many indicators might prefer Eco-efficiency (Pearce, 2001). For higher level decision makers Eco-efficiency has a broader scope allowing for a variety of actions and an improved ability to communicate green initiatives and to motivate actions. Care must be taken however in assessing and measuring Eco-efficiency.

The literature has highlighted that Material Efficiency is at the core of every sustainable manufacturing strategy. It is important that the debate on sustainable manufacturing does not get reduced to energy only. Given the primacy of the issue of Global Warming an emphasis on Energy Efficiency is reasonable, yet Material Efficiency can help directly with Energy Efficiency and material scarcity and equity remains an important and separate issue. Many manufacturers are either implementing or considering an Energy Efficiency strategy, and will be faced with some similarities to the issues raised in this literature for Material Efficiency, in particular the challenge of selecting the scope of the strategy (do we include the energy in the parts supplied to our factory, do we include the energy used in transporting our staff to work, etc). Material Efficiency has the potential to sit alongside Energy Efficiency strategies and initiatives; indeed without such a dual approach many opportunities for energy reduction may be missed.

Across a variety of manufacturing sectors these different strategies have been shown to deliver significant benefits, both environmentally and economically. These results can be compelling; however the data is often piece-meal and anecdotal, measuring different aspects of material and environmental performance in different manufacturers. Research is needed into existing practice and results, assessing the benefits achieved and the conditions under which they were achieved, both at the level of individual factories and the level of the product life cycle. This will help guide future manufacturing practice as well as future research into those tools and techniques that may support sustainable manufacturing strategies. In addition to observation of practice of these four strategies it is evident that more research is needed in understanding the interaction between goal, scope and measurement for sustainable manufacturing strategies, with the aim of developing measurement techniques and tools that work to ease the implementation of the strategies.

2.8 Generating Research Questions

As explained in earlier sections there are many techniques and practices in many types of sustainable manufacturing strategies that overlap with the Material Efficiency strategy. Thus the study by these other researchers, although not termed Material Efficiency strategy, was considered to be very similar to the investigation of the Material Efficiency concept as proposed by the researcher. Assuming this, the researcher studied the current literature and found that there are few other studies which assess the implementation issues such as motivation, challenges and the benefits of sustainable manufacturing strategies. However, none of these studies offers an overview of sustainable manufacturing strategy practices especially on Material Efficiency in the UK industry. Among these studies were:

1) Young (2001, as cited by Côté *et al*, 2006) and Vernon *et al* (2003) who have identified barriers experienced by SMEs when implementing environmental management and eco-efficiency.

2) Finnveden *et al* (2005) who found that recycling of paper and plastics is the most favoured practice.

3) An exploratory study by Gottberg *et al* (2006) presented motivations, drivers and constraints experienced by European lighting sector in performing eco-design.

4) Chapple *et al* (2005) found that waste reduction as a result of regulations or by voluntary action is costly to firms whether accomplished by end of pipe or process solutions. Yu *et al* (2009), does not find a positive relationship between firm environmental performance and financial performance for European firms.

5) Côté *et al* (2006) investigated the level of eco-efficiency demonstrated by SMEs in Nova Scotia, Canada. Their study presented lists of practices of eco-efficiency including Waste Minimisation, Material Efficiency and Resource Efficiency.

6) García *et al* (2008), presented factors that affect resource use and optimisation of the chemical industry in Northern Ostrobothnia in Finland, and presented the top practices, benefits and barriers.

7) Khanna *et al* (2009) discussed the role of management systems and regulatory pressures on company adoption of Pollution Prevention techniques.

8) Lilja (2009a) proposed that Material Efficiency is a better strategy compared to Waste Prevention for Finland.

Based on the preceding critical and latest literature review, it can be concluded that research carried out on Material Efficiency is very limited based on these evidences:

- Materials Efficiency tackled and branded different names along the life cycle of product and supply chain.
- The different names of Material Efficiency raised more confusion than clarity.
- There are no comparisons among these materials efficiencies and their related strategies in literature review.
- There is no comparison among these materials efficiencies and their related strategies practiced in companies.
- Less attention is given to Material Efficiency as a whole strategy besides its importance of being a core of every sustainability strategy and concept. Although covered in Resource Efficiency and Eco-efficiency as part of these strategies, the efficient use and environmental impacts of material are not well addressed.

Referring to the gaps, it seems that research on Material Efficiency is still at a premature stage as researchers are still struggling and addressing materials issues which are not easy. However, the Material Efficiency must be addressed and tackled no matter how complex the subject. From the gaps, the researcher has identified areas to investigate and decided to fill some gaps. Since the researcher chooses to tackle some of these gaps, the Research Questions have been developed to fill them. The research questions to be addressed in this research are as follows.

Research Question 1

Do companies use Material Efficiency strategies?

The first research question is exploratory and attempts to find out whether industry is practicing Material Efficiency and similar strategies which aim to reduce waste and material usage. Answers to this question can prepare the researcher and others to fill gap no. 1.

Research Question 2

Do companies use these strategies but call them something else?

The second research question is exploratory and attempts to find out if the companies used the same labels or names referred to by academics and literature. Answers to this question are used to fill gaps no. 1 and no. 2.

Research Question 3

How do companies use Material Efficiency strategies?

RQ3a What Material Efficiency strategies exist in practice?

RQ3b What Material Efficiency strategies exist in literature?

RQ3c What benefits do these companies achieve?

RQ3d What difficulties did they meet when implementing a Material Efficiency strategy?

RQ3e What actions did they take that helped the implementation succeed?

These research questions are exploratory and they attempt to further probe into understanding Material Efficiency practices in industry. The questions are designed to investigate how the companies are implementing Material Efficiency strategies including the challenges and benefits they have. Answering these questions helps fill gap no. 1, no. 2, and partially fill no. 3, no. 4 and no. 5. Answering these questions can

help academics and practitioners understand the practices and problems surrounding Material Efficiency implementation.

2.9 Chapter Conclusions

This chapter presents the contextual and critical literature of Material Efficiency, its related strategies and its issues with implementation. There are many Material Efficiency and sustainable strategies mentioned in literature which causes confusion for academics and practitioners alike. Four strategies have been identified as most commonly described by literature - namely Waste Minimisation, Material Efficiency, Resource Efficiency and Eco-efficiency. The critical review compared and contrasted those four strategies and identified the gaps in Material Efficiency research in literature. There is a significant gap in literature describing or analysing Material Efficiency practices. This research is therefore carried out in an attempt to fill these gaps by exploring the Material Efficiency strategies and its issues of implementation in industry. The method by which this research is carried out will be discussed in greater detail in Chapter 3.

3 RESEARCH METHODOLOGY

The aim of this chapter is to explain research design considerations and choose appropriate methodologies, strategies and methods in carrying out this research. This chapter demonstrates knowledge of the various approaches available to answer research questions and explains the path taken by the researcher in performing the research. At the end of this chapter, issues affecting research quality and measures taken to maintain research quality and rigor are explained.

3.1 Research Philosophy

Philosophy of research is a very important aspect of any social inquiry. According to the Concise Oxford English dictionary (2004), philosophy is defined *'as the study of the fundamental nature of knowledge, reality and existence'*. The dictionary defines research *'as a systematic investigation and study in order to establish facts and reach new conclusions'*. Most definitions in literature are more or less similar to the dictionary definition; nevertheless there is consensus in literature on the definition of research. According to Collis and Hussey (2009, p.3) there appears to be agreement from various authors that: *'a) research is a process of inquiry and investigation; b) it is systematic and methodological and; c) research increases knowledge'*.

This research adopted social sciences' research philosophy. According to The Cambridge Dictionary of Philosophy (1995), philosophy of social sciences is the study of the logic and methods of the social sciences. The research philosophy of social research must cover the concepts of epistemology and ontology as every science has its own ontology, epistemology and subsequently its own methodologies. The research is conducted to understand the real world (ontology) in such a way that produces knowledge of understanding, which in turn is valid (epistemology) through appropriate systematic methodologies.

To choose the right methodologies and consequently the right methods, the researcher must be aware of the ontological and epistemological assumptions that will be adopted. Although normally each ontological and epistemological assumption will have specific methods associated with them, this is not true every time. According to Blaikie *'methods can serve a number of masters, but they need to change their 'colour' to do so, and the data they produce will need to be interpreted within the particular ontological and epistemological assumptions that are adopted'*. To proceed with the decision on methodologies and methods the meaning of ontological and epistemology must be understood. Basically ontology is the study of existence. According to Bryman (2008), questions of social ontology are concerned with the nature of social entities. *'The central point of orientation here is the question of whether social entities can and*

should be considered objective entities that have a reality external to social actors or whether they can and should be social constructions built up from the perceptions and actions of social actors'. Epistemology on the other hand is the theory of knowledge. According to Bryman an epistemological issue is concerned with questions of what is (should be) regarded as acceptable knowledge in a discipline. '*A particularly central issue in this context is the question of whether the social world can and should be studied according to the same principles, procedures as the natural sciences. In determining what is the research philosophy to select, the first thing to look at is the epistemological issue which concerns the question of what is regarded as acceptable knowledge in discipline'* (Bryman 2008).

Subsequent decisions which need to be undertaken by a researcher are decisions on methodologies and methods. Strauss and Corbin (1998) defined methodology as a way of thinking about and studying social reality while a method is a set of procedures and techniques for gathering and analysing data. Many authors agree on the definition of method but not on the definition of methodology. Among the authors, Blaikie (2000) prefers a strict definition. Methodology according to Blaikie *'refers to discussion of how research is done, or should be done and to the critical analysis of methods of research'* and must '*include a critical evaluation of alternative research strategies and methods'*. Alternative definitions of methodology by Silverman, Creswell and Taylor and Bogdan are more relaxed, where the term methodology is defined as '*the way in which we approach problems and seek answers'* (Taylor and Bogdan, 1984), '*refers to the choices we make about a case study, methods of data gathering, forms of data analysis etc., in planning and executing research study'* (Silverman, 2004), '*defined as the entire research process from problem identification to data analysis'* (Creswell, 2008). The sections below discuss the alternatives of available methodologies and which methodology was chosen by the researcher.

3.1.1 Research paradigms

A philosophical assumption in research is also commonly referred as a research approach, assumption or research paradigm. Paradigm is a philosophical model or framework that originated from a world view or belief system which is based on the need to satisfy ontology and epistemology (Holloway, 1997). There are several levels of philosophical assumptions listed by Collis and Hussey (2009) but the researcher will only discuss two levels of philosophical assumption chosen in this research which are Ontological and Epistemological assumptions. Bryman and Bell (2007) divided ontological assumptions into two categories namely: *objectivism* and *constructivism*. The meaning of both assumptions is given at table 3.1. For epistemological assumptions, there are three philosophical epistemologies commonly used in research namely *positivism, interpretivism* and *realism*. Table 3.2 shows the differences between these three paradigms.

Objectivism	**Constructivism**
Objectivism is an ontological position that asserts that social phenomena and their meanings have an existence that is independent of social actors. It implies that social phenomena and the categories that we use in everyday discourse have an existence that is independent or separate from actors.	Constructivism/constructionism is an ontological position which asserts that social phenomena and their meanings are continually being accomplished by social actors. It implies that social phenomena and categories are not only produced through social interaction but they are in a constant state of revision.

Table 3.1 Ontological assumptions (source: Bryman and Bell, 2007, pp. 22 and 23)

In choosing ontological assumption it is important to understand the types of assumptions available. Ontological assumption concerns with the nature of reality. According to Collis and Hussey, positivists who believed in objectivism believed social reality is objective and external to the researcher which for them there is only one reality. At the other hand, the interpretivist believes that social reality is subjective as it is socially constructed. Researchers who adopt this type of assumption believed there are multiple realities as each person has his or her own sense of reality.

Positivism	**Interpretivism**	**Realism**
Positivism is an epistemological position that advocates the application of the methods of the natural sciences to the study of social reality and beyond. That stated only authentic knowledge is scientific knowledge and that such knowledge can only come from positive affirmation of theories through strict scientific method.	Interpretivism is taken to denote an alternative to the positivist orthodoxy that has held sway for decades. It is predicted upon the view that a strategy is required that respects the differences between people and the objects of the natural sciences and therefore requires the social scientist to grasp the subjective meaning of social action.	Realism shares two features with positivism: a belief that the natural and social sciences can and should apply the same kinds of approach to the collection of data and to explanation, and a commitment to the view that there is external reality to which scientist direct their attention.

Table 3.2 Three types of epistemological paradigm (source: Bryman, 2001, p. 13)

On epistemological considerations, positivism is mostly used by early scientists who used a very rigid definition of science. Most research that uses a positivism approach is research based on natural science which believes in universal laws. A positivism approach is a quest for objectivity and neutrality where the researcher needs to avoid

personal bias and keep a distance from the subject being studied. This approach is for research which looking for generalisation from sampling the populations.

Quite the opposite, interpretivism is commonly used by social scientists whose research is focusing on human beings and their way of interpreting and making sense of reality (Holloway, 1997). According to Holloway the interpretivism paradigms have their roots in philosophy and human sciences research especially in history and anthropology. Most qualitative research in these areas adopts interpretive paradigms. Different authors of social research methodology agree that Positivism is at one end of the spectrum of research paradigms, while interpretivism at the other end (Collis and Hussey, 2009; Bryman, 2008).

The realism approach is in between both paradigms. Realism is the belief that a reality exists independent of the perceptions of human beings. Realism is similar to the concept of critical social science put forward by Neuman (2005). According to Neuman critical social science or realism is similar to positivism as it agrees to view society as a currently unchanging order instead of as an ongoing process but disagrees with positivism as it does not take into account social context; that is dealing with the essence of real people and their capacity to feel and think. Realism disagrees with interpretive as it is only concerned with subjective reality which is too passive as it does not take a value position or help people in seeing illusions around them in order to improve their lives. Thus realism is best positioned at the middle of the spectrum. Table 3.3 illustrated the research paradigm continuum by several authors.

Authors	**Research paradigms** ◄——————————————————————►		
Collis and Hussey (2009)	Positivistic		Interpretivism
Hussey and Hussey (1997)	Positivistic		Phenomenological
Bryman (2008)	Positivism	Realism	Interpretivism
Neuman (2005)	Positivist Social Science	Critical Social Science	Interpretive Social Science

Table 3.3 Continuum of core epistemological assumptions from various authors (compiled by researcher)

This research is about comparing Material Efficiency strategy as discussed in literature and as practiced in the real world. Ontology decisions for this research require examination of the internal reality of subjects and their experience. An epistemology

decision for this research requires the researcher to interact with the subjects, actively involves with discussion if necessary, but maintains a detached relationship as the story and experiences of the subjects are important not their personal feelings. The methodologies for this research require interactional, qualitative analysis and interpretive skills. Based on those criteria, given the researcher's stance as well as the nature and purpose of this research, it is believed that for ontological consideration, the ***constructivism*** paradigm is adopted, and for epistemological consideration***, realism*** paradigm is the most suitable approach to use. As Neuman has put it critical social sciences or realism exist '*...as a critical process of inquiry that goes beyond surface illusions to uncover the real structures in the material world in order to help people change conditions and build a better world for themselves*'. Due to realism being in the middle of the spectrum it can lean towards the positivism end or the phenomenological end. By referring to Figure 3.1, it shows in this research, the researcher adopted methodologies associated with phenomenological or interpretivism philosophy.

3.2 Research Methods

In this section the decisions on methodologies which were taken at sections earlier were continued. Methodologies chosen here were then used to determine suitable methods. Methodologies in this study involved determining the purpose of research; and the research strategies were decided which will be discussed in this section. After knowing the research purpose and research strategy, data collection methods and analysis methods were decided. The sections below explain the choice of these methodologies and methods.

3.2.1 Purpose of research

A research project also can be classified in terms of its purpose. It can be exploratory, descriptive or explanatory, or a combination of these. Identifying research purposes is important in order to decide the next methodologies. The characteristics of these purposes are described in table 3.4 below.

As there has been very little research undertaken on this subject and the aim of this research is mainly getting insight into this new subject, the research purpose of this strategy is classified as an ***'Exploratory research'***. Exploratory research is research whose primary purpose is to examine a little understood issue or phenomena, to develop preliminary ideas and move toward refined research questions by focusing on the 'what' question (Neuman, 2005). According to Collis and Hussey (2009), exploratory research rarely provides conclusive answers to problems but rather gives guidance for further research.

Research Purpose	Description
Exploratory	▪ To find out what is happening, particularly in little-understood situations. ▪ To seek new insights. ▪ To ask questions. ▪ To assess phenomena in a new light. ▪ To generate ideas and hypotheses for future research. ▪ Almost exclusively of flexible design (qualitative).
Descriptive	▪ To portray an accurate profile of persons, events or situations. ▪ Requires extensive previous knowledge of situations etc. ▪ To be researched or described, so that you know appropriate aspects on which to gather information. ▪ May be of flexible and/or fixed design (qualitative or quantitative).
Explanatory	▪ Seeks an explanation of a situation or problem, traditionally but not necessarily in the form of causal relationships. ▪ To explain patterns relating to the phenomenon being researched. ▪ To identify relationships between aspects of the phenomenon. ▪ Maybe of flexible and/or fixed design (qualitative or quantitative).
Emancipatory	▪ To create opportunities and the will to engage in social action. ▪ Almost exclusively of flexible design (qualitative).

Table 3.4 Research purposes (source: Robson, 2002, pp. 59-60)

3.2.2 Research strategy

A distinction can be made between the types of research and data: **Quantitative or Qualitative;** and **fixed design** or **a flexible design strategy** (Robson, 2002)**.** Blaikie (2000) explained that *'Quantitative methods are generally concerned with counting and measuring aspects of social life, while qualitative methods are more concerned with producing discursive descriptions and exploring social actors' meaning and interpretations'*. Qualitative research is a form of social inquiry that focuses on the way people interpret and make sense of their experience and the world in which they live (Holloway, 1997).

Although the researcher opted for realism, the research is leaning towards interpretivism compared to positivism. Therefore, the researcher opted for interpretivism methodologies in data collection and analysis since most of this research involved investigating subjects through verbal revelations and experiences of the participants.

Collis and Hussey listed associate methodologies relevant for use by phenomenological researchers as can be seen in Figure 3.1 below.

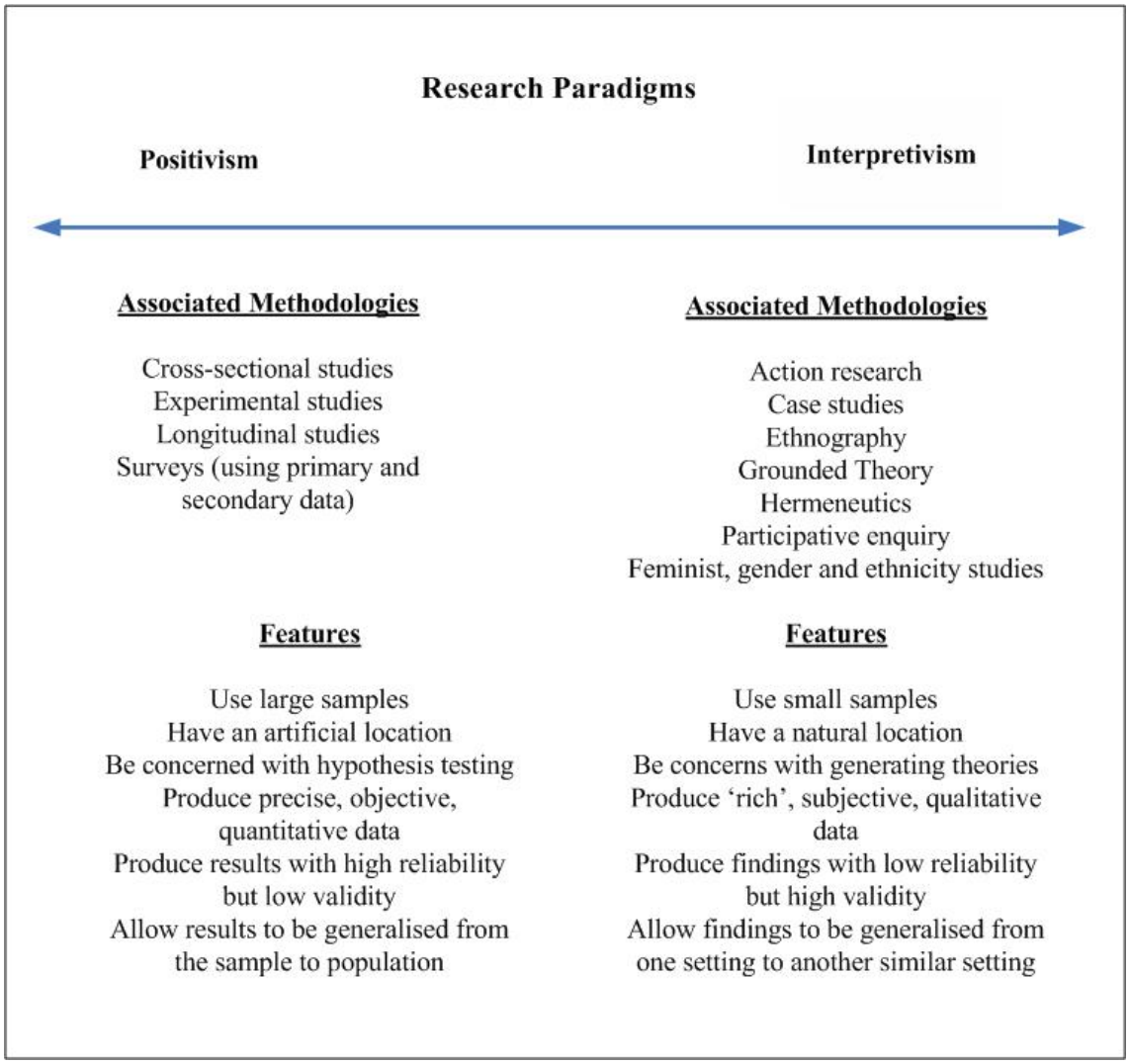

Figure 3.1 The spectrum of research paradigm and its associated methodologies (adapted from Collis and Hussey, 2009, pp. 57, 62 and 74)

Among associated methodologies listed by Collis and Hussey at Figure 3.1 only *action research, case studies* and *grounded theory* are relevant to the subject area. Action research is eliminated because this study is not intended to intervene or influence a change in companies, thus this study is considered a traditional research. Case study is the chosen method in data collection and analysis. Robson (2002) pointed out that case-study is a strategy for doing research where the researcher needs to investigate the particular phenomenon from multiple sources of evidence. Yin (2009, p.18) defined case study as *'…empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident'.* This study is in between the

Interpretive paradigm and the Realism paradigm in the phenomenological spectrum so *multiple case-studies* are chosen to understand the phenomena in industry. So it is decided that this research will investigate multiple case studies. Multiple case studies are chosen not for gathering samples, but to get an analytic generalisation (Robson, 2002). With medium size samples the researcher would not carry out an in-depth case study.

Other than case study, another methodology that is relevant to this study is *Grounded Theory*. The data collection and analysis method used throughout this study is *Thematic Analysis*, which arguably is quite similar to grounded theory and invites debates on both the techniques. Thematic analysis is commonly used by a qualitative researcher but rarely acknowledged as a method (Braun and Clarke, 2006). According to Braun and Clarke, thematic analysis is used by most qualitative researchers but is usually recognised as a tool rather than a method, on which they disagree. Braun and Clarke argued that people are always using thematic analysis and claimed it grounded theory. Robson (2002) pointed out that... '*the central aim of grounded theory study is to generate theory from data collected during the study which is particularly useful in new, applied areas where there is a lack of theory and concepts to describe and explain what is going on'*. Braun and Clarke stressed that grounded theory should go beyond mere description, which categories should be abstract concepts not simple clusters of associate phenomena. Braun and Clarke argued that grounded theory users who do not produce theory should not label themselves as using grounded theory but Thematic Analysis. Most authors however agree that grounded theory involves open, axial and selective coding[1]. The grounded theory also involves constant comparison[2] that requires comparing each section of data (in this research it is a case) to the next section of data. In this study, the researcher was using an open, axial, selective coding and to some extent has done constant comparison. Although Braun and Clarke argue that this research is thematic analysis rather than grounded theory philosophy, this study is adopting grounded theory analysis and can be extended towards having full grounded theory methodology if given an appropriate time frame and resources. The aim of this research is to explore phenomena. The deliverables of this research are to work towards theory building and to generate conclusions which enable further studies to be conducted on the subject, which is enough to be able to claim as using the grounded theory label. However to avoid confusion and debate the researcher is comfortable referring to methods used for collecting, analysing and interpreting methods in this

[1] Coding is the analytic processes which data are fractured, conceptualized, and integrated to form theory. - *Strauss and Corbin (1998)*

[2] *Constant comparison*- the constant comparative method consists of a series of interactive steps in which the researcher continuously compares sections of data, incidents or cases. (Holloway 1997, p. 33)

research as thematic analysis. The approach chosen in this research is illustrated by Figure 3.2.

3.2.3 Data collection

Every case study whether it is quantitative or qualitative should start with a general analytic strategy that identifies priorities and techniques to be used (Yin, 2009). The researcher is using qualitative data collection and analysis. Data collection is discussed here in terms of unit of analysis, access to companies, sources of information, and research instruments.

3.2.3.1 Unit of analysis

For an exploratory study, determining the unit of analysis is a challenge for the researcher. *'As a general guide, your tentative definition of the unit of analysis (which is the same as the definition of the "case") is related to the way you have defined your initial research questions'* (Yin, 2009). As this research is to investigate the Material Efficiency strategies being implemented among companies and how it is being done, so the unit of analysis of the research is the company which is implementing Material Efficiency strategies itself. This study chooses potential companies from those manufacturing companies which are known to be practicing some kind of Material Efficiency or related strategies that aim to reduce material usage and waste.

3.2.3.2 Access to Companies

Accessing companies is the most challenging stage of this research. As the researcher lacked personal contacts, recruitment had to be done in many ways such as by sending cold emails, doing cold calls, using the supervisor's personal contacts and going to seminars to recruit. At the end of data collection stage, ten (10) companies were recruited which consisted of nine (9) manufacturing companies and one (1) retailer. It is explained in earlier sections that this research is adopting case study, thematic analysis and phenomenological methodologies, which as a consequence influenced the sampling strategy. In this research, the theoretical sampling strategy is adopted which explained the smaller sample size used (as compared to quantitative sampling strategy). According to Eisenhardt (2007) when the purpose of research is to develop a theory rather than to test it, the theoretical sampling is the most appropriate. The aim of theoretical sampling is to work towards the theory building and selecting new cases is done because they are particularly suitable to be examined, gain a deeper understanding and facilitate the development of the theory (Eisenhardt 1989, Marshall 1996). Eisenhardt (1989) suggested that a number between 4 and 10 works well for case study research. Eisenhardt suggested that using fewer than 4 cases result in difficulty in generating a theory and using more than 10 cases will make it too complex with a huge amount of

data for the researcher to handle. A full list of participating companies and a brief description of their business is shown at Chapter 4 section 4.1.1.

3.2.3.3 Sources of information

For each case study or company the researcher interviewed two or more persons in different positions. It is not strictly the same job position for each company's access due to different companies having different level and scope of implementation. Other data such as the researcher's observations during site tours and secondary data from the company's sustainability reports, company's website and consultant's reports are used to help the researcher comprehend the companies' data and findings. For the secondary data that is used to validate the findings, the report on Waste reduction by the House of Lords (2008) is used. This report is an inquiry by the House of Lords on waste reduction practices in the UK to which academics, companies and government agencies were called to give evidence either oral or written. These individuals were selected by the inquiry to give evidence based on their expertise. The oral evidence was transcribed and made public in November 2008 by the House of Lords. Both oral and written evidence are published in a 499 page report, providing a rich seam of transparent data on company practices (as well as the policy interactions).

3.2.3.4 Research instruments

The main instrument used for collecting evidence in this research is a face-to-face semi-structured interview. A semi-structured interview is regarded as one of the most important sources of case study information; the strength of an interview is that it focuses directly on the case study topic and *'provides perceived causal inferences and explanations'* (Yin, 2009: p. 102). In this research, the literature review is not only a tool to build evidence for research gaps and to direct the research but is also used as a source of data that helps the researcher shape the interview questions and also as source of data that could be used as a comparative tool. Semi-structured interviews are used to capture rich information and knowledge from companies. Through interviews it is hoped that a lot of new information unknown to academia will be gathered. The researcher regards the knowledge of Material Efficiency and surrounding topics as new and confusing to the people in industry and academia alike. This is evident in a literature review done earlier. Also it is assumed that we do not know what is real practice in industry, thus the researcher had to put industries as a source of information rather than testing and validating propositions or hypotheses generated from literature. Thus other methods such as quantitative survey are not suitable as the academics have a little first-hand knowledge as to what is happening in industry. The semi-structured interview was chosen as a data collection method as it is the most flexible tool which enabled the researcher to gather data that gives an exploratory insight and the subject's depth, by encouraging the participants to reveal more information on the subject while maintaining control over the conversation. The purpose of interview according to

Patton (2002) is to allow the researcher to enter into the other person's perspectives. As suggested by Patton, qualitative interviewing begins with the assumption that the perspective of others is meaningful, knowable, and able to be made explicit. A semi-structured interview according to Jankowicz (2004) is conversation steering by the questioner to cover certain previously identified issues within a topic predetermined by the questioner.

In the semi-structured interview the researcher steers the conversation to the themes which were identified earlier from the literature review. From the critical literature review the gaps were identified and the research questions were developed to answer these gaps. The questionnaires for the semi-structured interview were designed to address these research questions accordingly. A constant comparison is a method used in grounded theory research (Holloway 1997, Glaser and Strauss, 1967) and theoretical building type of research (Eisenhardt, 2007). This research uses a thematic analysis method which is closely associated with the grounded theory method. This research also considered a theory building type of research which commonly uses a constant comparison technique. The researcher did change the questionnaires to explore more thoroughly new information found from previous cases. These changes were done when it was necessary to interact with participants and also with new or unexpected findings. Due to the fact that the strength of semi-structured is on its flexibility, this is allowed and expected as long the conversation (that is selected as data) is still around the themes which it is intended to cover. A list of original semi-structured interview questionnaires is shown at appendix 3.1.

With prior consent from the respondents, all interviews were recorded. This would free the researcher during the interview from being busy writing notes and allow the researcher to concentrate on the issues being discussed as well as to ensure that the information/evidence obtained is stored in its original form for future use and verification. According to Yin (2009), tape recorders provide a more accurate rendition of any interview compared to any other method. The tapes were then transcribed into text documents and stored electronically. Although all interviews were recorded, this will not eliminate the use of note taking. Note taking serves several purposes as highlighted by Patton, from helping the interviewer formulate new questions as the interview moves along, to helping facilitate transcription and data analysing processes. Interviews were conducted with the respondents, each of which lasted between 40 minutes to one hour and sometimes more.

3.2.4 Data analysis

Miles and Huberman (1994) defined data analysis as consisting of three concurrent flows of activities: *data reduction; data display*; and *conclusion drawing and verification.* Different to quantitative data analysis, qualitative data analysis has its own challenges. The challenges of qualitative data analysis lie in how to make sense of a vast

amount of data (Patton, 2001), and also because the data itself is in the form of words that can have more than one meaning (Neuman, 2005). Another challenge that adds to the difficulty is that the techniques of qualitative analysis itself are still being developed (Blaike, 2000). As this research is qualitative and data are in verbal and written forms, it is important to use a systematic method to make valid inferences from the text. Thus the first step of qualitative analysis is to reduce the amount of data. Although there is a lack of formulae in turning massive data into findings there are many qualitative research books which offer guidance on qualitative data analysis.

For the qualitative analysis, the researcher adopted thematic analysis which is almost similar to the ground theory analysis techniques where the initial stage of grounded theory is coding. *'The codes are labels which enable the qualitative data to be separated, compiled and organised'* (Collis and Hussey, 2009; p. 179). This can be done by doing open coding followed by axial coding and selective coding. Open coding is a basic level which is more simple and topical whilst axial and selective coding are more complex. Open coding involves identifying, naming and categorising the data. Axial coding according to Collis and Hussey involves connecting categories and sub-categories on a more conceptual level. Selective coding is a process of choosing one category to be the core category and relating all other category to that category. Open coding as described by Strauss and Corbin (1998) is the analytic process through which concepts are identified and their properties and dimensions are discovered in data. Selective coding according to them is the process of integrating and refining the theory.

3.2.4.1 Data preparation and tools used

Using NVivo helps managing data and analysis. The researcher does coding with the help of Qualitative Analysis Software; NVivo version 7. To input data to NVivo, the researcher had to transcribe interviews word by word. However during the interview some words were inaudible but this would not affect data preparation as the analysis is done in a way that the meaning of what is said is more important than a particular word. Transcription took a very long time as it is a menial task. The transcriptions are not only important for thematic analysis but will be used for quality checking purposes. This transcription was then imported to NVivo for analysis process. The NVivo helped the researcher with data reduction, data display, and conclusion drawing and verification. In data reduction NVivo assisted the researcher to do open coding, axial coding and selective coding. However the thinking and decision while coding was wholly done by the researcher as the software only assists the researcher with data management, managing ideas, graphically model and data query and report (Bazeley, 2007).

Before analysis the researcher read the transcription several times in order to immerse in the data to enhance understanding and familiarise with the data. This should be done before coding starts to eliminate coding mistakes.

3.2.4.2 Within case analysis

Eisenhardt (1989) stated a reason of doing within case analysis is to gain familiarity with the data and preliminary steps for theory generation. During the analysis, the researcher assigns a code to a phrase that gives evidence towards answering research questions. According to Miles and Huberman (1994), codes are tags or labels for assigning units of meaning to the descriptive information analysed. The names of codes could be originated from the word in the sentence or given by the researcher that is best describing the evidence. These code's names would be used as predetermined codes when analysing next cases. In this study, each company is considered as one case, although in one company there can be more than one interviewee and interview. Even though while analysing, the codes were grounded from the data, the researcher was always trying to maintain consistency from one case to another by doing constant comparison and re-checking the analysis. Codes from the first case study were used as a template to help the researcher coding subsequent cases. Codes are dynamic, although first the case's codes were used are a template, but as the coding process progressed, the researcher's understanding evolved and new codes emerged, making the earlier codes require amendments. The existing codes still required amendment even when all cases had been analysed. Researcher understanding evolved as the researcher reread the transcription and came to a new or better interpretation. The big challenges were in maintaining the consistency in interpretation and in assigning codes. After finishing the codes, which is the initial stage of data analysis, all codes were kept in their original form; they were not tidied and reduced in NVivo because the researcher preferred to make the tidying process step-by-step and documented. This way makes sure that any inconsistencies will be easily spotted. This analysis using NVivo stopped at this point, as the researcher then used a word processor to do cross-case analysis and synthesis manually. Details on the within-case analysis process are explained in Chapter 4.

3.2.4.3 Cross-case analysis

Next is the cross-case analysis, the reason for which is to force the researcher to look beyond initial impressions and see evidence through multiple lenses (Eisenhardt, 1989). In this study, the cross-case were done in two rounds to make sure a high quality of analysis was achieved. Generally the cross-case analysis for the first round started when the researcher put all the codes together to cluster them using a *dendogram method*. This clustering was stopped until the researcher reached the high level codes or themes. Using final codes now known as themes, the researcher checked the themes with cases raw codes and ticked the box if the company had the key criteria. The researcher then interpreted the findings by assigning weightage to the themes. From here it was possible to see which themes are important by looking at the weightage. The weightings used in this analysis should not be regarded as similar to quantitative weightings but rather in a way which was helping the researcher to prioritise the findings. The second round cross-case was done to make sure nothing was missing and any misinterpretation during

the within-case and first round cross-case analysis were amended. The details of cross-case analysis and the reason of using counting to highlight the significance findings is explained at section 5.1 paragraph 3 of chapter 5 of Cross-case analysis.

3.2.4.4 Validation

According to the Concise Oxford English dictionary (2004), validate is an act to; i) check or prove the validity of (something) ii) make or declare legally valid. Validity according to Holloway (1997) is an important element that establishes the truth and authenticity of a piece of research, together with reliability. According to Denscombe (2007), validity means the data collected and methods used are right. Right data means whether or not data reflects a truth, reflect reality and covers the crucial matters. Right methods means that the methods and tools used are measuring suitable indicators of the concept and getting accurate results. Validation was done in this research to reject or confirm the findings. Validation was done by comparing the themes from cross-case analysis with highly reliable secondary data. The secondary data is an inquiry report of Waste Reduction by the House of Lords (2008). More on how validation is done is explained in greater detail in Chapter 6 of Validation.

3.3 Research Quality

Science is concerned with rigor, and to prove rigor, the research must be reliable, valid and generalisable. In positivism study, reliability is about an indicator's dependency and consistency, and validity is about whether an indicator actually captures the meaning of the construct that we are interested in (Neuman, 2005). Generalisibility is about whether the sample can be generalised to a population. Unlike quantitative research, it is rather difficult to check the *'reliability'*, *'generalisability'* and *'validity'* of qualitative research. Although it is difficult, there are ways of showing research quality and rigour in qualitative research. Measuring research quality of qualitative research is not the same as quantitative research. Qualitative researchers argue on different standards for judging quality of the research. Instead of judging based on criteria such as *validity, generalisability* and *reliability* the qualitative research would be appropriate to judge by its *trustworthiness* and *authenticity* as criterion of how good a qualitative study is (Lincoln and Guba, 1985; Guba and Lincoln, 1994). Each aspect of trustworthiness has a parallel with quantitative research criteria in which *credibility* is parallel to validity, *transferability* parallel to generalisability, *dependability* is parallel to reliability and *objectivity* is parallel to confirmability. Although different researchers give a different number of aspects and criteria to measure research quality, in this research only the trustworthiness criterion is used and within this criterion only three basic aspects of research quality measures were deemed suitable by the researcher to increase research quality and rigour.

3.3.1 Credibility

A good way of checking the quality of qualitative research is focusing on credibility or trustworthiness of the research (Robson, 2002). It is however difficult to justify if the piece of qualitative research is credible just by asking people because people are prone to bias. One way in checking the research credibility is by checking if the researcher has reduced and eliminated possible threats to research validity. Padgett (1998) presents a list of strategies that are commonly used by researchers to reduce these threats namely: *prolonged involvement; triangulation; peer debriefing and support; member checking; negative case analysis;* and *audit trail.*

This research took a fixed time at each case study or company so no prolonged involvement arises. Triangulation in this research was performed by doing validation using high quality secondary data. Peer debriefing, support and member checking is done by the researcher's supervisor as he is experienced in the research subject. The supervisor also sometimes attended during data collection and participated during the interviews. He also supported triangulation by independently interpreting some transcribed interviews separately and compared them to the ones interpreted by the researcher. An audit trail was done by keeping the corresponding emails with the case companies, the interviews were recorded and the transcription was done and kept in a safe place. The researcher also kept the log book to record all research activities.

3.3.2 Dependability

Reliability in quantitative research is associated with the standardised research instruments. Guba and Lincoln (1985) proposed dependability as parallel to reliability as one criterion of trustworthiness. It is difficult to get the same information with qualitative research especially in phenomenological research as much unexpected and new information is revealed. Although the research was using standard semi-structured interviews, sometimes interviews got carried away and sometimes the interviewee dominated the conversation. The interviews also tended to focus towards the company's unique scenarios because the information revealed during the interview was interesting. The only way to ensure reliability of this type of research was by performing it carefully, with thorough and honest research. This can be achieved by having a log book, records and transcription to show audit trails (Robson, 2002). Cuba and Lincoln suggested having an accessible completed record of the research process starting from the research problem formulation until the data analysis decision.

3.3.3 Transferability

Generalisation in positivistic research means generalising from sample to population, generalisation in phenomenology research is the findings may be able to be generalised from one setting to another (Collis and Hussey, 2009). This is referred by many

researchers as analytic or theoretical generalisation (Robson, 2002). Sim (1998, p. 350) described theoretical generalisation as *'…here the data gained from a particular study provides theoretical insights which possess a sufficient degree of generality or universality to allow their projection to other contexts or situations'*. Doing multiple case studies however, according to Robson, should not be mistaken by trying to get statistical generalisation but rather analytic or theoretical generalisation. Transferability is the alternative term for generalisability or external validity. Rather than looking for sampling, it is looking for findings in one context which can be transferred to similar situations or participants (Holloway, 1997). To do transferability, Lincoln and Guba (1985) suggest that one uses thick description and describe accurately in detail the data and process. Similar to sampling, it gives rich and specific information to give a clear picture and allow people to make a judgement whether to 'transfer' the results to a different context.

3.4 Chapter Conclusions

In this chapter, all research design considerations are discussed and the appropriate methodologies, methods and tactics chosen to tackle research problems are explained. The selections of research philosophy, methodologies and methods are summarised in the table 3.5 and illustrated in figure 3.2.

Element	**Methods**
Research strategy	Qualitative
Research paradigm (Epistemological consideration) (Ontological consideration)	 Realism Constructivism
Research purpose	Exploratory
Research methodology	Multiple case study
Data collection method	Semi structured interview
Data analysis method	Thematic analysis

Table 3.5 Research considerations summary

This chapter also explains the research process that has been followed in this study. More details on data analysis are also supplied in the evidence and analysis chapters 4 to 6. In parallel to the phenomenological research conducted, sufficient research attention has been paid to assuring the research quality and rigor of the study accordingly. Having defined the research methodology used in this work, the subsequent chapters will show evidence and analysis of within case and cross-case study.

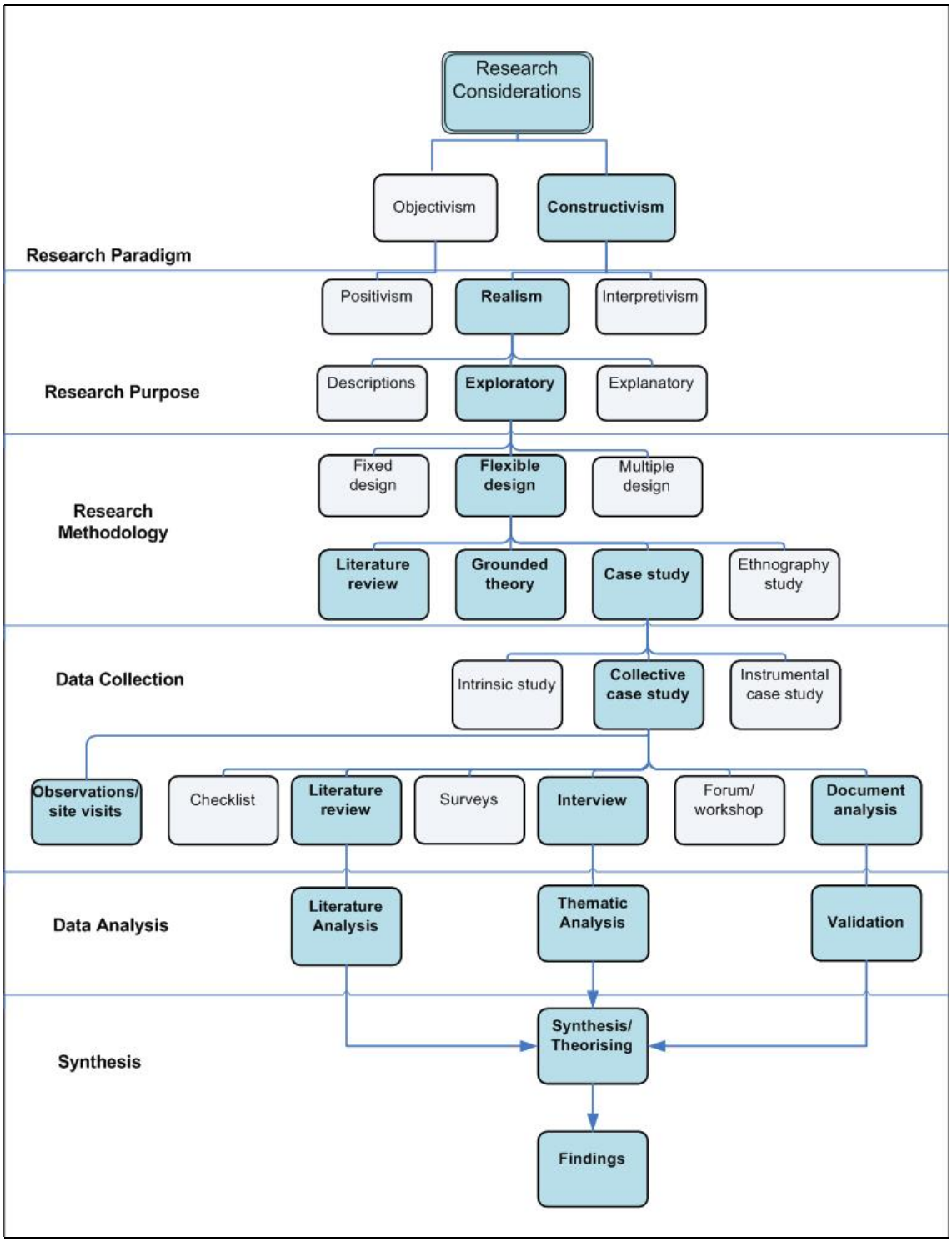

Figure 3.2 Approach chosen

4 CASE STUDY EVIDENCE

This chapter reports how the companies were chosen, from whom the data was collected, how data was analysed and finally presents details of how companies are practicing Material Efficiency strategies. The aim of this chapter is to show evidence collected from companies during the data collection stage. At the end, this chapter will present clusters found within case study analysis, which then will be used in cross-case analysis.

4.1 Analysis Methods

In this research, qualitative data has been collected. Data was analysed as within case analysis to show unique evidence for each company. Semi-structured interviews were used to capture the information from interviewees. This type of interview format was used as the researcher already has areas determined to cover which will be used to answer Research Questions. These interviews were then transcribed before the researcher comprehended the information. Morse (1994, as cited in Collis and Hussey, 2009) described comprehending as an act of acquiring a full understanding of the setting, culture and study the topic before commencing a research. Thus in this research study, comprehending is a step when the researcher reads transcripts several times to get close to the data and understand the issues underlying the words. The transcriptions were imported into NVivo to help the researcher in clustering the concepts and ideas found in the interviews. Clustering involves searching the data for related categories with similar meaning. This analysis is known as Thematic Analysis as the main purpose during the beginning of the analysis is to look for themes. When a set of themes is formed, more advance analysis can be employed to look for clusters and patterns among them. In this analysis, any sentences that give significant meaning are extracted and given a label, and are then organised under categories. These processes are repeated for each interview and the meanings are organised into clusters of labels. Common patterns then become obvious as the analysis progresses from data to data. First interviews usually become templates but it is not viewed as fixed, as this emerging pattern is constantly changed as the researcher's understanding of the subject deepens. In this process, codes for first interviews were still amended while the researcher is coding the last interview. When the coding is finished, each case or company has their own clusters. Although the researcher tries to be consistent in interpretation, the researcher still allows the labels and meaning expressed by the interviewee to be dominant at this stage. At this stage, each case's clusters are individually unique to express the uniqueness of each case studied. Clustering exercise using NVivo software is shown at Appendix 4.1.

Of course many clusters will appear under each area. In this thesis, the researcher will show the most significant clusters as evidence. One way of identifying significance is by studying the transcript, looking at the whole context and issues in order to find things that are emphasised and stressed by the interviewee. Another way of finding significance is by doing counting. Counting in this analysis is not used to look at frequency but rather to assess the importance of each issue, as the assumption used in this analysis is, when the interviewee mentions a particular thing or issue the most, the issue talked about is probably important.

Research Questions are not answered within the case analysis stage. Codes are clustered, and then worked towards answering research questions. A total of six (6) areas were investigated. Among these six areas, four (4) areas come directly from Research Questions: ***Constraints, Accelerators, Benefits*** and ***Practices***. Another two (2) areas have emerged from the data, which are: ***Factors that catalyse to have strategies*** and ***Factors that influence the choice of strategies.*** These two areas are discussed first in all case studies at sections below to help structure the presentation.

4.1.1 Research participants

A total of ten companies or cases were determined at the research strategy formulation stage as this is considered suitable for theoretical sampling strategy, as explained at section 3.2.3.2 earlier. The researcher experienced some difficulties in recruiting companies therefore recruiting took longer than expected. Due to the researcher lacking personal contacts, recruitment had to be done in many ways such as by sending cold emails, doing cold calls, using the supervisor's personal contacts and going to seminars to recruit. All companies that were initially contacted were selected as they gave the impression from their websites that they were practicing sustainable manufacturing strategies. Some of them had appeared in news and magazines published by government and non-government agencies. For example, one of the non-government agencies that published manufacturing companies' achievement on cleaner production and related sustainable practices is *the Manufacturer* which reports manufacturing case studies and manufacturers' best practices in UK. Companies recruited by personal contact were those that were known by the contacts to be practicing sustainable manufacturing strategies. Companies which had participated in relevant seminars were recruited; such as the series of seminars and workshops organised by Envirowise. The process of recruiting these companies begins with the researcher sending invitation letters. Followed by tactics such as sending emails, phone calls and going to seminars. There were 30 letters sent out, all were unanswered. Out of approximately 50 emails only two gave a positive response and were successfully recruited. Out of four seminars and workshops attended, two more companies were recruited. Three companies were recruited through the researcher's personal contacts, two at seminars and another three by the personal contacts of the researcher's supervisor. . At the end of data collection stage, ten (10) companies were recruited which consisted of nine (9) manufacturing

companies and one (1) retailer. The interviews were done between 2007 and 2008 and involve 10 companies. Interviews, interviewees and companies are listed in table 4.2. For confidentiality reasons companies are given identifications: Company 1, Company 2 and so forth. The interviewees are given identifications as Engineer 1, Engineer 2 depending on their job name and number of interviewees present during the interview. Total hours of interviews are 14 hours and transcripts total 325 pages.

Company	**Description**	**Interview**	**Interviewee**
Company 1	A global provider of **power systems** and **service** for use in civil aerospace, defence aerospace, marine and energy.	3	2 Operation Manager 2 Value Engineers
Company 2	The manufacturer of **ejection seats** and related equipments for the aviation industry.	1	1 Site Manager
Company 3	A European Furniture company, which has produced **universal shelving systems,** popular for its timeless design.	2	1 Managing Director 1 Head of Sustainability 1 Design Engineer
Company 4	Is one of the largest IT companies in the world and also is one of the world's leading innovators of **office equipment** technology.	1	1 Environmental Engineer 1 Operation Manager of company's recycling facility
Company 5	One of the world's largest **automobile manufacturers**.	1	1 European Environmental Manager
Company 6	A world leader in the design and manufacture of **industrial engines**.	1	1 Environmental Manager 1 Personal assistant to Environmental Manager
Company 7	The world's largest supplier of **CNC machines, Machines Centres and Manufacturing Systems**.	3	1 Health and Safety Engineer (ISO-coordinator) 1 Production Manager 1 Quality and Technical Support Manager
Company 8	A leader in the UK **corrugated sheet** industry. Has operated in the UK for over 30 years.	1	1 Safety, Health, Environment and Quality Manager
Company 9	The company is the UK's leading home and general **merchandise retailer.** Having two brands, which	2	1 Group Sustainability Manager 1 Packaging Development

	are the UK's leading brands, with large customer bases across the UK and Ireland. One of them has more than 60 years of market heritage and consumer awareness.		Engineer
Company 10	The company is one of the largest producers of **polythene film products** in the UK and European markets.	1	1 Operation Director

Table 4.1 Company description

4.2 Within Case Analysis

This section describes each company, explains their context in terms of sector and size and presents verbatim evidence structured by areas. The areas are taken from Research Questions and some emerged from data.

Areas that have been investigated in this study are:

I. Factors that catalyse to have strategies

Factors that catalyse a company to have strategies are the factors that motivate companies to have some form of Material Efficiency Strategies. Companies may not implement the full strategy but any part of Material Efficiency Strategies or similar is still regarded as a Material Efficiency strategy in this study.

II. Factors that influence the choice of strategies

Factors that lead to specific strategies are different than the factors that catalyse to have strategies. The former are factors that make companies decide to implement specific type of strategies.

III. Constraints

Constraints are the difficulties experienced by companies in the implementation of Material Efficiency strategies.

IV. Benefits

Benefits are things gained by companies when implementing Material Efficiency strategies.

V. Accelerators

Accelerators are factors that help speed the companies' Material Efficiency strategies implementation.

VI. Practices

Practices are tools, actions or strategies taken up by companies in employing Material Efficiency strategies.

In the evidence section below, Company 1 will be explained in detail compared to others. Verbatim data is presented under each area, with minimum interpretation. A selection of quotes is inserted to help describe clusters and to show evidence. At the end of each company, a review of the main observations is given.

4.2.1 Company 1

Company 1 is a global provider of power systems and service for use in civil aerospace, defence aerospace, marine and energy. Interview participant are two operations manager and two value engineer at two separate plants. One of the value engineer's job roles is material procurement.

4.2.1.1 Factors that catalyse to have strategies

The main concerns for Company 1 are regarding expensive materials which according to the interviewees relate to ***prices and material availability***. Prices of these expensive materials can get very high at very short notice, and thus will expose the company to commercial risks such as unavailable supplies, market fluctuation and very high price.

'Yes, it's getting expensive, but for certain elements there is not much of that element around so if we don't use it wisely there won't be enough of that material for what we probably need. So the availability of the materials may soon start driving the design of the engine. Whatever, the optimum design at the moment , in 10, 20 years maybe certain elements will be unavailable, so that may drive the engine's design.'(Value Engineer 1)

The next factor, which drives the company into having a strategy, is ***cost reduction***. Undeniably due to expensive material, cost reductions are needed to respond to this threat.

'.... the thing that makes it very, very important recently is that materials like nickel and cobalt have to be dug out of the ground. The price of those has gone very, very high. So what we're trying to do now is to minimise the amount of material we dig out of the ground which is environmentally good compared with all the material that we created and wasted in the processes. We then try to close loop back into the melting processes, so that instead of buying materials that are very expensive, we can get half of the reduced material that we buy actually reverted or waste that we collected ourselves. It

is the cost of our products, we are minimising our exposure to the effects of the elemental escalations that are very, very big in aerospace at the moment because all the elements are going up in price, dramatically.' (Value Engineer 1)

Other factors that catalyse the company to have a strategy are ***customer requirements***, ***legislation pressure***, the ***company's social awareness*** and ***reducing product weight***. The mixed factors of customer requirements, legislations pressure and company social awareness are among factors that make the company design products and processes that give less impact to the environment, such as reducing fuel consumption of the products, and green house effects. Reducing product weight is one way of responding to the above factors but can also be viewed as one of the factors that motivate Company 1 adopting sustainable strategies. Company 1 always strives to reduce product weight as the specification for the product dictates that light weight is better.

'Yes, within our company of course [product named], there is also hmmm...there is a big dependency on weight. So we are always looking at different materials to cut down the weight, but there again, we always see that as the weight of the material comes down, the cost goes up. We always strive to get lighter, stronger materials, as it helps with the efficiency of the engines. It cuts down fuel consumption, green house and all these things...' (Value Engineer 2)

4.2.1.2 Factors that influence the choice of strategies

The main factors driving Company 1 to adopt specific strategies are mainly ***price of materials*** and ***cost reduction***. Unsteady material supplies and high material prices both will increase costs for production, thus metal waste recovery is one of the ways to tackle cost.

'A.lot of it is to do with material cost and material availability as I said with titanium … hmm….some of this stuff...so again it is to do with the cost of material and again if we can get it in a form with less wastage we don't need so much of the material...so it's basically...the form it comes in and the amount of material we're going to use.' (Value Engineer 2)

Legislation no doubt will influence the type of strategies which the company chooses. There are several types of legislation and regulations affecting decisions made by Company 1. As for waste, there is legislation affecting them that makes them choose the type of strategies to have.

'The legislative…I can sense the level being reduced significantly over the last few years hmmm…and then the low cost in reality is recycling it against…because we were traditionally we throw the whole lot away and we had a serious contamination level with local authority and just did it, you used it you know until it got to in an appropriate

strength, and then you just dumped it or used to leave with us till less tracing fragrance and then dump it.' (Operation Manager 1)

Existing ***relationships with suppliers*** help influence the company's choices on types of strategies to adopt. A strong relationship with a material supplier gives an opportunity to revert back waste to the supplier, and promises that they will get a steady raw materials supply.

'I think the penny is dropping slowly that, the more we can do to get into partnership with this supplier, to do the best that we can to give them back what we don't use, it benefits them, and benefits us.' (Operation Manager 2)

Customer requirements, according to interviewees, sometimes constrain choices of strategies and sometimes influence the company into choosing strategies. Customer requirements on products cause the company to adopt or not to adopt specific strategies. One example is a customer request on reduced ***product weight***. This caused Company 1 to choose specific strategies such as light-weighting and materials substitution. Another example is, some customers requested specifically that the company must comply with ISO 14001.

'Yes…it's environmental. ISO 14001 is very big in [company] and the customers suppliers that we deal with.' (Value Engineer 2)

4.2.1.3 Constraints

For Company 1, ***design*** is the top constraint as the product has to achieve specification, with function as the first requirement, and at the same time the company is trying to reduce waste and environmental impacts. Failure to achieve this will compromise safety and people's lives. One of the products which Company 1 produces must withstand high temperature and high pressure but at the same time must be lightweight. For this, they have to do innovations all the time but innovation involves cost. They have constantly had to look for new materials that have new elements but usually are more expensive and harder to get hold of. Super materials not only expensive, innovation is harder when the customer keeps demanding a high power product with less weight and less cost.

'I can't see a way of reducing the amount the material that we take unless we start going close to size and make dramatic changes in[product] architecture. All we're trying to do is to recover amounts of material, save it going to waste as it were, keep it closed loop into our smelters. Look at ways of innovative design, which unfortunately take years and years to come along. We are always looking at ways we can be doing it better. Unfortunately, people are always demanding higher power for less weight… for lower cost, for lower emissions and that just demands that we work hard on our design process and it is harder to go for cheaper material.' (Value Engineer 1)

Based on same arguments as above, the interviewee expressed that ***cost*** is one of the obvious constraints to the company together with the design. Design and cost are related in preventing Company 1 from employing more sustainable strategies.

Measurement is difficult according to interviewees. Although the company has targets there is no clear evidence that measurement is carried out. The company has a recycling target which includes office housekeeping to minimise wastes such as paper.

'And while I am doing it the areas I was working in, nowhere had a hmm…recycle measure even just red or green that says we're doing recycle well or not. It is all about quality, cost, delivery, lead, time. So it is all about problem that goes that way, not this way …' (Operation Manager 2)

In segregation and metals recovery, there is a ***contamination*** problem caused by the swarf and fines recovered at low quality.

'We do have contamination issues anyway on the[component] because there are two titanium barrels bonded together, so there are certain bits of off cuts that can't go into that process but the machine swarf is all kept in six titanium barrels, poor quality barrels and it works very well, hmm…there is another barrel, those are the mixed ...hmmm to be fair same sort of thing we collect the titanium well from there, we don't do aluminium yet, we don't do it you know and hmm.. a bit of aluminium…'(Operation Manager 2)

As for ***undesignated manufacturing flow*** the problems arise when the machine is not dedicated to one material, segregation then depends solely on the priority of the employee at that time and their discipline. The same problems occur when segregating waste.

In terms of people, the ***employee's discipline*** gave problems in recovering waste efficiently.

'…and there is no discipline in places to do thorough segregation. The people, they said they would do it, but they didn't' (Operation Manager 1)

In response to Operation Manager 1 on the measurement problems, Operation Manager 2 linked the cause to the lack of ***communication*** on the matter.

'To be honest, I don't know if there is communication taking place but I can't imagine that communication is taking place but…hmm…we seem to be quite traditional in thinking that…you know "this is aerospace, we can't measure anything just go for, hmm no mixed swarf…'

Suppliers also become a constraint, as not all suppliers, especially overseas ones, are subjected to the same standard of practices.

"Not that I am aware of...I think they can…they can request…. but then we deal with companies not only within Great Britain, but companies around the world, where their environmental policies are not the same as ours, so I think they like to request that we do meet them…but I don't think it something that they can actually demand." (Value Engineer 2)

4.2.1.4 Benefits

Although there is was evidence of measurement given during the interview, the interviewees are aware that the strategies give a ***cost reduction*** benefit to the company.

'It is not so much the number that we saved, it is the number that we would have paid if we hadn't done it and we don't know how big the number will be, but we know it will be very big. So it has been a very successful strategy for [Company 1]. We know it is long way to go yet, but we know it has saved us a lot of money.' (Value Engineer 1)

This reduction in cost is achieved through getting a competitive ***material price*** by ***avoiding market fluctuation*** and ensuring ***materials availability***.

"In our industry, it is now probably one of the most important things, because the price of material has got so high. The two aspects to it are the environmental issues….of reducing the amount of waste products that we produce…things like that. That is one thing, that is legislation our company buys into…however the thing that is very, very important recently is that materials like nickel and cobalt have to be dug out off a ground. The price of those has gone very, very high. So what we are trying to do now is to minimise the amount of material we dig out of a ground which is environmentally good compared with all the material that we created and wasted in the processes. We then try to close loop back into melting processes, so that instead of buying materials that very expensive we can get half of reduced material that we buy actually reverted or waste that we collected ourselves. It is the cost of our products. We are minimising our exposure to the effects of the elemental escalations, that are very-very big in aerospace at the moment because all the elements are going up in price, dramatically.' (Value Engineer 1)

The other benefit is that the company is able to **reduce incoming and virgin materials** needed for production; this can be done by using recycling materials supplied by suppliers at a steady rate and cheaper price and by ordering close to size materials for production.

'… the chap in our organisation called John xxx. He purchases raw material and sells them back, the swarf and fines and stuff, recyclable. And he negotiates it up from a

purchase price based on a commitment to recycle so he gets money back from recycling but he also gets it up from a purchase price and he gets a better supply commitment when he is giving back a lot, taken back in again…'(Operation Manager 1)

4.2.1.5 Accelerators

When asked if a good ***relationship with a supplier*** can give a good advantage in terms of material supplies when there is a global shortage, the interviewee commented as below;

'*We probably would if we were more effective at living up to the commitment that we make to the supplier.' (Operation Manager 1)*

Another accelerator that helps the company with the strategies they choose is the ***company's social awareness.***

' Yes…within Company 1 of course, engines and aircraft, there is also hmm… there is a big dependency on weight. So they are always looking at different materials to cut down the weight…but again there is …we always see that as the weight of the material comes down, the cost goes up, so we always strive to get lighter, stronger materials. It helps with the efficiency of the engines. It cuts down fuel consumption, green house gas and all these…' (Value Engineer 2)

The existing ***ISO 14001*** implemented in the company can act as an accelerator that helps with the implementation, as the environmental awareness and systems are already there.

'Yeah...it's all about the ISO 14001 requirement.'(Value Engineer 2)

4.2.1.6 Practices

Among significant practices by Company 1 are:

<u>Design</u>

Fly to buy ratio - The fly to buy ratio is a method of expressing the finished part weight divided by the required material input weight, (i.e. the higher the 'fly to buy' ratio the better the material utilisation).

Material substitution - using materials that can be used for longer.

Environmentally friendly products - Company 1 is looking to produce products that have lower emission.

Manufacturing

Using non-toxic materials and processes - The Company tries not to use toxic materials and chemicals that harm the environment. For example they are now using a water-based cleaning agent.

Recover or recycling or re-use – The Company is doing closed looping on metal waste. Metal swarf is collected from machining operations and sold to metal smelters for a nominal fee. The smelters then process the swarf and sell it back to the company at a lesser cost compared to virgin titanium material. This strategy is called *'revert strategy'* in the company, which can involve re-organising flow lines.

Sourcing

Close to size - Buy materials that are close to the size of the part that needs machining to reduce materials waste.

Close relationship with suppliers - The Company tries to build close a relationship with their metals suppliers by committing to suppliers to provide them with recycled swarf, chips and fines through initiative called "*revert strategy*".

ISO 14001 standards - The Company comply with ISO 14001 and expect their suppliers also to comply with the standard.

Business and services

Leasing and components/material servicing - The company owns the products and rents it to customers. The service is provided by supplying customers the product, and then company is responsible for making sure the product is working to the expected performance. During maintenance, the company will replace the part without having to strip down the whole product after which the parts are then taken back and refurbished. The key feature of the service is that it undertakes to provide the customer with a fixed engine maintenance cost over an extended period of time. Customers are assured of an accurate cost projection and avoid the costs associated with unscheduled maintenance actions.

4.2.1.7 Case summary for Company 1

In Company 1, the prior aim of having some Material Efficiency strategies is due to the company using expensive materials such as titanium. Material Efficiency strategies started being taken more seriously in Company 1 when the company realised some materials they need are getting difficult to get hold of and the price can be very expensive due to market fluctuations. There are several similar factors that made the company decide to have Material Efficiency strategies and that influences the types of

strategies chosen. Among them are price of materials, material availability, cost reduction, customer requirements, legislation and relationships with suppliers.

The problems for implementing Material Efficiency strategies at the design stage are to balance product design and customer specifications, which would affect safety and performance.

Manufacturing constraints are manufacturing flow, employee discipline, recyclability and suppliers.

Benefits resulting from implementing Material Efficiency strategies are avoiding market fluctuations, reduced cost and material supplies at a cheaper price.

The strategies and tactics chosen are in response to an expensive material price and availability threats. In manufacturing, among the top strategies practiced by the company is by having a close relationship with suppliers to maintain a steady supply of scarce materials, through doing waste segregation, reverting and recycling back waste material to suppliers. In design, the company is striving to substitute material and design products that produce less emission. In service to customer, the company offers choices on service-oriented products.

4.2.2 Company 2

Company 2 is a manufacturer of ejection seats and related equipment for the aviation industry in the UK and abroad. Environmental objectives and targets have been established and are regularly updated as part of continuous environmental improvement. A priority objective is the reduction and management of waste through better utilisation of raw materials, energy resources and water supplies, as well as minimising waste at source, and employing re-use or recycling techniques. Evidences below were given by the Site Manager.

4.2.2.1 Factors that catalyse to have strategies

Employee awareness and suggestions are among the main reasons for company 2 in deciding to have a Material Efficiency strategy. In fact, it was the earliest factor that triggered the decision.

'The motive at the very beginning was driven by frustration within the employees. The employees were seeing something there that could be made proper use of and we the management had turned the blind eye to it.'

Proactive and innovative management is one of the factors that leads the company to take Material Efficiency seriously. Awareness and efforts at the management level contribute to seriousness in implementing a Material Efficiency strategy. According to

the interviewee, the management are open to the suggestions and constantly checking the progress of any strategies they decide on.

'And whenever I go to spend something they said "what is this part of?" and they want to tick it off to see whether that processes is going in the right direction.'

Management personnel for example with power to influence change are proactive and always looking for ways to improve the process and minimise waste.

'So we are looking at set-up time, reducing set-up, in fact one of John's favourite was SMED. He loves working on presses and in a Single Minute Exchange of Dice, he kept saying to us all " I am thinking about reducing set-up time, thinking about taking a set-up out all together", so you have got all the tools in the machine, you could present the material out of machine, the machine has got a big enough merit…'

According to the interviewee, the company has very strong principles on ***Social responsibility.***

'John and Jim refer to the local stakeholder, not necessarily the stakeholders who part own the company, but they have an impact on the company. And we were tempted to take care of them. One of the policies that they have is they attempt not to subcontract outside of a 60 miles radius of the factory.'

Cost reduction is among the main reasons for the company to take up the strategy. Company 2 is aware that wastage can increase production cost and cost on handling waste itself. By separating and protecting their waste from weather, they get a better price from the recycler.

'Absolutely…absolutely. Yes we said to them that we must protect our material from the weather. We want all of our material containers to have tops so the weather doesn't go inside the skips. They must be interested in that, because as far as they were concerned, if they collected contaminated materials, they may give you reduced prices. It was very selfish basically and Ampthill was the most proactive. Ampthill said "sure we will put tops on them, we will protect it, we will get good materials, we get top dollar and you get top dollar!'

Company's culture is one of the factors that caused the company to implement a Material Efficiency strategy. Company 2 is a small family business.

'It was a family as well. Family ….hmmm when Deming…hmm…the culture of delighting the customer and the family decided they wanted to reduce delivery times the ….the…manufacturing processes. And it was the family that encouraged us all to look at our various different processes in the push field.'

Time is costly, thus ***saving time*** is among the aims that the company wants to achieve when implementing a Material Efficiency strategy.

'Yes. We have set a standard now and that standard gives you uses…you know…we make seats and have an actual survival pack which deploys out of it. The guy can take it over to final assembly and actually pack all the articles inside it and then they can say "right if you take out that reading like corner we can get an extra article packed away inside that" and they may produce another one overnight..'

Without ***management awareness*** it is almost impossible for the company to decide to have a Material Efficiency strategy. Company 2 is motivated to have a Material Efficiency strategy as the awareness and knowledge shown by management on the matters is very high.

'We realised that 14001 and its environmental management system is going to be the right thing for this site back in the early 90's. And the health and safety advisor and myself have been working for 4 years putting things together for this complete system in here. But all the green folders are part of ISO 14001 systems and hmmm pretty realised…'

Similar to Company 1, the ***customer requirements*** is again one of the factors that pushed the company to have strategies.

Health problems are the reason for the company to implement a coolant management system.

'When we first looked at coolant, we realised that we were spending 7-8 hours per month cleaning the machines out and putting the fresh coolant in. 7-8 hours of lost time per month on each individual machines and cleaning them out, changing the coolant, then you have the problems of course disposing the coolants which were costing us a small fortune to get rid of . We then realised, as it got closer and closer to the end of the month with that coolant getting dirtier and dirtier, you got more and more problems with people on their hand with dermatitis. As the coolant got dirtier the dermatitis problems got worse. We looked at the system's log and the systems log shows us that at the beginning of month with cleaner coolant incidents were very few and as it gradually got towards at the end of the month, dermatitis, cracked hands and that sort of thing steadily increased.'

4.2.2.2 Factors that influence the choice of strategies

Having a ***proactive and innovative management,*** makes a company choose specific strategies. Management in Company 2 are proactive in finding the best ways for the company to reduce waste and materials usage.

'We have been told first thing this morning that John has signed documentation for us to go water-based….so taking out the other aspects to its as well, which is good news, very good news…So that they are….very, very active. I am here most mornings at five to seven and don't leave till gone five at night. They are here before me and still here when I go'

As evidenced in Company 2, ***employee awareness and suggestions*** lead to specific strategies.

'We found out how many people were on site, all the way around the site including the tool room inspection, finishing, everybody. And we got them all in the canteen, and said "What we are looking at is the processes, what can we do?" And it was not a professor and it was not a lecturer that came up with the ideas. It was the guy on the machine that came up with the ideas and we put the process together.'

A ***company's social responsibility*** is one of the factors that make a company choose to source locally rather than source globally. Companies refer to this strategy as localisation.

'John and Jim refer to the local stakeholder. These are not necessarily stakeholders who own the company, but they have an impact on the company. And we were tempted to take care of them. One of the policies that they have is they attempt not to subcontract outside of a 60 miles radius of the factory.

Advanced technology can reduce waste of time and materials which in turn reduces cost.

'Without it going anywhere nears any person who is using it, and that's saved a huge amount of time in our machine and of course, a lot of materials.'

Saving time is one factor that is associated with cost, thus anything that contributes to cost is a factor that comes into consideration.

'Not waste any machine time either which is valued at £120 per hour.'

As with in the Company 1, ***cost reduction*** and ***customer requirements*** are among the factors that influenced Company 2 to choose which types of strategies to adopt.

Management awareness which is shown by management understanding and knowledge on waste and materials usage problems and opportunities also helps influence the types of strategies the company chooses.

'I think it is because we have already started building systems, we have already decided to commit ourselves to going down a specific route…hmmm…It has something that has been…I believe in the philosophy that employees are the frontiers of knowledge.

Because you're the manager, it is doesn't mean to say you've got all the answers, employees have got it, and that's what we do; we start to use employees. The employees make suggestions, we modify them and we push them forward. And that's the way it grew. It was not driven by management,. The management encouraged them to speak, when they realised the potential of it. There are a lot of things that occurred, things like collecting together items for recycling rather than them going to the waste stream…that are now being donated to local schools, now being donated to charity and things, it is like that. So it is not from the companies' point of view a money- making issue…'

An ***Innovative agent or supplier*** is the factor that influences the company decision. Innovative suppliers are open to any suggestions and requests from the company, and also give suggestions to improve Material Efficiency in the customer's company.

'Yes we said to them that we must protect our material from the weather. We want all of our material containers to have tops so the weather doesn't go inside them…. They must be interested in that, because as far as they are concerned, if they collect contaminated materials, they may give you reduced prices. It was very selfish basically and Ampthill was the most proactive. Ampthill said "sure we will put tops on them, we will protect it, we will get good materials, we get top dollar and you get top dollar!"

Health problems other than acting as a motivator to the company to implement a Material Efficiency strategy such as coolant management also help decide the type of strategies.

4.2.2.3 Constraints

The company's management is trying to achieve some strategies through designing. These efforts are, however, limited by the ***customer specification***. The customer specification includes safety performance of the product which is crucial in this type of industry.

'It is very difficult when you have a customer that keeps specifying that they want high grade this and high grades that but in a lot of circumstances the head of design who is John and the chief technician who is Robert, his son, are continuing to look at materials to... I walking into their offices last week and they were looking at different types of flexes for a different type of harnesses?'

Through manufacturing processes the company is constantly trying to reduce machining waste. One way of doing that is by ordering close-to-size multi-shaped materials. However this order sometimes discourages an ***uncooperative supplier.***

'….within that we realised…that we are buying a multitude of material of all different shapes and sizes. The production engineering department have said if you want to make

a 2 inch square block the best material to buy would 2 inches and one six tenths all they way round and just skin it off. So therefore, all of these different blocks that we wanted to make, we started to order in a multitude of different types of materials. We had hundreds of them and of course we were going to the mill and saying "we want two and a sixteenth square bar two foot long just for our short quantities" and they were laughing and putting us on the backburner and saying "we will deliver it to you in 4 months time".'

4.2.2.4 Benefits

Similarly to Company 1, ***cost reduction*** is the obvious benefit to Company 2. The company also discovered that they are ***making money*** if they really segregate their waste carefully. Other than reducing cost and making money, the company found that the other main benefits are ***minimised waste, minimised time*** waste and also ***morale building***. According to the interviewee, in relation to time:

'Not waste any machine time either which is valued at £120 per hour.'

On **Morale building** the interviewee found that less waste of time, effort and materials can help with morale and motivation of the employees.

'The other important thing I found with this is the morale. If you're on the machine, and you're putting something like that up on machine and taking 30 or more tools and is taking you 5-6 hours to set up the machine and you produce that at the end of your shift and someone comes along and chucks it into the bin afterwards, that is so demoralising. But if you don't see that on your machine until they've got a drawing and are already produced and that's morale building. There is nothing more frustrating than to produce what that you think is a good component but then following day someone comes down and says to you "can you do it all over again because we changed the radius (sigh)".'

4.2.2.5 Accelerators

Proactive and Innovative Management is one of the company's biggest factors that push the company to adopt a Material Efficiency strategy. The company management recruit employees specifically to tackle waste in the manufacturing processes.

'Yes…That's was John [xxxx] in fact, he head-hunted him. He heard that he had a really good reputation for rationalisation of material, rationalisation of processes, and John head-hunted him and brought into the company, specifically for that reason because John is very keen on reducing the operations that are an ally to the semi processes and different things like that. Hmmm he even looked at the quantitative tools that the guy is using in the shop and attempted to eliminate the movement between stores and operations.'

Management awareness **and knowledge** indeed can be viewed as an accelerator. Knowledge is a valuable resource as management knowledge can help the company with the choosing process of the Material Efficiency, its implementation and its constraints.

'I believe in the philosophy that employees are the frontiers of knowledge. Because you're the manager, it doesn't mean to say you've got all the answers. Employees have got it, and that's what we do; we start to using employees. The employees make suggestions, we modify then and we push them forward. And that's the way it grew. It was not driven by management, the management encouraged them to speak, when they realised the potential of it.'

Available technology is among the accelerators. By advanced tools and technology such as using prototype machines, the company reduces materials waste and time wasted on designing products.

'Ohhh….without any doubt absolutely, looking at cutting technology allied to some of these machine and knowing that a cutter will last for several hours but then telling the machine that it will only last for 6 hours, grind it for 10 hours and put it into the machine and compensate again. We are getting cutters to last 7 times more than normal life. Whereas before we were putting it into the machine, telling the machine that it will last for 7 hours and throwing it away afterwards. Look at the cutter saving that you get from that…'

Innovative agents or suppliers also can be an accelerator to the Material Efficiency implementation as they can support implementation and give guidance and tips.

'And that was the company called Ampthill Metal Company AMC. They came in and helped us to set up the systems. They came in and helped us to talk to employees. It is very rare for us for an outside company to come in and want to get involved with the employees and help us research the different materials that we are using because at the time when we first started looking at it, we found that brass was considered the most important material, the most saleable material and all the rest of it was considered to be rubbish and it was dumped in one pit and taken away. We got nothing for it. Since then, we worked with Ampthill, we worked out the system where everything is put on specific brackets, we identify 9 themes different types of wastes streams and those go even down to the carbide tips of the machine they collect and put into the bin. Once the bin gets to a specific weight they take it away, things like copper electrodes from welders, scraps from the tool room, scraps from the finishing processes.'

Government agency assistance is one factor that helped the company with Material Efficiency implementation.

'We had been using Envirowise to assess our electricity consumption. Hmmm we were looking at how could we reduce our annual energy expenditure and the person who came in was an advisor to Envirowise and saw what we are doing with Andy the swarf management and coolant management and he went back to Envirowise and said I think there is an ideal case study there for you to produce and encourage other people to follow the same route, and they came down and took a whole series of pictures of the situation.'

Good ***communication with employees*** helps the company know what are the suggestions and complaints from employees. The employees can communicate their ideas in this context, how to reduce waste and materials to the company's management.

'Yes, the thing that I did was hmm…because I am an old timer here….I went round to meet the employees and started talking to them and said "look, okay what would you like to do? If there is something that we can do around the factory, what you like us to do?'

Company's culture such as less hierarchy in communication, good teamwork, and a sense of belonging are among the factors that helps speed the implementation of Material Efficiency strategies.

'Yes it is part of family culture….If It's makes senses ….let's do it…you don't have to have a committee to agree…you know.'

In the same way as Company 1, Company 2 is building a ***close relationship with a supplier***, in this case the recycler. This particular recycler is proactive and comes to the company to assist the company to produce purer and high quality metal wastes.

4.2.2.6 Practices

Among significant practices by Company 2 are:

Design

Design out toxic processes - The Company has taken out and still continues to take out many environmentally unfriendly chemicals from the processes.

Minimise waste **-** Other than minimising material usage the company also always finds ways to minimise waste, either from resources recovery or by trying to prevent the waste being produced in the first place. An example of this practice is using a stereolithography machine to do prototypes. This according to the interviewee saves a lot of time and reduces the amount of waste.

Manufacturing

Maximise materials usage during machining - The Company always finds ways not to waste materials. In manufacturing processes, the company tries to maximise the use of materials. One of the examples is that the company is always trying to use close to size materials such as using standard billets to produce multitudes of different parts.

Recover or recycling or re-use - The Company segregates and sells metal swarf to a recycler. The company uses a simple system to separate coolant from swarf. This is done by tipping the skips at an angle before the metal contractor comes in to collect. A pipe is slid down the square tube and sucks the coolant out. This makes the swarf coolant free and the company is paid higher prices by the recycler.

Material's identification and segregation - The company groups and names different types of metal waste and swarf into 18 groups. This is to make sure segregation is efficiently done and there is less contamination of the swarf because high quality swarf sells at a better price. The other benefit of easy identification of the metal waste is making it easier for employees to do their job.

Centralised metal-working fluid recycling systems - Using these centralised systems removes coolant from machines, cleans and returns it to the machines on a continuous basis. Problems such as waste of time and coolant fluid have been eliminated. Previously one of the problems identified was that machines were cleaned every six to eight weeks, taking four to twelve hours each, with the old machine coolant being transported off-site for disposal. This not only wasted the coolant, and added cost for safe disposal, and also brought a stop to manufacturing for significant periods of time. The employees also complained that they had skin problems due to dirty coolant.

Sourcing

Localisation - The Company's policy is to try not to subcontract outside of a 60 miles radius of the factory.

Business/services

Create a culture of belonging - It is a family company which is taking care its employees, their health, welfare and suggestions. The company is committed to improve its environmental practices. The company is monitoring surrounding area by checking its wildlife sightings each year and has provided a natural woodland area for employees to be able to relax and enjoy their lunch break.

4.2.2.7 Case summary for Company 2

Company 2 is a small-medium family-owned company. For Company 2, employee awareness, frustration and suggestions are viewed as one the main factors that made the company start to deal with waste problems. This is helped by having management with proactive and innovative attitudes. The positive attitude and employee awareness and suggestions is bridged by the good communication that is practiced by the company. Cost reduction is just another factor influencing the company decision on implementing any Material strategies but is also viewed as a benefit from the implementation of Material Efficiency strategies. The strategies are realised by the company employing many tactics such as using a stereolithography machine and other available tools and technology. The company is not only using advanced technological tools and equipment but uses simple tactics and innovation to achieve the aim of reducing waste and material in use. According to the interviewee, constraints experienced by the company are few. These are customer specifications and an uncooperative supplier. Benefits gained by the company are cost reduction, reduced material and reduced time and an increase in employee morale. Among important accelerators are the proactive and innovative management style, management awareness, available technology, supplier's help and government help. Among the strategies practiced by the company are a lot of segregation, improving manufacturing process, product design and sourcing locally. The company prefers to use simple solutions if available to solve waste and efficiency problems before resorting to the higher technology solutions.

4.2.3 Company 3

Company 3 is one of the largest providers of office equipment technology. The company actively imbedded the culture of reduce, reuse and recycle to materialise the concept they introduced for realising the society that re-circulates resources. Recycling is a last resort and the company claimed that only around one per cent of its products is recycled, the rest is reconditioned and reused and its final end-of-life date postponed indefinitely. For this company, only waste on products was investigated during the interview as the plant visited is the company's recycling facility, thus waste and materials at the manufacturing facility are not covered.

4.2.3.1 Factors that catalyse to have strategies

Cost is among the main factor that encourages Company 3 to employ Material Efficiency strategies. Having recycling, material recovery, reusing parts and refurbishing machines and offering a solution service instead of bulky materials according to the interviewee will subsidise the cost of new products. Reduced cost will eventually help the company become more competitive. Being competitive is one aim of practicing Material Efficiency strategies.

'If we manufacture products using the usual materials and we have now a waste strategy in place for material recovery, effectively we could still produce a good product, and we still perform well, the problem is, it will cost so much money for the customer to buy. Because we reuse parts and we recycle parts and we recover material costs, that money subsidises the cost of new products and that's how... you know, the more recycling you do the more profitable it is for you. Because obviously you save your manufacturing cost but you also become more competitive.' (Environmental Manager)

As the parent company to Company 3 is a Japanese company, ***Japanese management culture*** has a big influence in the company. The company's environmental perspective is no exception. Green culture in the company started long ago before pressure from legislation arose. As mentioned by interviewees, the company was being proactive long ago, without pressure from legislation and the influences are from its Japanese roots.

'And I believe, I honestly believe regardless of the government legislation, it is The Company which is still setting standards." (Operation Manager). This is added by another interviewee … *"The point is the reason we do that is the same reason why we became the market leader because we recognize that people want to use environmentally friendly products and need to deal with companies that take the bigger view rather than just make a sum of money. So a Japanese company is quite good at that.' (Environmental Manager)*

The need to have strategies that support the ***sustainability culture*** is one of the factors that make company 3 practice Material Efficiency strategies**.**

'It is not, it's purely we believe that we need a sustainability culture and probably if you look at the Japanese as a race, so I'm separating out the nationality here...' (Operation Manager)

Not only do Japanese management principles give a big influence to company thinking, but the company's ***lean practices*** are also one major factor that made company practice Material Efficiency strategies.

'Yes, yes because really..... I have found from the European point of view that all of these processes are overlapped, it's like Just in time; Just in time 15 years ago was a buzzword, now if I have a large inventory because I'm not just in time, that large inventory passes as form of waste and the cost of storing that is Muda; is waste. So within lean manufacturing it is a similar sort of thing, so all of these things are overlapped, and you pick the one thing that perhaps you are focusing on at a particular time.' (Operation Manager)

4.2.3.2 Factors that influence the choice of strategies

To reduce operation and product ***cost*** through materials recovery and waste reduction is one of the top factors that influence the company decision in choosing the types of strategies to have. Based on evidence, material cost is one of the main reasons Company 3 does material recovery.

Choices of Material Efficiency practices by Company 3 are no doubt influenced heavily by its ***Japanese management culture***.

'So you know for us the challenge is, the Company and the CEO would not turn around and say "We'll go and improve yourselves environmentally", he will say "Go and improve yourself environmentally but make it so that you do not spend money unnecessarily to reach that objective". Now the first address would be to reach environmental targets without spending any money, so from a business point of view the pressure is on us. We have to deliver, but it's no good saying that I'm going out and buying this facility because that will help me process this, it might add £50 to the price of the copier. So although we are doing good for the environment, we won't get away with that. We will have to try achieve our objective economically but still consider the environment.' (Operation Manager)

Having a ***lean system*** is one factor that makes the company choose specific strategies. For example, the waste elimination strategy suits their lean system according to the operation manager.

'….In this instance; our biggest initiative in the last year has been an elimination of Muda; and Muda is waste. And of course when you first hear the terminology you'd think "Oh I am dealing with waste, I am controlling the waste" But it's not just the waste that goes through out the door, it is the waste in the process and that can be every single process from administration, or the receipt, processing the order through the manufacturing cycle, through any cycle that you have.' (Operation Manager)

Short product life span and ***quick technological changes*** are both the nature of types of products and services offered which are the most significant constraints. This results in the company having to design products that can respond well to this kind of constraint in order to reduce waste and costs.

'We.... the culture of the sales activity has usually been leasing for the last 20 years or so. Initially the people purchased the product; the focus is on selling the product outright, the reason we are into leasing and rental is that it is part of our normal corporate strategy now. It's because, the life.... the average life of the machine in each stage is between two and three years because of technology and changes. Because products coming out now are more than previous products and the customer is driving that as well as the environment and design, people won't commit to spending a capital

sum and buying equipment which in two years time they have to change. So leasing is the preferred option because that way their leasing can carry on.' (Environmental Manager)

The company's social awareness also influences the company decision on the types of strategies, for example, the company's decision on producing environmentally friendlier products.

'The point is that the reason we do that is the reason why we became the market leader, because we recognize that people want to use environmentally friendly products and need to deal with companies that take the bigger view rather than just making a sum of money. So a Japanese company is quite good at that.' (Environmental Manager)

4.2.3.3 Constraints

The product's short life span due to ***quick technological changes*** is the constraint that is experienced by the company, so the strategies they choose should respond well to both factors. The strategy they choose for example is to prolong service life by updating the machine with new parts and software rather than making the machine last longer.

'Photocopiers and office equipment generally is like everything these days, in a year's time it could be out of date. So they could not charge hundreds of pounds for that, because in a year's time you would need to change it, you need to upgrade technology, you need something that.... I don't know… do something else.' (Environmental Manager)

4.2.3.4 Benefits

Minimising persistent waste is the main benefit achieved by Company 3 from practicing Material Efficiency strategies.

'If you look at, hmmm effectively... this here, can be a combination of machines and parts, so for every machine the only aspect of general waste that goes for incineration which is not reused is one as the percentage of that the other. So what you have got, if you have got less than half a ton against 380 tons, as a rough figure, although I can't give you it machine by machine, I can say to you, we are the only facility in the United Kingdom which disposes of machines and equipment and therefore if this is the level of control that we have with our waste, this will be typical of the input and the output in terms of material, and we are left you know with the ratio of the page of half of ton to 380 which obviously is very-very small.' (Operation Manager)

By actively practicing and striving with Material Efficiency and sustainability strategies, Company 3 is always ***complying with any environmental regulation*** but is also always one ***step ahead of any legislation***.

'To give you an idea, that ROSH legislation that came in July last year had a list of six substances which manufactures of electrical products have to take care off. The company is working on their own list of 13 products, 13 substances. So they are all removed in addition. So we are ahead of legislation. So that's another reason why hazardous waste is not a feature of our products.'(Operation Manager)

Similar to most companies investigated, the benefits found by this company are ***reduced cost*** and ***Minimising incoming materials.***

'We have to have a certificate of conformity that ROSH is part of the standard purchasing contract. And we will work with our material suppliers and our designers and our… you know component suppliers to try to minimise a) material b) costs within the products they supply.' (Operation Manager)

Another benefit that is evident from the Material Efficiency and related strategies implementation is ***reduced emissions***.

'In terms of CO2 impact or greenhouse gases impact the biggest section is what we call the end use section, you know the manufacturing, so there is improvement in how we make things and the toner is one of those.' (Environmental Manager)

4.2.3.5 Accelerators

Having ***environmental objectives and targets*** helps the company not only achieve its environmental goals abut also helps the company implement Materials Efficiency strategies.

'I think the company sets new standards every single year. If you read it, this is not just rhetoric; if you read all of these (showing reports) you will see that the company works not on the basis of designing the products and then making sure that it meets all current legislations. The biggest factor within all of our, we have what we call a mid-term plan. In every three years Japan issues a (inaudible) year plan and a key element of that is continuous improvement, kaizen. People call it kaizen but it's continuous improvement and we have year on year to show an improvement in quality, in effecting products so that they meet the environment in which they are being used, but the message is that it's sustainability ongoing.' (Operation Manager)

Having a ***fixed Environment Strategy cascaded down*** is helping the company in carrying out Material Efficiency strategies as it is clear communication for employees and also acts as a target for the company to aim to achieve.

'We do publish them from the environmental point of view. We do have separate business strategies and policies from head office in Japan. And each year we have environment and sustainability reports that are issued and that really outline all the

environmental issues that take place. Your comment about what business strategies we have: we have a firmly fixed business strategy which covers the environment and each year that is cascaded down through each of the organisations, in Tom's case in the sales side. For the manufacturing side, and we often have certain objectives to meet on the environment hmmm we could kick off there because Tom mentioned the fact this morning to me about helping our report on the issue this year and that certainly will give you a flavour of our business strategy in the approach to the environment.' (Operation Manager).

Japanese cultural influence and ***Lean practice*** are both significant factors that help accelerate implementation of Material Efficiency strategies. Having Japanese culture influence management and lean practices widely within the company, solid waste and materials inefficiency is just another form of waste to be tackled which are not a big problems to Company 3.

'So lean manufacturing, Quality Circles, cellular manufacturing, Kaizen and every single current technique that you look at and see, the company has either adopted or used as part of their culture. And culture is the thing, it isn't just a bolt-on system that you say "okay , this month we going to look at these and do these". The company insists that it is imbedded in the culture of the organisation...' (Operation Manager)

Company decisions to ***invest heavily in Research and Development on the environment*** give benefits to the company and help supply the company with knowledge and solutions on how to implement strategies successfully.

'We are also the market leader in what we do in almost every country in the world, particularly in Japan which is a massive market, and certainly in Europe and definitely in the UK. As a consequence we have a lot of money that goes back into research and development of the product but we equally put a large amount of money into the environmental activities; recycling and obviously all the stuff we have been talking about such as life cycle design so it is not just coming out with the product that will have more features in the future than other competitors, it's a question of putting money and how we can build the products to be environmentally friendly, and that would extend from the use of the right materials from the right suppliers through to the methods we use to make products and also a very importantly because you saw from other chart, talking about this one here.' (Environmental Manager)

Other than research and development, the company even put ***one person in charge of legislation.*** Having people specialised in the legislation is considered as a resource and an advantage. This helps accelerate Material Efficiency implementation.

'"We are.... part of our European headquarters in Amsterdam, we have one of the gentlemen there who is in the environment office and whose only function is to be

involved in the EU Parliament in Brussels. So he will lobby and discuss legislation coming out in every country. When we manufacture our products, or when we design our products they are designed to meet all requirements worldwide because our business is worldwide. So even if there is legislation in the UK but not in the America it's still made to conform to UK legislation and also in America. So we meet all manufacturing standards. There are some recognized standards measuring environmental efficiency such as Blue Angel in Germany and Nordic swan in Scandinavians countries. So we have a.... In fact we exceed all the minimum standards, that's the easiest way to say it. We are way in advance of much of any legislation coming true, like RoSH legislation and the WEEE directive.' (Environmental Manager)

4.2.3.6 Practices

The company has implemented many strategies and tactics to reduce waste and minimise use of materials. Below is a list of several tactics practiced by Company 3.

Design

- Design for Environment
- Design out hazardous waste
- Look at entire life cycle
- Environmentally benign materials-*"Using plant based materials in products rather than oil"*
- Produce materials and energy efficient products
- Product design
- Life Cycle Analysis tools (LCA)

Manufacturing

- Incoming material specifications check
- Lean production
- Recycle, Reuse, Refurbish, Recovery
- Minimise persistent waste through waste recovery
- Sourcing
- Influence suppliers
- Preferred suppliers - *"…the criteria for being preferred suppliers is that you use recycle materials or you have environmentally friendly processes in place."*
- Minimise materials during purchasing
- Educate and share knowledge with suppliers
- Waste as other people's resources

Business and services

- Listen to customers

- Influence customers on decisions
- Invest in the environment
- Environmental objectives and targets
- Audit waste trail
- Waste as other people's resources
- Zero landfill
- Customer selects solutions
- One person in charge of legislation
- Fixed environment strategy cascaded down
- One step ahead of any legislation
- Try to comply with all regulations/standards everywhere in the world
- Use statistics
- Take back programme
- Complying to the End of Life directive.
- Zero landfill

4.2.3.7 Case summary for Company 3

This company offers solutions or service-oriented products. The materials used to make a product are from advanced mixed materials which includes a lot of plastics. The factors that caused the company to implement Material Efficiency and select the type of strategies and tactics are cost reduction, Japanese management culture and lean practices. Quick technological changes and product short life span also affect the type of strategies adopted and its implementation. Top benefits claimed by the company are minimised persistent waste, staying ahead of any environmental legislation, and cost related benefits. The important accelerators for Company 3 are good communication within the company's environmental objective and targets, and fixed strategy cascaded down. Japanese management culture influence and lean practices are also identified as significant accelerators in implementing Material Efficiency strategies. Company 3 adopts many strategies and tactics that are practiced widely in the company through sourcing, designing, manufacturing and services. Having mixed materials products does not seem to be a setback for the company, as the company always finds ways to improve Material Efficiency, Resource Efficiency, waste and toxic reduction.

4.2.4 Company 4

A European furniture company producing universal shelving systems aiming to supply furniture that allows customers to live intelligently and responsibly by buying less, but of a better quality, and making it last longer.

4.2.4.1 Factors that catalyse to have strategies

Company 4 uses ***common sense*** when choosing strategies. When asked 'what is the main reason for having Material Efficiency strategies', all interviewees said that it is common sense to have them.

'It just stuff that we believe in. I think what seemed common sense to us.' (Design Engineer)

Employee skill and understanding versus paper qualification is one important factor that influences the company to have a Material Efficiency strategy. Employees in Company 4 are selected based on their learning ability and understanding of business rather than based on qualification. The company would rather employ people who have less relevant qualifications as long they understand the business. Based on the interviews, it is evident that the correct profile of employees can lead to awareness of implementing Material Efficiency strategies.

'I got a degree in sculpture and I think it is the best; I won't change that for anything. It's taught me to look like that, and I mean you had to always have so many people telling you "What are you going to do without degree?", but to me, a sculpture degree is about problem solving, and that's what I've taken away from it. I and think that the most valuable thing that you can learn in life, is problem solving.' (Head of Sustainability)

In recruiting the right employees the company management takes time, as evident from the Managing Director saying '…..*you see the link to our recruitment policy because we take the time, we speak to people on the phone. Sometimes it is nice when you speak to them first and then they come to interview, they will have trial day, they will have a trial period, they may have an extended trial period and at the end of that we still might kick them out. So it might be six months from beginning to end and then although we are a small business with limited resources we will still sit here and go "is not the right person, off the bus" and we kick them out so we have taken the time.' (Head of Sustainability)*

As the result of tight employee selection, the company has ***self-empowered and highly disciplined employees***. The company imposes few rules and gives employees freedom in doing their job. That makes the employee become proactive and creative in proposing and performing Material Efficiency strategies.

'What we're all about in this business is measuring output, is people getting on and doing their jobs efficiently and intelligently. And that is much more expected around here.' (Managing Director)

Company and employee awareness is one of the factors that make the company have a Material Efficiency strategy. When it was suggested that legislation and customer pressure are among the reasons that make the company engage in Material Efficiency, the company's managing director's response was *'No, none of those'* and company's staff was *'It is all driven by us' (Head of Sustainability)* and *'It just stuff that we believe in, I think what seemed common sense to us.' (Design Engineer)*

Another contributing is ***customer awareness***. Customers are aware that Company 4 offers quality and longer-life products. The company's customers know that having their products means having them for as long as possible regardless of current trends.

4.2.4.2 Factors that influence the choice of strategies

Employee skill and understanding versus paper qualification are among the important factors that influence the company in choosing the types of strategies to implement. Having quality and creative employees, who understand the business and processes, influences the choice of strategies practiced by the company. Many strategies implemented by the company are innovative, small and low cost such as material reduction in packaging.

'So it might been six months from beginning to end and then a small business with limited resources we will still sit here and go "is not a right person, off the bus" and we kick them out so we have taken a time. And then as decided through that round take the time ohhh where else we and i want to go off a long track that you can start apply that taking the time to an awful lot of what we do in our business and therefore what we now doing is taking that to the cookery writers and the fashion writers that company as a business takes time. So hang on, you as a furniture business you going after the cookery writers and the fashion writers to tell them that you a furniture company takes time. What that's all about. To us it is makes sense but to all other people looking from the outside the (inaudible) stark staring bonkers. And we might be is that relevant to what you are doing?' (Managing Director)

Due to employee selection based on their understanding and good grasp of the business the company gives employees greater freedom. So ***employee self-empowerment and discipline*** are factors that also influence the types of strategies chosen by the company. Giving freedom and flexibility to employees in performing their work is a company virtue. This in turn results in employees looking for ways to reduce waste through suggestions and innovations. Employees are self-empowered and self-disciplined in carrying out tasks. In terms of discipline in budget spending, one of the staff said;

'In the five and a half years that I've been here, I've never had a budget for anything, including this building, I've spent quite a lot of money on tools and all sorts of things: New ways of manufacturing things. I've spent a lot of money, but I've never had a

single budget for any of it. If we use a term at all, we use the word cost-effective. If there's a reason to buy something that's going to bring more efficiency in the workshop, then I will do it. If it's anything above a certain amount of money, which I think is a little bit scary, then I'll ask my Managing Director.' (Design Engineering)

'On working time, the interviewee response was "They come in at whatever time they want to in the morning and they go when they're finished. One of them starts early and leaves early, and they're all happy.' (Design Engineer)

Company 4 is using ***common sense*** when deciding to select the type of Material Efficiency strategies to use. When shown a list of strategies available in literature, the Design Engineer emphasised common sense as the important factor in decision-making. Commenting on carbon offsetting:

'Well, it completely lacks common sense doesn't it, you know, this whole carbon offsetting.' (Design Engineer)

'Well, I can understand that one. It is the simplest and most obvious: The most efficient use of our resources. Material Productivity: we don't use that phrase because Linda described earlier about how to get more shelves out of a bit of cheaper steel. It is common sense: use a language that everyone can understand.' (Design Engineer)

Design and technology compatibility is one factor that helps the company produce products that last a long time.

'But the technology in there is completely different to the technology in there, that's 25 years old , that's current production, they are utterly interchangeable in your systems so you can ...hmm obviously in a very limited way in which we have used the technology that there is no chip in this.' (Managing Director)

The product type Company 4 produces has a ***long product life.*** This of course influences the types of material strategies to support the product's design and services.

'Yeah, when we thought about materials well for example the cabinet hmm 50 years old but in year 2000 we changed the look of the front, the drawer has changed, and the drawer runners have changed 5 times in the last 7 years. And so we upgraded the drawer needed (inaudible) to Milan and you have this beautiful drawer self closing and we have got self closing and we added that to keep up but at the same time if a customer came along and bought the cabinet 20 years ago they can buy a cabinet now and it goes directly next to it and looks so much exactly the same. The new one will close easefully and the old ones are a bit creaky but essentially it is a same product, it fits the dimension. They are all are exactly the same.' (Design Engineer)

As with several companies discussed before, both customers and suppliers influence the type of strategies implemented in the company. The ***close relationship with customers*** claimed by the company will make it possible to have a service-oriented strategy. A ***close relationship with suppliers*** will make the company choose and practise packaging minimisation and re-use more easily.

4.2.4.3 Constraint

During the interviews, there was not very much evidence of problems and constraints experienced and revealed by the company in practicing Material Efficiency strategies.

Difficulty in Making Decisions is one of things that interviewees admitted that troubled them a bit. Prioritising decisions to make sure their products have less environmental impact is the most challenging issue. Their only solution if they are not sure is to make their product life as long as possible.

'We have to make a decision.' (Design Engineer)

'Well if you don't know the energy in the whole system of materials then for heaven's sake make that materials last as long as long as possible.'(Managing Director)

There was ***no assistance from any government agency*** although the company has requested assistance on information and guidance on certain issues.

'But that was Envirowise and it was on a starch problem, because I had been introduced by somebody at (inaudible), absolutely. And they never came back, oh I followed them up, because it was 6 weeks later. "Oh we shall come to you". I followed up again but they never got on with it so…' (Managing Director)

Problems giving away waste are other constraints they are facing. It is difficult to give away waste that is potentially re-usable by another party.

'…some items are very difficult, I try to get…hmmm we do have an off cut of these, I am been trying to get kind of, you know that children may be interested in it and basically I try loads and nobody is interested…it is like free clean materials for kids to make a rocket out of, but nobody is interested. What is wrong with the world?' (Head of Sustainability)

4.2.4.4 Benefits

Several benefits derived from having Material Efficiency strategies in practice. One of them is that the company is more ***agile*** due to its readiness for change, response to environmental pressures or adopting other Material Efficiency strategies due to a long history of practicing Material Efficiency strategies.

'Ohh where did that come from originally? Originally back in the 50s there was a common sense way of running a business, of creating products that work, that last a long time, could be serviced for a long time, could be repaired, and you had an incentive to look after them, taking them with you, being able to add to them, subtract from them to even stack them away back then, even needing as few materials as possible to clean them with. Well, yeah it is like (inaudible) to clean it like any surface stuff, the idea they would not be easily soiled surfaces even that, so it was purely common sense. The issue of saving the planet wasn't on the agenda in the 50s and 60s. And so what is totally reassurance is that it started as common sense and now that this whole issue of saving the planet comes on the agenda you then look and go, "ahh that's the way we should run the business", and then you go, "ohh hang on the way we are running the business is not so bad anyway". And the common traits all the way through has been common sense.'(Managing Director)

Other notable benefits are ***reduction in packaging cost*** and ***reduction in packaging waste***. The company invented the re-usable packaging or containers so the suppliers send the parts using the container, and take the empty containers away with them.

'Hmm these things, we paid for these things to be made. This normally costs us £50 per…and it lasts 5-10 years depending how caring the suppliers is. Some of these have been damaged and have been repaired, so rather than throwing away we went to repair it…the idea of this is when the supplier drops these things off , they also pick up the empties, take them back and we never have empty cardboard boxes or anything else, we always reuse our packaging.' (Design Engineer)

4.2.4.5 Accelerators

Due to ***tight employee selections***, the company has disciplined, creative and quality employee, who understand the business and processes. This results in fewer communication problems. In turn these qualities help the company implement Material Efficiency strategies. According to the Managing Director they are really careful in selecting their employees to maintain a small manageable workforce that can really do the work.

'... it might been six months from beginning to end and then a although we are a small business with limited resources we will still sit here and go "is not a right person, off the bus" and we kick them out so we have taken our time.'(Managing Director)

The type of products and materials used to build the products offered by the company are ***long-lasting*** and the emphasis is on services rather than fashion.

'Although a lot of our systems use steel and aluminium, again we use a lot of power to produce these things but at least they are going to last very long time so you have to look at it that way that they are going to last very long time. And our customers are

going to want to keep them for a long time. They are not something that they buy for five years and throw away. So it is a waste of electricity (inaudible). They are buying because they know they are going to keep it forever. It is an investment.' (Managing Director)

The product ***design is not influenced by seasonal trends***. It is an advantage for Company 4 as the products they sell do not fall into the category of products which have to follow trends. This makes the products remain in use by the customer for longer, and customers do not change them because they look outdated, but rather use them as long as possible, and rely on their service rather than their looks.

'It is like a clothing fashion you know, it is (inaudible) one week and the next week something else. You know that is just not us….I think some people have seen us in a fashion magazine because somebody did a feature on us, they got interested in the system because it was advertised in that way and they actually realised what incredibly good shelves they are you know and then they buy more, nothing to do with the magazine anymore because somehow they are falling in love with the shelves because it is actually possible, believe or not, you know.....Yeap, so fashion probably you know has probably helped occasionally but it is not the main reason why people buy the shelves.' (Head of Sustainability)

Put together ***type of product*** the company sells is an important factor that helps the company with Material Efficiency strategy. The product uses primary resources such as metals which are easy to recycle. The company is also constantly trying to eliminate materials that have an impact on the environment.

'Yep, but we almost completely recycle our aluminium under the screws, take it (inaudible) from the wood, steel, there are no ...hmm there is no bonding going on here but, no bonding! There are a couple of little bits that we bond but very…. So end of life is absolutely a sad end of life. That for us is defeat.' (Managing Director)

Although technology always changes, the company is trying its best to cope with technology changes while maintaining its aim of reducing environmental impacts.

'And then again we have got things like material technology changes, hmm the things come along that we think are going to last longer and we use them. We are looking at new cabinet panels which are obviously greener and last longer hmm when they do run out you can get rid of them, that's the way, not so bad on the environment. It is more about materials which don't impact on the planet as much, so although a lot of our system are steel and aluminium and again we use a lot of power to produce these things but at least they are going to last a very long time so you have to look it that way that they are going to last very long time. And our customers are going to want to keep them for long time, they are not something that they buy for five years and throw away.

So it is waste of electricity (inaudible). They are buying because they know they are going to keep it forever, it is an investment.' (Managing Director)

Design and technology compatibility is another factor. Compatible technology which is suitable for a product that has a long life helps the company with the Material Efficiency strategy. Without compatibly between the old design and new technology, the company cannot maintain production of similar designs and products.

Yeah, when we thought about materials well for example the cabinet hmm 50 years old but in the year 2000 we changed the look of the front. The drawer has changed, and the drawer runners have changed 5 times in the last 7 years. And so we upgraded the drawer need that (inaudible) to Milan and you have these beautiful drawers self-closing and we have got self-closing and we added that in order to keep up but at the same time the customer who came along and bought the cabinet 20 years ago, they can buy a cabinet now to go directly next to it and look exactly the same. The new one will close easily and the old ones are a bit creaky but essentially it is a same product, it fits the dimension. They are all are exactly the same. (Design Engineer)

Relationship with customers supports the company's efforts to produce greener products that will produce less waste and environmental impacts. This is done by maintaining a relationship with the customer by providing services so that the customer can use the products much longer.

'You educate them, they don't need it precisely about (inaudible), they don't need it that wide and they don't need pink in colour with purple spots on it, you educate them that for what they need to do, that size and that size in off white frankly is going to do the job for them. If you really want to do pink with purple spots put your pink and purple (inaudible) on it, buy your pink and purple spots (inaudible) that don't wear out in five years time or whatever.'(Managing Director)

Having the attitude that views ***technology as a choice*** but not an obligation allows the company to use many Material Efficiency strategies to help reduce materials used and reduce waste.

'And then again we have got things like material technology changes, hmm things come along that we think are going to last longer and we use them. We are looking at new cabinet panels which are obviously greener and last longer hmm when they do wear out you can get rid of them, that's the way, not so bad on the environment. It is more about materials which don't impact on the planet as much so although a lot of our systems use steel and aluminium and again use a lot of power to produce them at least they going to last a very long time so you have to look it that way that they are going to last a very long time.'(Design Engineer)

There is ***no measurement,*** as the company's opinion is that measurement is action that is not helpful and in fact would slow the strategies.

'Do they have speedometers on formula one cars? No they don't have speedometers on formula one cars because you're driving as fast as you bloody you well can go. So you don't need to know if you're doing 100 or 190 do you? So you don't measure it.'(Managing Director)

4.2.4.6 Practices

Among significant practices by Company 4 are:

Design

- Compatible design and technology
- Design not influenced by seasonal trends
- Modular design for packaging
- Multipurpose packaging
- Use safe parts
- Using environmentally benign material
- Less budget control
- Long product life

Manufacture/assembly

- Employee self-empowerment and self-discipline
- Recycling and reusing

Sourcing

- Sourcing environmentally benign material
- Influence supplier
- Relationship with supplier
- Select suppliers
- Minimise packaging (Modular design, Multipurpose packaging)

Business/service

- After sales service to prolong product life
- Use common sense
- Educate customer

- Technology as a choice
- Projected green and responsible image
- Use simple environmental jargon
- Avoid measurements
- Minimise packaging (Modular design, Multipurpose packaging)

4.2.4.7 Case summary for Company 4

The company's management claims that using material efficiently and reducing waste are all common sense to them and has been their aim for a very long time. The company also has skilled employees who understand the business well regardless of their qualification. Employees are given some degree of freedom and self-discipline. These are significant factors that make the company take up Material Efficiency strategies and choose the types of strategies to implement. The constraints, which are viewed as minor by the company, are the need to make decisions to prioritise actions regarding waste and impacts, government agency lack of help when asked and problems giving away useful waste. The benefits are reducing packaging cost and waste, and the company is agile in implementing other environmentally related strategies. The product types sold by the company are types which are long life, using environmentally benign materials, and the design is not influenced by seasonal trends. These characteristics give a lot of advantage to the company in helping them in practicing Material Efficiency strategies. Tight employee selection helps the company by having employees that understand the business process, which no doubt accelerates company Material Efficiency strategies. Other than trying to reduce the material and waste in manufacturing process especially in recycling and reusing, the company has made impressive efforts on redesigning the packaging so that the packaging waste can be reduced. In design the company is striving to use materials that give less impact to the environment alongside efforts in making the product last as long as possible. The company is proud to offer a lasting product to the customer and offering service to maintain the product life.

4.2.5 Company 5

The company is one of the world's largest automobile manufacturers. The company claims to embrace the concept of sustainability in its broadest sense, which involves economic, environmental and social stewardship.

4.2.5.1 Factors that catalyse to have strategies

Evidence from Company 5 highly strongly indicated that the ***company's environmental awareness*** is one of the motivations to embrace Material Efficiency strategy. The European Environmental Manager, when asked if government legislation forced them to implemented Material Efficiency and sustainable strategy, said:

'No I think it came a little bit before that, I think it's from the company's philosophy going right back to its inception. It had to make do with what it had rather than…and then added "really the company family were thinking of resources as being global resources as well not just resources available to the Company so being careful with energy, being careful with the earths precious resources if you like, and that's going back until the 1990s before a lot of this really became...' (European Environmental Manager)

Company 5 has a very strong ***company philosophy and culture*** and claims that the company takes the environment quite seriously, that resources must be utilised efficiently and that all waste must be eliminated.

'...It is a core philosophy and when the company in the early 90s started to characterise its business what it aimed to do with its business and its guiding principles in other words, how does it conduct it's business within the world environment was identified as being the key item at that time and from those guiding principles the Company's Global Earth Charter was written and that's physically where the link comes from, so it is literally part of our stated company mission. If you go right back to the original statement our mission is to produce products which work in harmony as far as possible with society but provide a societal need, the societal need being transport basically so it goes right back. That's why we were doing it at that point so we are trying to satisfy that need at the least impact to the environment.' (European Environmental Manager)

The company's aim to ***reduce waste*** and the ***company's production system*** are also the factors mentioned by the company as motivation to practice Material Efficiency strategy. The company recognises that all sorts of waste are cost, so the company is always striving to eliminate waste.

'I think from a materials efficiency point of view everything is sort of referred back to the company's production system so essentially what we are trying to do there is reduce waste or whatever (inaudible) so for material efficiency as an example if we look at the press shop we would be trying to reduce the amount of scrap that comes out from pressing a pane..' (European Environmental Manager)

Another reason to have the strategies is for ***target and communication.*** One example of the target is a company's goal to communicate and encourage everybody inside the company and to communicate with stakeholders of what the company is doing and trying to achieve.

'The reason we quote the zero waste for land fill is it's a very convenient milestone to achieve for our members to say actually we don't send anything to the hole in the ground. It is slightly divorced from the actual activity, it's a result which we have

chosen to communicate, to use internally or use as a target for our own benefit.' (European Environmental Manager)

4.2.5.2 Factors that influence the choice of strategies

Company philosophy and culture; ***company environmental awareness***; and ***the company's production system,*** the factors that motivate the company to take up Material Efficiency strategies are also the factors that influence the company to choose specific strategies above others. These factors are similar to those that influenced Company 3.

Company philosophy and culture that encourages maximising available resources, makes the company choose a strategy that is easily and readily available, preferably without extra cost.

'No I think it came a little bit before that, I think it's from company's philosophy going right back to its inception. It had to make do with what it had rather than, it didn't have an unlimited purse for example so when it started to build cars it wasn't able to do what Ford did which is have a press nearly for every panel in those early days, I know Ford don't do it that way, but it had by nature of its ambition to do well but a limited resource it had to find smart ways of doing things so it started to do die changing and things like that which meant that it has always been careful about resources…' (European Environmental Manager)

The strategies the company chooses must go hand-in-hand with the ***company's production system*** or ***lean production.***

'Basically I think we had a clear mission that was led by the top we did have various KPIs. Waste is one of the KPIs, therefore a strategy is necessary. What are the strategies that we use? Well one obviously is to use the company's production system that helps us identify the areas to attack…' (European Environmental Manager)

Company environmental awareness always influences the company's decision on which type of strategies to choose. Evidence given below shows that the strategies chosen because the company wanted to be careful with energy and resources.

'…it has always been careful about resources and the resources that were [inaudible]. Really the company family were thinking of resources being global resources as well, not just resources available to the company so being careful with energy, being careful with the earths precious resource if you like, and that's going back until the 1990s before a lot of this really became…' (European Environmental Manager)

Target and communication makes the company choose the strategies that are suitable to communicate to employees, customers and to motivate actions.

'The reason we quote the zero waste for landfill is it's a very convenient milestone to achieve for our members to say actually we don't send anything to the hole in the ground. It is slightly divorced from the actual activity, it's a result which we have chosen to communicate use internally or use as a target for our own benefit.' (European Environmental Manager)

Another factor that makes Company 5 choose a specific strategy is ***materials type.*** The European Environmental Manager was saying that recycling strategies were chosen for metal recovery as it is easiest to recycle compared to other types of materials, which need to use different strategies to recover and reuse them.

'Well I think metals is actually one of the easiest ones to consider because for years and years and years the metal industry has been based upon recycling scrap, and the steel industries, the suppliers Corus and (inaudible) and Nippon steel and all the other companies, they've been so used to using recycled materials that they'll give an absolute guarantee for their steel. Their quality control is excellent and they are able to make many different grades of steel for different components of the car very consistently. If the plastics industry was able to do the same thing using reground materials and what have you there would be an increase in use of it.' (European Environmental Manager)

4.2.5.3 Constraint

The important constraint faced by the company in material recovery is ***fluctuation*** in recycle material.

'Yes and of course in that respect we are somewhat hampered by a couple of things. One is consistency of material supplies so for example it's not so easy for a manufacturing environment to manage a wildly fluctuating recycled content of a plastic material. It's OK if it's fixed at 7%, 10% or whatever it is and it's stable at that then you can do high volume manufacturing with that material. You can set all your parameters on your die maker or your injection machine and yes we have a good condition. If it wildly fluctuates it's more difficult for us to manage. Then we have an expectation from the customer for aesthetics and things like that so that sometimes will limit us. We couldn't use reground plastic bumpers which have been painted in the production of a new black bumper because it would be all mixed colours it wouldn't meet the quality requirement.' (European Environmental Manager)

The other constraints that that company face are similar to Company 1 which is on ***design*** where the company needs to take make sure that new design would not jeopardise quality and safety.

4.2.5.4 Benefits

Similarly to Company 2, the most significant benefit to the company from practicing Material Efficiency strategy is ***waste reduction***. Again ***minimised use of raw materials*** is one of the benefits identified by Company 1.

A working ***target and communication*** is the other benefit gained by the company. Having the Material Efficiency strategies is a target that the company is working towards for sustainability and can act as a tool to communicate to the customer in portraying a good image.

'The reason we quote the zero waste for land fill is it's a very convenient milestone to achieve for our members to say actually we don't send anything to the hole in the ground. It is slightly divorced from the actual activity, it's a result which we have chosen to communicate, to use internally or use as a target for our own benefit.'
(European Environmental Manager)

4.2.5.5 Accelerators

The ***company's production system; company's philosophy and culture;*** and ***company's environmental awareness*** are accelerators that appeared in previously discussed companies.

'I believe that honestly it's the consistent approach, the congruent approach all the way through the organization. It's attention to detail and we are very persistent about it. It's built into our everyday activities. It's not an add-on. It's always been fairly core and because it is linked to the company's production system it's not seen as an environmentally green activity, it's seen as part of our business ethic and it's related back to that very core bit in the middle it's so strong that…' (European Environmental Manager)

The ***availability of advanced technology*** is no doubt helping companies in minimising waste and using material efficiently. With the technology, the company can select the material that can achieve the aim but technology can also help with the implementation of Material Efficiency strategy such as using the materials that are easy to recycle and technology that can help with recycling.

'Yes in some cases we use the same technologies, in other cases there's been a newer technology developed. In terms of injection moulding the sheets, the thing that came first was the material and then the material made in those three basic components could make up the instrument panel but now when we pull the instrument panel out of the car at the end of the line polymer so it can be recycled a lot easier than previous versions.'
(European Environmental Manager)

The manager said the company gave employees a ***clear definition of strategies*** and tactics so that they know and understand the processes and tasks.

'I think they do work, it is there for us why do they work and why don't they work. You have to have a clear definition of something. If you are going to compare A with B you need to make sure it's an apple with an apple so you need some clear definitions and constantly we are readjusting the definitions when people find loopholes or they find a gap or something. Well where do we put this or where don't we so that needs to be done consistency as well, and where possible some sort of long term thing so it's no good having a sort of KPI and then hopping onto another KPI next year maybe you allowed an extra one but did not take away the other original one because it's the process of refinement rather than replacement I think.' (European Environmental Manager)

The company's employees understand and are aware of their responsibilities in executing the task of trying to reduce waste and use materials efficiently. The ***employee awareness*** no doubt helps a lot with the success of Material Efficiency practices.

'I think it's all there really, at all levels right from a global basis we are reporting in our KPIs and our response to the company's direction that goes right down to a group member, team member on the production line. He knows that he has to segregate his waste or put it in a certain bin and he should be able to explain the reason why and what is his contribution and so it's very much involved in the ocean cannery (inaudible) system which you've already mentioned.' (European Environmental Manager)

The company hold research and development as important. The ***research and development (R&D) budget*** helps the company find out what type of materials are best to use, and types of techniques and strategies to take in order to reduce waste, material, usage and environmental impacts.

'Yes absolutely so the image in the future is that they talk about winning the materials there. Technically if you take the car of course if you really are careful about it you could disassemble a car and probably recycle 99% of it but the amount of labour that would be put into that is enormous so you won't do that, so the way the Japanese researchers and developers in this area have looked at it is how can we use win material very quickly and that means by putting a hook on it and dragging the wire harness out so the wire harness….' (European Environmental Manager)

Other accelerators such as communication and suppliers are similar to those found at previous companies. Existing good ***communication*** practices in the company is no doubt among the most significant accelerators. Any strategies the company wish to implement would fail if communication is not there to explain the strategies from management to employees. The company has established a good relationship and

closely ***works with suppliers*** in practicing chosen Material Efficiency strategies. Without working closely with suppliers it is not possible to achieve so much in practicing a sustainable strategy.

4.2.5.6 Practices

Below are listed of practices by the company during design, manufacture, sourcing and at the business level.

Design

- Focus efforts to prolong product and material life
- Use improved recyclability materials
- Use environmentally benign materials
- Design for Environment
- Design for Reuse and Recycling

Manufacturing

- Lean production system
- Use less material during machining
- Practice closed loop strategy (usually collecting own waste or end of life product and re-using the materials from these)
- Reusing and/or recycling the waste
- Have internal control standards, Key Performance Indicators (KPI)

Sourcing

- Influence supplier
- Work with suppliers

Business/services

- Inspiring employees
- Provide spares so customer can prolong product's life
- Use common sense
- Waste reduction
- Research and development
- Waste identification and segregation
- Environmental targets and plans

- Subscribe to Zero Waste or 'Green, clean and lean' programmes
- Influence customer
- Have a set of targets and communicate them
- Conduct and implement Eco-audit, Environmental Management Systems, ISO 14001, prior prevention, risk audit, LCA
- Strive to stay ahead of any legislation in any country in the world where the product is marketed
- Collect and keep waste data
- Resource Efficiency
- Lean production system
- The programmes and tactics listed above are practiced widely and at all levels.

4.2.5.7 Case summary for Company 5

The company's environmental awareness and the company's philosophy and culture are the great influences that motivate the company to implement Material Efficiency strategies. The culture imbedded in its production system is to reduce any types of waste. Continuous efforts to eliminate material and energy waste were long practiced before the global awareness on the environment started. For the company, waste is cost, so all waste must be eliminated. Due to Japanese management influence the company claims to have higher environmental awareness. The company not only uses the strategy to achieve its environmental target but also as a tool to communicate with the customer. These factors also help explain the types of strategies the company chooses.

Only two constraints were found to affect the effectiveness of Material Efficiency strategies implemented. Fluctuation in recycled materials and design constraints potentially affected the aesthetic and performance qualities which are important criteria to the customer.

Reflecting on the motivation for the company implementing the strategies in the first place, the company mentioned benefits they expected, which are reduced waste, minimised use of raw materials and target and communication.

The company's production system, philosophy, culture, environmental awareness and communication also function as accelerators. Other accelerators are suppliers and available technology.

The company practices Material Efficiency related strategies at almost all levels and in all areas: design, manufacturing, sourcing and business level. Among the top strategies practiced by Company 5 during design is Design for Environment, material recovery at

the manufacturing stage and working with suppliers at the sourcing stage. At the business level, the company inspires employees by communication to have waste targets such as zero to landfill. The company can be regarded as practicing Resource Efficiency and an Eco-efficiency strategy based on evidence given. The company also dedicates resources for research and development of new strategies.

4.2.6 Company 6

The company is the manufacturer of industrial engines in the UK and abroad. In the UK the company has already been in the business for 75 years. The company recognises the responsibility to minimise the effects of its activities on the environment and protect it for future generations. The company has a long standing programme to recover and reclaim failed major components from the market place.

4.2.6.1 Case summary for Company 6

Having a vision and target influenced the company to have some strategies to reduce material waste. By having vision and putting a visible target for employees to see, the company is hoping it can facilitate employees' awareness. The significant factors that influence the types of strategies which the company chooses are influenced by barriers mostly from top management and organisational issues. The problems are mostly from organisational related issues such as the problem of measuring effectiveness; tracking waste; making decisions based on limited information; management thinking and working culture. There are a significant number of problems specifically from management and working the culture for instance communication problems, lack of top management understanding and awareness.

There is no other benefit evidenced from the interviews other than having a vision and target. According to the interviewees the company is struggling to implement Material Efficiency strategies due to the many constraints they face.

The vision and target are the only accelerators revealed from the interviews that help the company drive the strategies.

Among the practices that the company implemented are ISO 14001, using a matrix for measurement, for instance using zero matrix for strategies and tactics that are visible.

4.2.7 Company 7

The company is the UK plant of one of the world's largest suppliers of CNC machines, Machining Centres and Manufacturing Systems. This company machines mostly metals so the metal recycling and segregation is top of company's agenda together with many other strategies.

4.2.7.1 Case summary for Company 7

The parent company of Company 7 is a Japanese company which makes it a similar case to Company 4 and 5. Interestingly unlike Company 4 and 5, Company 7 practiced Material Efficiency such as metal swarf recycling earlier than the parent company. The company gained accreditation to ISO 14001 in 1998 and has implemented swarf recycling and environment related housekeeping for many years. Among top factors that catalysed the company into having strategies are the company's environment awareness, a long history in environmental concerns and customer request.

On the other hand, the factors that influence the company to choose the type of strategies are the type of products and materials used which are mostly metal because the company is not affected by many regulations such as WEEE. The company also gets material supplies easily as the materials used are mostly cast iron and steels.

The only constraints to the implementation exist because there is no other measurement other than simple percentage and there is no target, which the company views as not a real problem at all. Another issue is that the technology changes fast, but that is not seen as a constraint by the company as the customers will use the product for around 10 years and then sell to a third party. Also the company is not pressured by too many regulations and does not have problems getting material supplies.

The significant benefits experienced by the company are cost reduction and waste elimination. Due to the materials machined in plant being metals, it is easier to measure and highlight the strategy's effectiveness especially in terms of weight and monetary value.

A factor that accelerates the process is the company's environmental awareness that has been practiced for quite a long time. In fact the company claimed that awareness started in the early 90's and was initiated by them not by the parent company in Japan. In some practices they become an example to the parent company and others.

The company does a lot of recycling, in fact materials recycling such as for swarf and coolant, and also office recycling are widely practiced and regularly communicated to employees. The company also reduces waste by reducing packaging when necessary and designing products that is more environmentally friendly and better over time.

4.2.8 Company 8

A leader in the UK corrugated sheet industry and has been operating in the UK for over 30 years. The company is currently actively doing waste minimisation to reduce operation cost in order to produce corrugated sheet at competitive prices.

4.2.8.1 Case summary for Company 8

The company manufactures simple products that produce no toxic waste. The factor that triggers the company to minimise waste and use materials efficiently is the competition with other manufacturers. The product has no loyal customers, if the customer can find other corrugated sheets with the same quality more cheaply the company will lose sales. One way of reducing cost in order to reduce waste is to minimise waste and use materials efficiently.

The factors that influence the company to choose the type of materials are also due to the reduced cost on corrugated sheet production and due to the nature of corrugated sheet which is classified as a simple product in that there is no toxic waste produced and there is no design involved.

The only constraint the company faces is on manufacturing processes because some waste is unavoidable. Although the materials used and product produced are simple and non-toxic, some waste is still being generated.

There are a several benefits gained by the company according to the interviewee such as increased competitiveness, reduced virgin materials, reduced waste and reduced cost. As the material used by the company is only a simple material; pulp sheet or board, it is rather easy to measure how much waste and savings are made. The benefits expected and measured are all related to cost and savings which are viewed as factors to increase the company's competitiveness.

Due to the nature of material and product used the accelerators to implement Material Efficiency strategies are the efficient machine, no pressure from legislation, non-toxic waste and simple products produced.

Because the company has to face some complexity with its materials and products the company chose to focus on reducing waste resulting from manufacturing inefficiency. Among the top strategies adopted by the company are striving to improve process and layout to reduce waste, improving machine efficiency, using advanced technology, facilitating employee awareness and recycling.

4.2.9 Company 9

The company is the UK's leading home and general merchandise retailer. Having two brands, which are the UK's leading brands, with large customer bases across the UK. One of them has more than 60 years of market heritage and consumer awareness. The company is committed to promoting the reuse, recycling and recovery of WEEE by contributing to the appropriate compliance schemes.

4.2.9.1 Case summary for Company 9

Company 9 is a retailer that actively imbedded sustainability into its corporate responsibility strategies. Among factors that pushed the company to have Material Efficiency strategies are the company's ethical awareness, customer preferences, and legislation. Customers are now more environmentally aware and the company responds to this awareness by providing choices in products that suit their needs and trying to reduce the environmental impact on the running of their business.

The factors that influence the choice of strategies are also the company's ethical awareness, customer preference, market trend, legislation and marketing common sense. Marketing common sense means that to survive the competition is to respond well to customer environmental awareness.

Some constraints faced by the company are the difficulty of weighing, capturing or measuring the benefits, making decisions in prioritising, systems constraints, and not having control over packaging.

The top benefit that the company sees is that it saves money. Although the original motivation behind the company’s subscription to the idea of implementing material efficiency related strategies is merely because of corporate image. As expected the other main benefits identified were an improved green image and reduced waste which are viewed by company as added advantages.

Among the accelerators that help with the implementation of Material Efficiency strategies in Company 9 are the company's ethical awareness, customer request, market trend and cost reduction. Ethical awareness, customer request and market trend pushes companies to subscribe and improve the Material Efficiency strategies implemented in the company and when dealing with suppliers. Cost reductions are benefits gained from the strategies which also acted as an accelerator for the company to implement its strategies more widely and with greater effort.

As a retailer there is not much that the company can do to reduce waste and to increase Material Efficiency through product design. Efforts are concentrated on packaging and choosing the product range during sourcing.

For strategies involving suppliers, the company is trying to influence suppliers to work with them to come up with better packaging in order to reduce waste. The company strategies are to communicate, influence and educate the customer on the choice on products, and to offer hassle-free take back and returns. Inside the warehouse, the company is trying to separate waste, use environmentally benign packaging and recycling the waste as much as possible.

4.2.10 Company 10

The company is one of the largest producers of polythene film products in the UK and European markets. In terms of size, the company is a SME[3] Company. The company is currently doing waste minimisation to reduce material waste as much as possible.

4.2.10.1 Case summary for Company 10

Company 10 uses materials that are linked directly to the price of petroleum and thus depends heavily on the price changes of a barrel of oil. Due to this problem, the company is facing problems with fluctuation of supplies. When the supplies are tight, the supplier asks a higher price for materials. Thus the price of materials, cost reduction and material availability are among the top priorities that lead company to adopt Material Efficiency strategies. Other factors are waste and lost opportunity which means the company not only tries to avoid materials from being wasted, but avoiding waste of time and overhead cost.

Among significant factors that influence the choice of strategies are material availability, price of material and waste due to the manufacturing process. These factors are all related to the type of materials used by company which are scarce and expensive.

There are several constraints faced by the company, all of them related to materials and the product type itself. Among the constraints are polymer degradation, difficulty in substituting materials and product. The issue of polymer degradation is that polymers are advanced materials (e.g. plastic could be made from synthetic or semi-synthetic polymers), so recycling the materials has proved to be difficult. The other constraint faced by the company is on health, standards and safety issues, for example customer companies such as pharmaceuticals sometimes specify that they only want the product that has been produced from virgin materials only, due to hygiene standards. It is difficult to substitute materials and suppliers because the process is too sensitive as little variants can influence the product quality and specifications. The constraint related to suppliers involves the difficulties of influencing the supplier, as they do not listen to a small company which runs its business like Company 10. According to the interviewee the company is at the end sector where suppliers are a thousand times bigger than them. The other constraint is that the company sometimes has to choose whether to minimise

[3] In the UK, sections 382 and 465 of the Companies Act 2006 define a SME for the purpose of accounting requirements. According to this a small company is one that has a turnover of not more than £6.5 million, a balance sheet total of not more than £3.26 million and not more than 50 employees. A medium-sized company has a turnover of not more than £25.9 million, a balance sheet total of not more than £12.9 million and not more than 250 employees. (The Companies Act 2006 (Amendment) (Accounts and Reports) Regulations 2008, 2008).

waste by running at maximum production efficiency; customer demand versus flexibility. To have maximum production efficiency the company would like to run the process in sequence (e.g. width and colour sequencing) to minimise waste, but then it would reduce its flexibility to respond to customer demand.

The only benefit enjoyed by the company in implementing Material Efficiency strategy so far is cost reduction due to waste reduction as this is the one that was targeted by the company and is easily measurable.

The accelerator for the company to implement Material Efficiency strategies is proactive salesmen that continuously try to sell downgrade products/waste to customer. The salesmen usually find new markets for the downgrade by influencing customers of potential use of the lower grade of product or else the waste will become persistent waste to landfill.

Among strategies adopted by the company are recycling materials back to processing where possible, creating markets, influencing and educating customers, minimising waste wherever possible and tracking waste.

4.3 Chapter Conclusions

This chapter has presented evidence gathered using a semi-structured interview in industry. There are ten cases which consist of from one to four interviewees for each case. The cases are selected mostly from manufacturing industries which have implemented some form of Material Efficiency strategies or at least tried to implement them. Only one out of ten companies is a retailer company but has worked closely with manufacturing companies over many years. The evidence presented in this chapter is that made available during interview. Evidence from the companies' brochures and websites, and a small amount is from other related interviews handled by others researching the same issues are also used by researcher to help comprehend the data and findings.

The evidence presented comprises results from within case study analysis. The evidence in this chapter is presented in the form of clusters which are labelled with supporting data in the form of quotations extracted from interviews. The evidence is presented case by case, referring to areas being investigated namely: Factors that catalyse companies to have strategies**,** Factors that influence the choice of strategies, Constraints, Benefits, Accelerators and Practices.

From the data and within case analysis it is observed that each company is unique, thus experiencing different factors in deciding upon and choosing strategies, different constraints, benefits, accelerators and practices. Also in some situations it was found that there are similar factors experienced by the companies. This depends on factors

such as company history, culture, type of products, type of materials used and even size of organisation.

This chapter has discussed the findings from each case study. The next chapter uses these findings as an input for cross-case analysis, as the next step towards answering the research questions.

5 CROSS-CASE ANALYSIS

This chapter presents the results of the cross-case analysis. The cross-case analysis is used to explain the data across cases in order to make it possible for a researcher to interpret their overall meaning. The aim of the analysis is to come out with significant themes that will be used towards answering research questions.

5.1 Research Methods

The main reasons why cross-case analyses are performed are to deepen understanding and explanation (Glazer and Strauss, 1970); and to increase generalisability (Milles and Huberman, 1994). In this particular type of research, which investigates multiple case studies, cross-case analysis is a way of generating patterns to seek understanding.

Pre-cross case analysis starts when the researcher does the within-case analysis for the second case. While coding is progressing the researcher keeps checking the previous case's codes or clusters. Although the researcher tries to maintain uniqueness within each case analysis, there is also a need for some level of consistency as early as the start of the analysis. This is done to prepare findings from each case for cross-case analysis. Actual cross-case analysis starts when the researcher extracts all clusters from cases and puts them together regardless of where the clusters occur. Analysis is done in such a way that it is possible for the researcher to keep track of where each cluster came from. This is possible because the researcher records each step of analysis stage by stage. Cross-case analysis is done in two rounds. Round one is where the clustering analysis is done from company one to ten. From this first round of cross-case analysis, the result in the form of themes is then obtained. The second round is done where interview transcripts are re-read and then compared to themes obtained from the first round to make sure any findings that were missed during the first round of cross-case analysis and even within-case analysis is covered. The first and second round analysis will be described in detail in the following paragraphs.

During the first round of cross-case analysis the clustering was done by putting the clusters together. Then they were reduced into higher-level nodes using a *dendogram technique* at three levels. There were 582 of the lowest nodes or clusters (level 3) which were then clustered into 150 nodes (level 2), which were then clustered into higher nodes or 112 nodes (level 1). The higher level categorisations were built by categorising all clusters together and labelling them with new names or names that came from one of the cluster's names. This higher-level category of clusters was labelled by the researcher as *"theme"*. The example of the dendogram technique used in this research is shown in Figure 5.1 to demonstrate how the clusters have been reduced and categorised. In this example the clustering shown demonstrates how to get a theme from clustering the

clusters from ten cases. The theme shown in this example is only limited by the company's culture which accelerates the implementation of Material Efficiency strategy. In the next step, the themes were reduced into a list of significant themes using *Summed Indices Table* which can be found at Appendix 5.1. Then themes were listed under their areas then put against each company; the researcher then checked themes against the companies' evidence. From there the researcher could identify which themes were more important than others. A general rule was applied where themes that were repeated by three (3) or more companies were considered significant themes. The quantity three (3) was used as a cut-off point as it provided a rich set of themes, which reduced 112 themes to 55 themes, while remaining manageable by the researcher. Assigning weight-age or counting for each theme showed some quantitative aspects of the analysis, but it is stressed here that counting went into the background. The reason counting was used is according to Miles and Huberman (1994) a) to see rapidly what we have in a large batch of data b) to verify a hunch or hypotheses c) to keep ourselves analytically honest, protecting against bias.

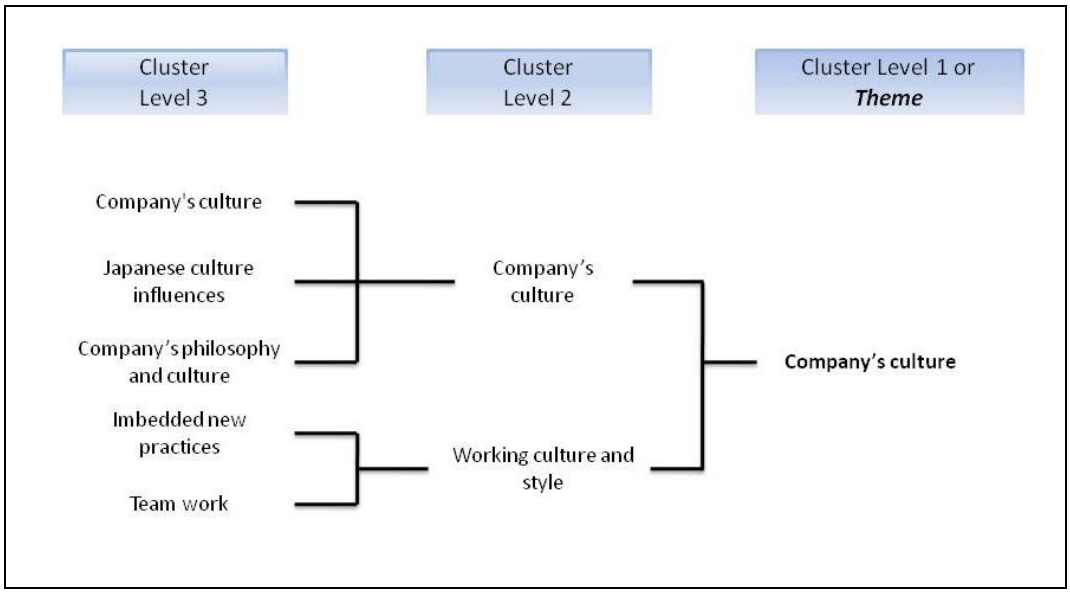

Figure 5.1 Dendogram technique used in the clustering process

During the first round of analysis, analysis was progressing from case one to case ten. While analyses were progressing, the researcher's understanding, knowledge and skills developed. It is expected that the researcher's understanding and knowledge while analysing data at case one were different at case ten, which could lead to inconsistencies and overlooking certain evidence. The illustration of the first round of cross-case analysis is shown by Figure 5.2 below.

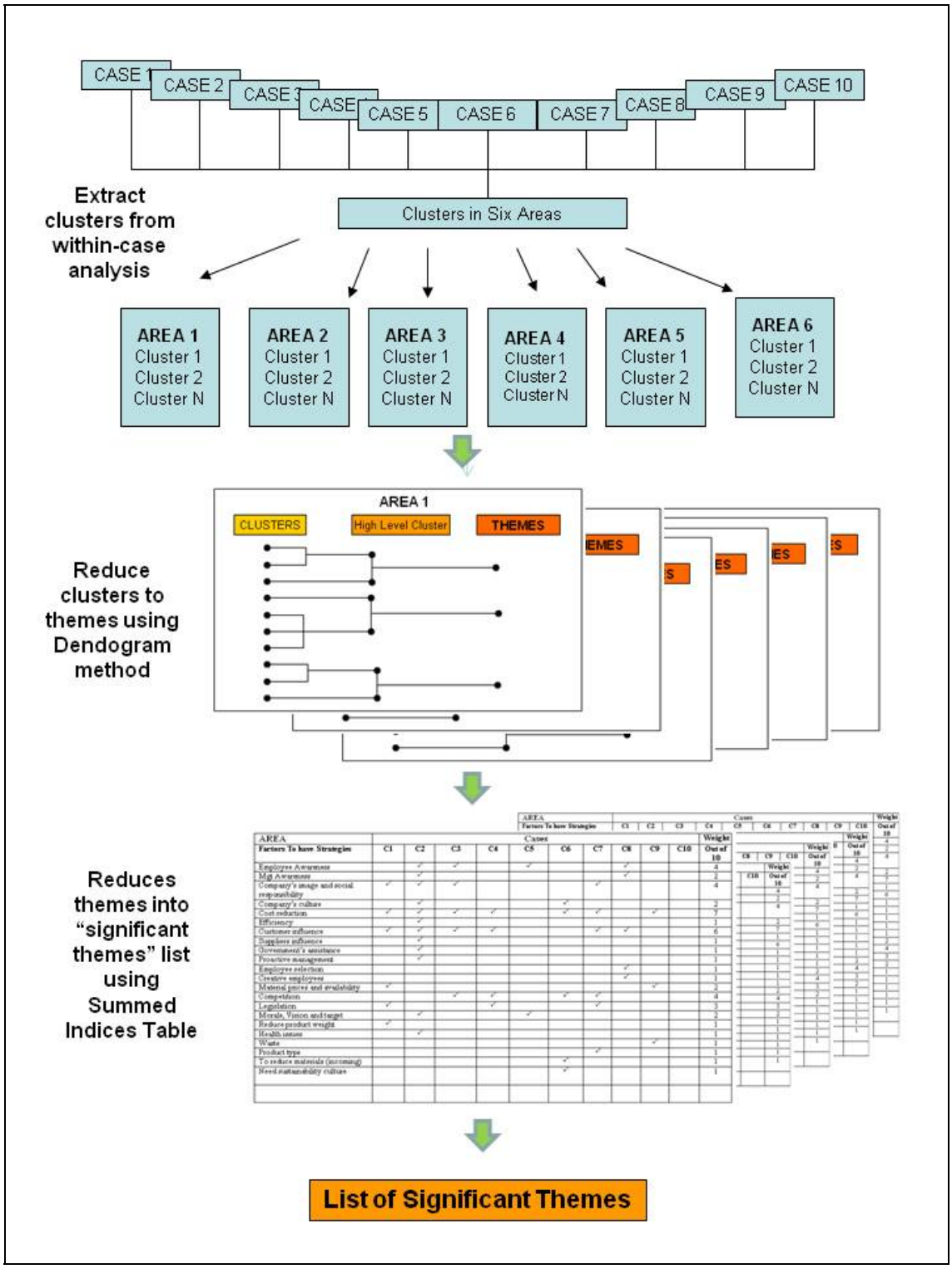

Figure 5.2 Cross-case analysis first round

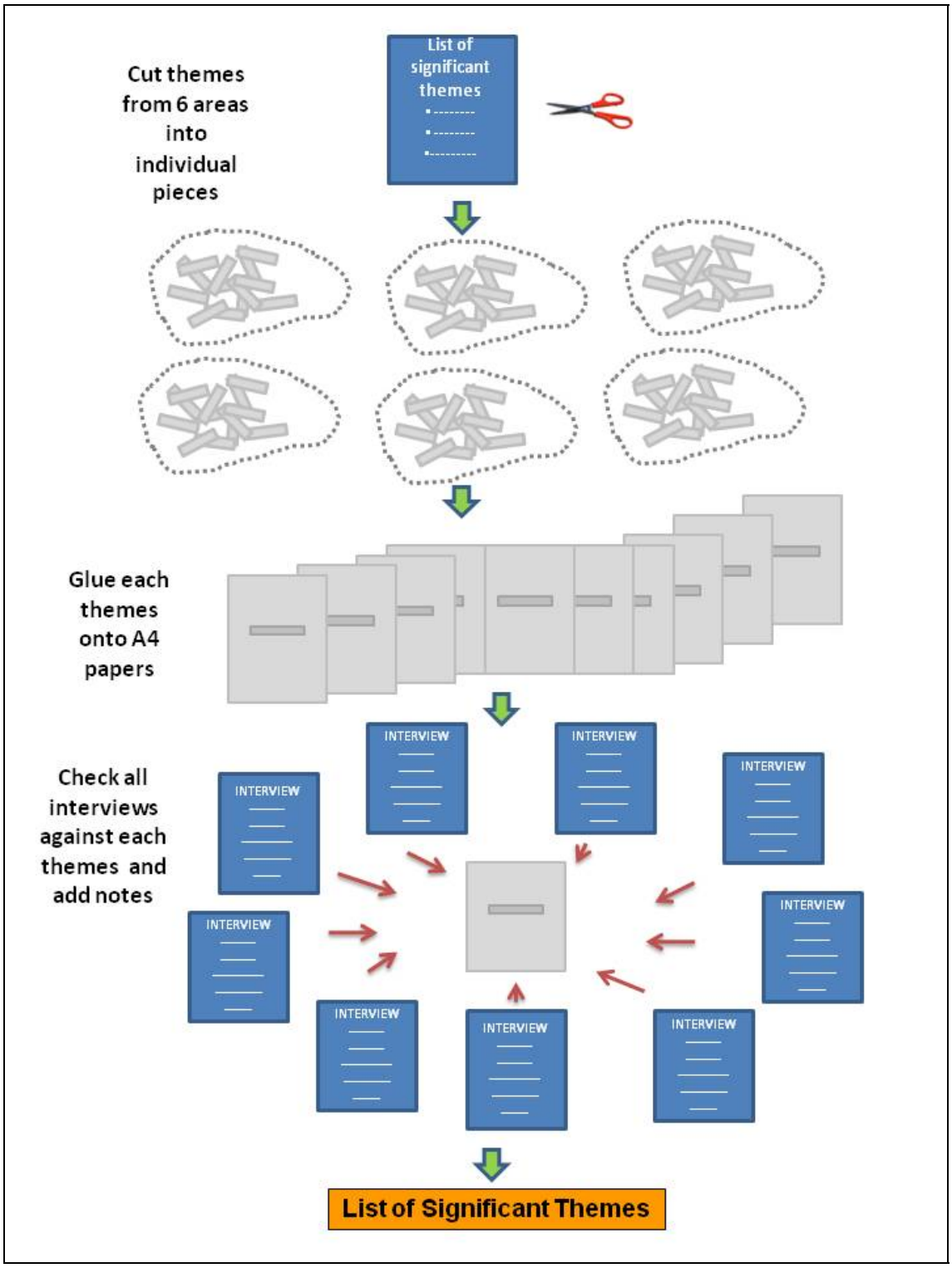

Figure 5.3 Cross-case analysis second round

The second round of cross-case analysis was done to provide fair analysis coverage. The second round was also done to correct and improve judgement for both within and cross-case analysis and reduce the possibility of data being plucked out of context. In the second round of cross-case analysis, all significant themes were each cut and pasted on a separate piece of paper. Then all interviews from cases were re-read and any interesting points checked against the list of themes. Mental notes were added to the piece of paper that contained the significant theme, to increase the researcher's insight and help with the synthesis process. There were themes that were not significant but became significant after the process was finished because the researcher may have overlooked that evidence during the first round. When the second round of analysis was finished, the researcher came out with final list of themes. The illustration of the first round of cross-case analysis is shown by Figure 5.3 below.

The comprehensive list of themes is at Appendix 5.2. In sections below only significant themes are presented and discussed. This chapter emphasises the themes emerging from the cross-company data and does not present individual items of data such as quotes, documents and others as these were presented in Chapter 4.

5.2 Comparing Cases

Below are the significant themes listed under each area which are discussed across the cases. The meaning of each area is explained briefly and factors that motivate manufacturers to choose and implement Material Efficiency strategies are presented first, followed by constraints, accelerators, benefits and practices to help ease the chapter's flow.

5.2.1 Factors that catalyse to have strategies

Factors that catalyse a company to have strategies are those factors that motivate companies to have some form of Material Efficiency strategies. Companies may not implement the full strategy but any part of Material Efficiency strategies or similar is still regarded as a Material Efficiency Strategy in this study. Below are the list of significant factors that motivate those ten companies to implement Material Efficiency and related strategies.

5.2.1.1 Cost reduction

Cost reduction is the most popular reason that made companies decides to have some form of strategies in tackling inefficiency in materials use and waste. Seven (7) companies claimed that having some strategies on material usage has saved them an amount of money. Having some form of Material Efficiency strategies not only saved money in dealing with waste but also saved materials from being wasted thus leading to a reduction in cost. There are several companies that say they make some profit selling their waste to a recycler. From the study, it was found that the companies that put cost

reduction as the main factor that influenced them taking up Material Efficiency strategies are companies which are using: *a) scarce and expensive materials; b) types of materials whose waste is easily identified or c) types of materials whose waste is not easily recyclable into the production process.*

There is evidence from the data that shows that although cost is not the primary reason it surely can add weight to the decision when opting for material efficient strategies. If the strategies are not reducing overall cost, this can be factor that discouraged companies from doing Material Efficiency.

5.2.1.2 Customer influence

Customer pressure and customer influence are the second most popular reasons for six (6) companies opting for a Material Efficiency strategy. Although in many cases customers did not request directly that the company has Material Efficiency strategies, pressure on the company by customers and the market about environmental awareness pushed the company to have some form of Material Efficiency strategies. Customer awareness and customer requirements lead to changes in market trends, thus to capture the market companies are responding by fulfilling customer expectation. This is done not only by changing the product design, using substitute materials, even changing the manufacturing process but also by the way materials are being sourced.

5.2.1.3 Company's image and social responsibility

The company's image and social responsibility are among factors that make a company have a Material Efficiency strategy. It is not clear which one is the cause and which one the effect. Six (6) companies interviewed are aware that having green practices will give a good image to the company. There is one company which mentioned that the company cares about the wellbeing of the local people whom they call one of the stakeholders, more than they care about their image.

5.2.1.4 Management awareness

Management awareness is an important factor triggering four (4) companies to have strategies; therefore strategies most likely came from top management or are supported by top management. If management is aware of the importance of having Material Efficiency and realise its benefit and its cost, they will make an effort to have strategies in place. Management with knowledge is better as they will not just jump on the bandwagon to follow the trend but rather do things that need to be done to stay competitive.

5.2.1.5 Employee Awareness

Employee awareness can play a role, and that made four (4) companies decide to implement Material Efficiency strategies. Companies that are open to employee suggestions are usually the ones that have this element of having employees driving the changes. The awareness of employees can be seen as they give suggestions to improve processes. Effective communication between management and employees coupled with management awareness and pro-activeness will increase existing employee awareness.

5.2.1.6 Competition

Four (4) companies are trying to deliver what the customer wants by following market trends due to competition to attract customers. Among the customer trends is using environmentally friendly products. The other way to increase company's competitiveness is to reduce product cost, including reducing wastage and material during manufacture. Competition is fierce involving products that have little or no customer loyalty. For this type of product, the price and other minor things determine if the customer stays or not.

5.2.1.7 Company's culture[4]

A culture comprises the values and practices shared by the members of the group. Thus the company culture comprises the shared values and practices of the employees and management inside the company. For example a company culture that is influenced by Lean production views waste in any form as something that should be eliminated. The companies which have a lean culture are supposedly among the first companies that would take Material Efficiency strategies. Also the companies whose company culture has a very a close relationship between employees and management and very good communication are also among the ones which are most likely to have environmental strategies. There is evidence at four (4) out of the ten companies that shows that the company's culture plays a role that makes the companies decide to have Material Efficiency strategies. One company described themselves as a small family-oriented company; the other three are influenced by Japanese management culture, with a Japanese company as the parent company.

[4] Company culture can be defined as "the specific collection of values and norms that are shared by people and groups in an organization and that control the way they interact with each other and with stakeholders outside the organization". (Hill & Jones, 2001)

5.2.1.8 Legislation

At least three (3) companies out of the ten recognise having to have some Material Efficiency strategies because they were pressured to reduce waste in response to the legislation. These companies have them as defensive acts rather than proactive acts in response to these pressures, simply saying that they have Material Efficiency because they need to comply with legislation.

5.2.1.9 Material price fluctuation and availability

Only two (2) companies have this factor, but the factor is chosen as significant by the researcher as it is mentioned directly with great concern by these companies as impacting on their future ability to continue operating. Selecting this factor is ignoring the general rule in selecting significant themes, but this factor made a good exception for a very good reason. Evidence from the data shows that both companies have one similarity; both use scarce and price-sensitive materials. These companies mentioned that they are pressured to have Material Efficiency strategies because higher material price and materials scarcity will increase their cost. One company is using titanium which is a very expensive material but recyclable. The other one is using petroleum-based materials, where the price of materials depends on petroleum price fluctuation. The type of material used also makes the company face recyclability issues such as down cycling and materials contamination problems.

5.2.2 Factors that influence the choice of strategies

Factors that influence the choice of strategies are different than the *factors that catalyse companies to have strategies*. Factors that influence the choice of strategies are the factors that influence the companies to choose a particular strategy above others. The significant factors that make companies decide to implement specific types of strategies such as emphasising recycling in a waste minimisation strategy, or selling service in a Material Efficiency strategy, or collecting end-of-life products, etc are discussed here.

5.2.2.1 Cost reduction

Cost reduction is the top factor that makes six (6) companies choose which strategies they are opting for. Cost is not only a factor that makes them decide to adopt the strategies in the first place, but cost also plays a role in deciding which strategies to take up which give cost benefit. The companies choose strategies that give them a cost benefit which are the strategies that can reduce waste, material cost, and increase sales or maintain customer loyalty. At the same time the cost invested to implement the strategies in the long run must be lower than the cost of not having those strategies. From the data, evidence shows that companies which are using expensive, scarce materials, doing recycling and close-loop the material back to production, has reduced the company’s dependency on virgin materials thus cutting material costs.

5.2.2.2 Product type

According to the data, product type is second most common factor that makes companies use specific strategies. Simple products or complex products influence the types of strategies that companies chose. From the data it is shown that there are strong links between the type of products and the type of strategies chosen. Simple product manufacturers tend to choose simple strategies such as waste minimisation as these types of strategy solve their problems easily. This same argument also goes for the type of materials used and the types of waste produced.

The types of materials used to produce products also influence the type of strategies chosen by companies. Different strategies are used if a company uses more basic and easy to get hold of materials compared to expensive and scarce materials. For example Company 1 and 7 which are using mostly metals to produce their products will have fewer problems with recycling compared to Company 3 which is using a lot plastic materials. Thus Company 1 will choose metals and swarf recycling and all other strategies related to metal recycling but Company 3 may choose a product service system which involves getting back materials and refurbishing the products.

The type of materials used and type of product produced also determined the type and quantity of waste generated, which in turn influence the type of strategies chosen. The data shows that if a product produces little or no toxic waste, then the strategy used will be different to the strategies for a company whose product produces toxic and large quantities of waste. Some companies produce products that are not affected by many regulations, thus these companies are more relaxed and tend to employ fewer strategies. If these companies employ any strategies it is due to other factors such as cost, competition, social awareness, and company image. Company 8 says that they are not affected by any regulation so far, as they produce simpler products and produce very minimal chemical waste.

5.2.2.3 Management awareness

Management awareness is an important factor that influences five (5) companies to choose the type of strategies. Management with knowledge has a higher awareness of waste and materials cost for now and the future compared to management who lack knowledge. This knowledge and awareness influences decisions on the type of strategies that companies choose. Aware companies are more proactive and innovative in findings ways to reduce waste, environmental impacts and materials use. Evidence from Company 6 is one example that shows that lack of management awareness not only constrains the implementation but also makes the company choose strategies that are pleasing to the eye such as strategies that can be seen rather than strategies that are effective.

5.2.2.4 Customer requirements

Four (4) companies have customer requirements as one of the important factors that influence the type of strategies chosen. Due to customers becoming more aware of environmental impacts, customer attitudes have changed and they request products and services that give less impact to the environment. This leads to changes in market trends, thus the companies have to respond to it in order to stay competitive. Customer requirements however can give two impacts to companies: *1) it restrains the companies' choices in design and in determining manufacturing processes; 2) it pushes companies to be creative in finding ways to produce products*. Restraining choices means that companies have to deliver products or services that fulfil customer expectations on environmental performances at the same time not compromising their actual performance and functionality. Being creative in producing products or services means that the companies are pushed to seek ways to produce products that deliver both environmental and actual performance which of course poses big challenges to companies. Company 9 reported that customers expect green products to be better than the ordinary products, or at least of the same quality.

5.2.2.5 Legislation

Three (3) companies say that the type of strategies they chose were influenced by the existence and type of legislation imposed on them. It also influenced the amount of effort put in by companies in realising Material Efficiency strategies. Two (2) out of these three companies, that is Company 1 and 9, have taken defensive acts rather than proactive acts. A defensive act means that the company reacted by taking up strategies to comply with legislation to protect the company from legislation penalties. Company 8 says there is no legislation imposed on them so far, and this makes them more relaxed in choosing the type of strategies to have. Most strategies Company 8 adopted are strategies that enable them to reduce production costs.

5.2.2.6 Available technology[5]

The data reveals that the availability of technology can support implementation of Material Efficiency related strategies by influencing the types of strategies adopted by three (3) companies. This factor influences in two ways, either the technology helps with the implementation or constrains the strategies. One example from Company 2 which shows that technology can help reduce waste is a prototyping machine which can be used to help the company significantly reduce materials wastage and time during

[5] Technology (noun)- a) the application of scientific knowledge for practical purposes. b) machinery and equipment based on such knowledge. c) the branch of knowledge concerned with applied sciences. (Concise Oxford English dictionary, 2004)

product design. An example at Company 3 showing technology which constrains the strategies are quick change technologies that make the products obsolete faster, so the company has to design products that could be upgraded and reused, or resort to a product service system. A product service system (PSS) is one of the sustainable techniques which will be explained in greater detail at section 5.2.6.10.

5.2.2.7 Company's culture

Three (3) companies mentioned the company's culture repeatedly. It shows that the company's culture does influence decisions on the types of strategies they choose. Company 2 does say that it values customers and surrounding neighbours and its waste strategy includes customers and people living nearby. The other two companies are Japanese companies, whose culture is to eliminate waste and include the environmental agenda at the very early stages whilst planning the companies' objectives. For example the culture of delighting the customer and the family, made them reduce delivery time while deciding on creating the company's mission and objectives. The company culture influenced them to look at more than waste and cost but also at the resources level and environmental impacts. All three companies have a successful lean production in place, so the culture of lean production already influences whatever they do.

5.2.2.8 Company's image and social responsibility

Three (3) companies are seeking ways to project an environmentally responsible company image and show that they have social responsibility but at the same time make sure they can benefit from it. Strategies they choose will balance the image social responsibility promises and also gives benefits in terms of profit. For example Company 6 is choosing types of strategies that are visible to employees to facilitate employees' awareness and show the company target.

5.2.3 Constraints

Constraints are the difficulties or barriers faced by companies prior to and during the implementation of Material Efficiency strategies. Below is the list of significant constraints experienced by those participating companies.

5.2.3.1 Design constraints

Design is the most frequent barrier to increased Material Efficiency raised by five (5) companies interviewed. It is not mainly the design process itself but rather the consequences of having the designs changed in trying to adopt specific Material Efficiency strategies. Among factors that influence choices in design are customer requirements and specifications. At the same time the products must be able to fulfil functionality requirements and other standards. Changing design for Material Efficiency strategies will affect customer and product performance. For example, from the data

there is evidence which shows that when a new type of material is to be introduced, the designer has to have customer specification, product performance and safety in mind. For example one product of Company 3 uses quick change technology. Product design for this type of product also very challenging as the product should be designed in a way that materials would be easily retrieved to be refurbished or if possible recycled at the end. For Company 1, designing a product has to be a balance between material choice and the product's requirements such as the product's weight and extreme temperature resistance. Therefore the designer has to keep in mind many factors such as customer requirements, product specifications, materials cost, recyclability, and the environmental impacts of the product and waste during manufacturing, during use and after use.

5.2.3.2 Measurement and target

Measurement is important to indicate the direction of achievement of every strategy, but measuring Material Efficiency strategies is not easy. Problems regarding sustainable strategies measurement are discussed extensively in literature in section 2.2. Evidence from interviewees, shows four (4) companies do not perform measurement other than simple measurement such as in monetary, percentage, volume and weight, or have no measurement at all. For them measuring waste is complicated and time-consuming since their target is to reduce waste as much as possible. Some companies do take measurements which will then become a communication tool and are used to set targets. However this not an easy task as it is hard to capture and measure waste as this involves tracking the waste. Most of the time measurement not put as a priority because in many cases companies have to prioritise production targets.

5.2.3.3 Decision making

Problems with measuring the real value of environmental impacts and strategies effectiveness cause difficulty in informing decisions thus leading to difficulties in prioritising. Four (4) companies say that it is not easy for them to make decisions and prioritise by choosing types of materials and types of tactics, and it is difficult to weigh the benefits. For example, Company 10 says it has difficulties in prioritising whether to do a batch production or not. This is because doing batch production is economical but then it will reduce flexibility in producing products and also make it more difficult to respond to sudden demand.

5.2.3.4 Supply chain and supplier constraints

Reducing waste and material is not limited to activities inside manufacturing facilities in companies but needs to involve suppliers and customers. Involving suppliers upstream is important in order to make sure incoming materials are not wasted. Four (4) companies interviewed reported that they encountered problems with uncooperative

suppliers and experienced constraints in the supply chain. Uncooperative suppliers are suppliers who do not listen or do not entertain requests from the company in terms of supplying the amount of material as needed and over-pack the material and products. Supply chain constraint often involves overseas suppliers which involves contractual issues; not complying to the same regulations, not having control over packaging, inability to control sourcing, and logistics problems. Small companies may experience problems in a long supply chain. Company 10 gives evidence that they facing difficulty influencing suppliers due to the type of products produced and due to the size of the company, which is small, which made them less significant in the long supply chain.

5.2.3.5 Product types

Three (3) companies experience difficulties with the product type they produce. The product type determines the types of materials used and waste produced. Some materials are not only cheaper but easily recycled, but others are not. Some product wastes are difficult to recover and re use, and some waste is more toxic. All these give challenges to companies and influence the types of strategies they choose. Companies which use a lot of metals may use recycling strategies. Companies which use advanced materials which are difficult to recycle may have to choose strategies such as prolonging the material life through offering services rather than products. Company 3 uses mixed materials and resorts to a product service system as they can recover the product from the customer and then refurbish it.

5.2.3.6 Organisational barriers

Organisational barriers are constraints mentioned by three (3) companies interviewed. Organisational barriers can come in many forms. It can be from the employer, the employee, company culture, national culture, the system or the way the business is being run. From the data, among barriers that are considered to be organisational barriers are: 1) *Employee*; lack of awareness, not willing to learn, lack of motivation, no ownership, resistance to change, 2) *Management and systems*: lack of support, lack of understanding on sustainability issues, traditional thinking, surface thinking which only sees financial benefits, the company's culture, communication problems, un-integrated business unit and so forth.

Barriers like these will give great constraints to companies implementing not only material strategies but any other strategies. From the study it has been seen that companies which have a traditional thinking culture pose greater problems compared to companies which are less traditional such as lean practicing companies or companies which are a family-oriented type of company. This family type company has higher family values which contributes to less communication problems.

5.2.3.7 Manufacturing processes constraints

Manufacturing processes and flows are not easy to change to accommodate Material Efficiency strategies. The companies must put in effort and money to do this. Undesignated manufacturing processes and flow reduce the effectiveness of the strategy and also discourage implementation. To reduce materials contamination, segregation has to be done religiously. This is difficult as employees have to fulfil manufacturing targets. Three (3) companies have given evidence on manufacturing process constraints. For example, an interviewee at Company 1 said that undedicated machines give them problems in segregating swarf to the highest quality so they have to rely on employee discipline instead, but then employees have other problems such as having to meet production targets. This makes them have no time to clean the machine of swarf religiously before machining different materials.

5.2.3.8 Recyclability

Three (3) companies have problems with recyclability. One of the problems with recycling is that not all materials can be recycled back to a desired state; in fact most waste is down cycled. Down cycling is the recycling of a material into a material of lesser quality. One good example is plastic recycling, which turns the material into lower grade plastics. Recycling waste is limited and nothing much can be done by companies to recover waste. Companies can try separate waste as much as possible by putting extra efforts to the extent of changing manufacturing processes and flows but many factors influencing recyclability lie in the materials themselves. The materials either cannot be recycled into the desired state that can be useful to production, or separating materials from other waste is deemed difficult. Some companies have to sell their mixed materials with lesser value and other companies have to find markets for their unwanted waste. Companies which use fewer types of materials and types of materials that are recyclable have less problems with recycling.

5.2.3.9 Employee constraints

Examples of employee constraints are problems with employee's attitude, awareness and support, which is important for companies to implement any strategies and to drive changes. Three (3) companies reported that employees are too apathetic, lack discipline in continuing to realise the strategies, fear to change when introducing new practices and also lack awareness of Material Efficiency and the company's environmental target.

5.2.4 Accelerators

Accelerators are factors that help speed the implementation of companies' Material Efficiency strategies. There is a difference between factors that motivate a company to implement, factors that influence the choice of Material Efficiency strategy and the accelerators meant in this discussion. The accelerator in this particular context is

anything that is already there in the company regardless of whether the company decides to have Material Efficiency or not. The accelerators shown below are evidence gathered from the study.

5.2.4.1 Management awareness and knowledge

Management awareness on the whole issue of environmental impacts and its cause can help with the implementation of Material Efficiency strategies. Having some sort of social responsibility, social awareness and ethics at the company level helps accelerate implementation of seven (7) companies' Material Efficiency related strategies. It helps by way of facilitating communications; reducing barriers to decisions to take up strategies, and by more allocation of time, money and effort to execute strategies. High management awareness causes the environmentally related strategies to become imbedded easily into the companies' strategies, aims and objectives. Having management with high awareness also makes the strategies communicated from the top down.

5.2.4.2 Available technology

Available technologies involved with the advancement of products, production and materials help accelerate the implementation of Material Efficiency strategies. Examples of such technologies are advanced tools, advanced materials, knowledge and efficient modern machineries which can help with recycling, material recovery and waste reduction. There are at least five (5) companies which revealed that technology helps them a lot in reducing waste and material usage. Although technology seems to be moving faster, Company 3 views it as a choice and not as pressure to adopt. The company says that it always seeks compatibility between design and technology so the products will last longer.

5.2.4.3 Suppliers

A good relationship with suppliers is one of the top accelerators for Material Efficiency implementation at five (5) companies. Good relations mean that the companies work with proactive suppliers, have a close relationship, are able to educate and share knowledge with suppliers and are also able to influence suppliers. Companies usually choose suppliers to make sure they can establish this close relationship. A good supplier means they are willing to respond to the company's Material Efficiency requirements. Company 3 says suppliers which have good common sense are all that they need. Suppliers like this will respond to company requirements such as environmental and ethical audits, working with companies to reduce packaging, understanding that companies want to reduce materials during purchasing and reduce waste during manufacturing.

5.2.4.4 Employee awareness

Evidence shows that at least four (4) companies have employee awareness as an accelerator for the Material Efficiency strategies. Employee awareness is there when the employees know what their company material efficiency is and general environmental target, what role they have to play and what discipline they have to observe to achieve the target. Company 7 knows that any programs are difficult to run without support and awareness by employees and have put in effort to educate the employees. To make sure employees get the practices from the beginning, training is given and company environmental objectives are briefed when they join the company. These companies also communicate the policy, targets and strategies widely and encourage employees to achieve the targets. For example Company 8 gives a bonus for employees achieving the material efficiency target.

5.2.4.5 Company's culture

Company culture is important in shaping management and employee attitudes and working styles. It also influences the companies' overall strategies and objectives. Several interviewees gave evidence that the company's culture is important in making the implementation of Material Efficiency related strategies possible. It also influences the management and employees working style such as team work. Companies whose parent company is a Japanese company or companies who are adopting Japanese management culture and practices such as lean production have a unique company culture. Two (2) companies say that Japanese culture influences how they view waste and material efficiency. This in turn affects how the companies view waste and resources and then accelerates the implementation of Material Efficiency strategies. Another example of a company's culture is evidence from Company 2 which is a small-medium size company and has a strong family-oriented culture. The company is not owned by public shares but wholly owned by its employees. The interviewee explained many times that family-oriented culture influences how they treat environmental impact and waste inside the company and in the surrounding area.

5.2.4.6 Lean production system

A lean production is an accelerator for Material Efficiency strategies. Having a system and disciplines that see waste as things which should be eliminated gives an advantage for companies to implement Material Efficiency strategies. At least three (3) companies say that having lean production makes their task of running Material Efficiency strategies easier and it becomes effortless and natural.

5.2.4.7 Product types

The type of product produced, the type of materials used and types of waste produced help companies implementing Material Efficiency strategies. Companies which use

easy materials such as metals are more motivated in carrying out recycling activities as it is more straightforward to do so. Evidence from three (3) companies shows that the type of product that the company produces and the type of material used can be an accelerator to the Material Efficiency strategy implementation. For example, some materials or products are easily recycled compared to others. Some products are better offered as product service oriented compared to others or are more cost effective by prolonging their life.

5.2.4.8 Environmental standards and ISO 14001

ISO 14001 is environmental management system that can be an accelerator to Material Efficiency strategies. Although almost all companies have ISO 14001 standards, evidence at three (3) companies shows that ISO 14001 can be an accelerator for Material Efficiency implementation. Having ISO 14001 can be a simple indicator that the company is willing to improve their environmental practices. Companies which have ISO 14001 are concerned with the environment and are more likely to take up other environmental strategies.

5.2.4.9 Communication

Good communication inside the company so that management and employees can communicate effectively is an accelerator to the Material Efficiency strategy implementation. There is evidence at three (3) companies which shows that communication is an important factor that helps with the speedy implementation of any strategies. Company 2 for example communicates with employees to find out problems with waste and material efficiency and consider their suggestions.

5.2.4.10 Environmental target from top management

Having an environmental target is one of the factors that accelerate Material Efficiency implementation. Three (3) companies have it cascaded clearly from top management. This is communicated often inside the company and also published in yearly environmental reports. These targets are general and specific strategies are cascaded down to each business function for each of them to achieve.

5.2.5 Benefits

Benefit is something of advantage gained by companies when implementing Material Efficiency strategies. This section shows evidence of benefits frequently gained by the companies studied.

5.2.5.1 Reduced cost

Reduced cost is no doubt the most significant benefit that is quickly spotted by companies especially for companies which do monetary measurement. Eight (8) companies agreed that having Material Efficiency strategies reduces waste and material usage thus leading to reduced overall cost and saves them money. Company 1 commented that having a *"revert strategy"* can give it the advantage of having a steady supply of raw material at a competitive price. Company 10, where the waste cannot be recycled but down cycled to a lesser grade, has no choice but to try to prevent waste as much as possible. An assessment made by Envirowise[6] on Company 8 in the year 2003 showed that the company achieved cost savings of £151 000/year after the company did waste minimisation programme.

5.2.5.2 Reduced waste and environmental impacts

Reduced waste is another significant benefit reported by companies. Not all companies however can give evidence in terms of numbers of reduction in waste as some of them do not measure waste. There is evidence at four (4) companies that shows that strategies they practice contribute to a reduction in waste. Although there is no evidence from other companies that does not mean that waste is not reduced as that evidence was not captured during interviews. Reduction in waste includes minimising persistent waste which goes to an incinerator and to landfill. These wastes alternatively are recovered as input to their production, or to sell to suppliers to become other companies' resources. Company 8 achieved 395 tonnes/year of waste reduction in 2003 after a waste minimisation exercise helped by Envirowise.

5.2.5.3 Reduced virgin and incoming materials

Three (3) companies say that strategies have reduced their use of virgin materials or incoming materials. These either minimise materials that will become waste during the processes or materials supplied and needed during the processes. The material supply is reduced when virgin or incoming materials are substituted with recycled materials that have been recovered and close-looped into the production processes by the company. Minimising materials during purchasing can reduce waste as the company only brings in materials as needed and strives to maximise materials usage during manufacturing processes. Examples of this strategy are practiced by companies ordering material parts

[6] Envirowise is a free, government-funded programme which gives advice to UK businesses on environmental issues, such as how business can improve efficient use of raw materials and resources and do waste reduction at source. (http://www.envirowise.gov.uk/)

that are close to size and use forging to get the part size needed rather than order in billet form. Minimising materials coming in also includes minimising packaging coming in which also will reduce waste. Company 4 encourages suppliers to take back their packaging and re-use them. Segregating and recycling materials back into production can save a lot of money over purchasing new materials. Not all companies can do this as it depends on how complex materials have been mixed at the end of the process and on degradation issues.

5.2.6 Practices

A practice is a tool, action, technique, method or strategy taken up by companies in employing Material Efficiency strategies. The section below shows evidence of the most frequently used practices at the companies studied.

5.2.6.1 Material and waste recovery

All ten (10) companies interviewed do at least some waste and material recovery. In fact this is the most popular and first strategy companies chose to do. This includes segregating, recycling and re-using materials, for example, Company 3 does repair, refurbishment and remanufacturing. These are ways to recover material and waste and return it as input into production or to avoid waste become persistent waste. Waste also can be avoided from becoming persistent waste by offering it as a resource to other manufacturers, as practiced by Company 2, 3 and 4.

5.2.6.2 Design

Changing design is the second most frequently mentioned tactic used by the companies studied. In design, eight (8) companies out of ten are trying to reduce waste and materials use through product design during manufacture, during use and after use. The designers at least try to meet one of them if not all. Among the tactics they use are designing for the environment, using environmentally benign materials and designing more environmentally friendly manufacturing processes.

5.2.6.3 Relationship with suppliers

Maintaining a good relationship with suppliers is one of the good practices that seven (7) companies have or are trying to establish. As stressed earlier a good relationship is an accelerator for companies in realising Material Efficiency strategy. This good relationship means that companies work with proactive suppliers, have a close relationship, are able to educate and share knowledge with suppliers, and are able to influence suppliers in order to achieve their Material Efficiency goals.

5.2.6.4 Relationship with customer

Building a good relationship with the customer is one of practices used by companies. At least seven (7) companies do communicate, educate and influence customers on decisions about products regarding sustainable choices. This includes strategies such as working with the customer, helping the customer in their choice and listening to the customer for suggestions. Companies also offer choices for take back and returns, and after sales services.

5.2.6.5 Efficient use of materials

Six (6) companies interviewed practice efficient use of materials tactics. These include purchasing close to size parts, reducing the products materials and weight, reducing the material input, checking incoming material specifications and reducing packaging. Another instance of efficient use of materials is Company 7 using grease instead of oil as a coolant.

5.2.6.6 Use tools, techniques, environmental programmes and standards

Most companies use one or more tools or techniques, and they reported that the tools are helpful or likely to be helpful (some companies had just introduced new tools and could not link the tool to evidence of improvement). These companies hoped that tools would act to improve motivation for material efficiency, though there was no direct evidence for increased motivation. At several companies, for example Company 2, the interviewee did say that tools and techniques help them to reduce materials usage and waste and to improve material efficiency. Tools can be techniques and equipment which can be used during designing, production and so on. For example tools such as LCA software can help companies to analyse environmental impacts of their products and processes. Target and strategies can also act as a motivator tool for companies to help them to move in the direction they desire. These include techniques, methods or systems such as a Coolant Management System, ISO 14001 standard, Lean Manufacturing, Zero landfill, Zero matrix, Energy saving, Pollution Prevention, Take back policy, Clean production and much more.

5.2.6.7 Environmental target and objectives

Six (6) companies have targets and objectives to improve the companies' material efficiency and waste reduction. All these environmental targets and objectives are communicated to employees inside the company or made available in company environmental and sustainability reports or on the company's website. Company 3 has a clear fixed environmental strategy cascaded down from the top management. Company 6 on the other hand, chooses to have an environmental target put somewhere that can be seen by employees and visitors to motivate and increase awareness of the company's environmental strategies among employees and visitors.

5.2.6.8 Measurement and audit

At least five (5) companies measure their waste and the effectiveness of their Material Efficiency strategies. But most of measures are confined only to simple measurement such as monetary, weight, volume and percentage. This measurement is to inform actions and for communication purposes. Out of these five companies, two companies do waste audits to track the movement of their waste. There is one company, Company 4, which refuses to do measurement as it views the act as a waste of time. The company has a target to do material efficiency as much as possible and refuses to spend time checking and measuring.

5.2.6.9 Select, educate and train employee

Five (5) companies educate and train employees to make them understand the company strategies and goals on material efficiency. Company 3 only selects employees who are quick to understand the company's business to make sure the employees are aware and understand the company's business and strategies. Encouraging employee awareness is done by not only communicating with them but by listening to their suggestions as well. The selection of employees is done to imbed new practices and to allow employee self-empowerment and discipline.

5.2.6.10 Product service system[7]

Five (5) companies interviewed provide more services other than the traditional way of offering the product. Company 4 provides solutions and services rather than products. Company 3 provides products that are designed to last a very long time, thus providing service by adding solutions if required and repairing and enhancing the existing products. Company 1 and 4 offer a rental service and are responsible for part repairs. Company 9 does offer the service of taking back the customers' old products, and making the product return policy easier. These services which companies offer can reduce waste from customer usage, which most companies would happily leave to the customer to handle. In fact these companies find profit by offering the service to the customer, and some companies get back the materials and re-use them to produce products and services.

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[7] 'A product service-system is a system of products, services, networks of "players" and supporting infrastructure that continuously strives to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models' (Goedkoop *et al*, 1999).

'Product Service-Systems (PSS) may be defined as a solution offered for sale that involves both a product and a service element, to deliver the required functionality' (Wong, 2004 as cited by Baines *et al*, 2007).

5.2.6.11 Prolong product's life or material's life

This strategy is adopted by four (4) companies interviewed. However this strategy however may not suitable for all product types. Some companies' encourage the customer to change products by putting fashion into it which makes the customer feel they have to change products because of trends. Some feel they need to change because the technology which supports their products changes. Some change because they cannot upgrade their product performance because the product is not upgradable, but a few companies interviewed are happy to prolong their product life for customer usage. This includes designing products that can be upgraded, are compatible with technology, and that come with services.

5.2.6.12 Manufacturing and machine efficiency

Increasing manufacturing and machining efficiency is a strategy adopted by four (4) companies. Examples of strategies to improve manufacturing efficiency gathered from the study include tactics of having close-to-size parts, redesigning the system, redesigning the processes, improving the process and layout to reduce waste, designing out toxic processes, choosing sustainable manufacturing processes, designing out hazardous processes and maximising materials usage during machining and having efficient machines. For example, evidence given by Company 8 shows that the company always strives to improve its manufacturing efficiency by optimising the use of space by re-engineering the warehouse layout; optimising the use of raw materials by standardizing the preparation process for line operators and much more. Company 8 also relies on efficient machines to reduce waste and materials usage by investing in the latest machines that are more efficient. They reported that having efficient machines that produce less waste saves them a lot of money.

5.2.6.13 Implement sustainable strategies

Almost all companies investigated were incorporating Waste Minimisation and Material Efficiency related strategies. Five (5) companies implement Resource Efficiency related strategies. To what extent they embrace their Resource Efficiency strategies is not known as this was not investigated in this study. Only two (2) companies claimed that they implement waste and Resources Efficiency strategies and also aim to minimise the impact on society and future generations. These two companies are considered as practicing Eco-efficiency because they are making an effort to reduce the wider impacts.

5.2.6.14 Lean Production System

Four (4) companies interviewed have successfully implemented lean production. These companies also are the most advanced in their Material Efficiency strategies. Two (2) of the companies say they probably operate at Eco-efficiency levels. Three (3) out of these

four companies are Japanese manufacturing plants in UK. All of them say that lean production helps with the Material Efficiency and waste reduction strategies. Having lean practices and systems in place, they are trained to improve any wasteful processes and identify waste. This includes material and energy waste. In lean production, waste is cost and should be eliminated.

5.2.6.15 Reduce packaging materials

At least three (3) companies do make efforts to reduce packaging. Reducing packaging involves a reduction of waste in-house and also a request to suppliers to reduce packaging that comes with products and materials. To do this the companies have to inform and work actively with suppliers. Reducing packaging includes packaging considerations such as reducing packaging materials, using environmentally benign material, and using multipurpose packaging.

5.2.6.16 Legislation compliance

Three (3) companies are putting special efforts into complying with regulations. Company 3 goes to the extent of trying to always stay one step ahead of any environmental legislation anywhere in the world. This is done by putting a special officer to look into this issue alone. This is to make sure their products are accepted in any country in the world without any legal problems on environmental issues.

5.3 Issues and Concerns with Qualitative Data Analysis

Doing qualitative analysis is not an easy task as it is proven to be painstaking and lengthy. Cross-case analysis does not just involve an act of putting nodes from each individual company together and analysing them but the researcher has to perform the research rigorously to make sure the research quality is maintained.

There are weaknesses of qualitative analysis as pointed by Denscombe (2007) where the five disadvantages are: *i) The data may be less representative, ii) Interpretation is bound up with the 'self' of the researcher, iii) There is a possibility of decontextualising the meaning and iv) There is a danger of oversimplifying the explanation v) The analysis takes a longer time*. These weaknesses are eliminated by the researcher employing several tactics and the tactics used are discussed in greater detail below.

The data may be less representative. Denscombe worries about qualitative analysis being attacked for its generalisability because many researchers are judging generalisability through a quantitative stance. However, according to Gummesson (1991, as cited in Collis and Hussey, 2009) in a phenomenological study, generalisation is sufficiently done by generalising from one setting to another, unlike positivistic study which is generalising from a sample to a population. There is generalisation as long as the study captures the interactions and characteristics of the phenomena being studied

(Normann, 1970, as cited by Collis and Hussey, 2009). More discussion of the generalisation of phenomenology study is explained by the researcher in sub section 3.3.3 at Chapter 3 Research Methods. More explanation of how the researcher increased generalisation or external validity is explained in Chapter 6 of Validation.

Interpretation is bound up with the 'self' of the researcher. The researcher's own identity, background and beliefs have a role in influencing the creation and analysis of data. To avoid this bias, the researcher has taken several measures such as recording the interviews, transcribing, performing peer checking and validating the findings. These measures are also explained further in Chapter 6 of Validation.

There is a possibility of decontextualising the meaning. The researcher is aware that it is easy for the data from words to get taken literally out of context, which is a real danger in qualitative analysis. According to Denscombe, decontextualising happens when the meaning of data is lost or transformed by wrenching it from its location while doing coding and categorising. During analysis, the researcher has taken great care doing the analysis by using NVivo software that helps in locating the context in its actual transcription when needed. The researcher also recorded the analysis process clearly stage by stage so it is possible to check how the themes developed. By doing the cross-case analysis twice, the researcher tried to minimise 'decontextualising' errors.

There is a danger of oversimplifying the explanation. Oversimplifying the explanation in this regard according to Denscombe involves the possibility that the researcher will underplay or disregard data that does not fit because of its inconsistencies, ambiguities or alternative explanations that can inhibit clear generalisation. The researcher tried to eliminate this danger by continually referring to transcriptions of each case during the analysis. Using qualitative analysis software such as NVivo makes this process of getting back to the original sources easier.

The analysis takes a longer time. This is true, and the researcher has taken the necessary approach to help with the analysis. The researcher used the NVivo software to help reduce the data and to aid the analysis by helping with assigning codes, sorting and data management. The software also helped the researcher in tracking the findings back to their context. All data was kept in the form of transcriptions and analysis, done step by step, and recorded so that the findings emerged from a rigorous and trustworthy analysis.

The researcher is aware of issues that could affect data analysis and that whatever approach is taken, there will be advantages and weaknesses. The researcher did try to minimise the bias and weaknesses as much as possible in order to conduct a rigorous research process and to present valuable findings.

5.4 Chapter Conclusions

This chapter shows the evidence resulting from cross-case analysis. Compared to Chapter 4, this chapter shows evidence which emerged when all the individual evidence was put together and analysed. There are no quotes presented in this chapter as they are already presented in Chapter 4, hence evidence in this chapter is only in the form of themes and descriptions of their significance. From ten cases which have been analysed, the analysis gives 116 themes of which 55 themes have been selected as significant. From these 55 significant themes, 9 are factors that catalyse the company to have strategies, 8 are factors that influence the type of strategies, 9 are constraints, 10 are accelerators, 3 are benefits and 16 are practices. The full list of themes can be found at Appendix 5.2. The group of significant themes from this chapter is not final but it is working towards answering research questions. In this chapter, issues and concerns that possibly could affect findings and research quality and rigour have also been pointed out. Consequently suitable measures that have been taken to reduce these concerns during data collection and analysis were also discussed. To further reduce the threat to qualitative results, validation will be carried out. In the validation process, the significant themes that have been described in this chapter will be confirmed or rejected to increase the research quality which will be explained in greater detail in Chapter 6.

6 VALIDATION

The overall aim of this chapter is to show that the researcher was being careful by reducing validity and reliability threats during data analysis and while generating the findings. The data processing and analysis were done carefully and several tactics were employed to maintain research quality. Themes which were generated from cross-case analysis were refined in this chapter through careful selection of the valid ones by rejecting or confirming them after comparing them to secondary data of an expert's opinions.

6.1 Validation during Data Processing

This chapter will show how the researcher performed the validation both during data analysis and on findings in order to enhance the research quality. A high quality of research is necessary for this study to make sure that this piece of work is credible, transferable, dependable and confirmable.

Unlike quantitative research, qualitative research involves intensive study on small groups or units within the subject as analysis, so the studies are bound to be in depth. It is easy for a qualitative researcher to get overwhelmed and lost as interpreting qualitative data is not easy and is time consuming. Padgett (1998) presents a list of strategies that are commonly used by researchers to increase research validity namely: *prolonged involvement; triangulation; peer debriefing and support; member checking; negative case analysis;* and *audit trail*. In this study, the researcher employed two techniques to improve research quality during data analysis. These are *member checking*; and *audit trail*. Both validations undertaken are explained in the next subsections.

6.1.1 Validating data processing and interpretations using Member Checking

Member checking is one way to increase research credibility. The researcher compared the analysis of coding from two interviews' transcriptions with codes from another researcher who also studied the subject matter. The other researcher in this exercise was the supervisor who had been asked to code separately and compare the results with the researcher's codes. On one transcript, there was a 62% similarity and the other one also had a 62% similarity. This shows that the researcher's interpretation ability was not inept. This also can act as peer support which contributes to guarding against researcher bias. Although Holloway (1997) disagreed that superiors should participate in peer debriefing because of the power relationship involved, the involvement of the superior in this exercise was to check the interpretation skills of the researcher not to overrule the results. The extract page of the comparison table is shown at Appendix 6.1.

6.1.2 Validating data processing and analysis using Audit Trail

Geertz (1973a, as cited by Bryman 2008) encouraged qualitative researchers to produce a "***think description***", that is a rich account of a subject studied. These descriptions then can be used by other researchers as a database for making judgements about the possible transferability of findings to other settings (Guba and Lincoln, 1985). In this research, interviews were recorded with interviewee permission, they were transcribed and analyses were documented. This method proved useful to the researcher because during analysis the researcher is always checking back to the source if any doubt arises. Complete records of transcriptions, audio and data analysis decisions were kept in an accessible manner as required to prove that this research is dependable. This no doubt increased the research quality of this piece of work because the researcher was being careful. An example of an interview transcription is given at Appendix 6.2.

6.2 Validating Findings

In interpreting the data, several tactics were employed to reduce researcher bias such as using secondary data and expert opinions to confirm or reject findings. Below are the validations done to the set of significant themes that emerged from cases analysis. Validations were done by comparing the findings to secondary data which is Waste Reduction evidence as reported by the House of Lords (2008). The Waste Reduction inquiry included verbal interviews between the House of Lords committee and the representatives from government agencies, academics and companies, including many manufacturers who were represented by senior managers.

These evidences are highly reliable, due to the seniority of the people answering the questions and the full transparency of both the answers and the questions. Each person giving evidence received a full set of primary questions at least 2 weeks before giving evidence. The Inquiry Committee starts with these questions and can then develop their own, making it a well-organised semi-structured interview. Interviewees are sent the transcripts and can comment on them before publication, including sending additional data. Although the data used are secondary data, the data was transcribed into 499 pages of text and published by the House of Lords; the interviewees were carefully selected experts from well known academics and industries (achieving a much higher ratio for replying to research inquiries than is typical in academic research). The researcher judges this to be of sufficient transparency, validity and reliability to be used as secondary data. These transcribed evidences were uploaded into NVivo software to help the researcher do the analysis more efficiently and, most importantly, more effectively. Appendix 6.3v shows an excerpt of interview transcripts from one of the inquiry sessions. The validation process took over 6 weeks, as the coding process is time consuming. However the process was faster than the coding done for the within case analysis, as the themes were pre-determined. The validation process starts when the researcher read and re-read the evidence, and did coding for data reduction. The coding

starts with an open coding followed by axial coding. Selective coding was mostly skipped as for the validation process, pre-determined themes were used (the themes from cross-case analysis). A selective coding technique was used when the researcher found evidence that can be established as new nodes which did not appear to belong to any of the original themes. These themes are considered 'new themes'. Initially in the validation, the researcher was looking for evidence to support or reject the themes and also took note of the significant comments made during the inquiry. The researcher found that most themes were confirmed, including the ones that were excluded earlier by the researcher (least significant). There were only a few rejections when themes were compared to evidence from the House of Lords. These were then dismissed by the researcher as the themes rejected were also confirmed by other interviewees in the inquiry report (the Lords Inquiry itself had drawn conclusions regarding the inconsistent evidence presented to them). The 'new themes' which were not presented in the findings were highlighted if it was found that there was strong evidence in the report. There are 68 quotes for 10 new themes; there are 26 quotes for 14 rejected themes and 586 quotes that supported the original 122 pre-determined themes. The total quotes discovered were 680 quotes which indicate that the validation carried out by the researcher was both thorough and extensive. The cover page of the House of Lords report, the list of interviewers, interviewees and questions posed by the committee are at Appendix 6.3i, 6.3ii, 6.3iii and 6.3iv.

The following subsections show evidence in the form of selected quotes excerpted from the report that were used to confirm and reject themes.

6.2.1 Factors that catalyse to have strategies

All themes under the ***factors that catalyse companies to have strategies*** were confirmed. Only two themes were rejected but nevertheless confirmed at the same time. The ***Legislation*** theme was not fully rejected as it is not one of the factors that catalyse companies to have strategies, but rather it shows that sometimes there are companies who get away with legislation if the legislation is not correctly enforced. Thus according to the evidence from the House of Lords, the legislation effectiveness is questioned; it is not truly a factor that motivates companies to implement a Material Efficiency strategy.

Confirmation

Factor/catalyse	***Occurrences***	***Sample quotes***
Cost reduction	*12*	*'... if you were to talk to manufacturers, of course, they are interested in **cost reduction**. They see waste as cost and they are interested in stripping that cost out of their*

		manufacturing system.' (Professor Simon Pollard, Cranfield University Centre For Resource Management And Efficiency)
Customer Influence	*11*	*'Sustainability is not a key consideration at the moment although more and more businesses are beginning to take certain aspects of sustainability into consideration such as ease of material recycling. This is more common practice with larger businesses (ie companies such as Panasonic, Herman Miller). Drivers include legislation,* ***consumer demand*** *and supply chain considerations.' (Dr O'Connor, Eco-design Centre Wales)*
Company's image, and social responsibility	*14*	*'….* ***corporate social responsibility*** *was used as a marketing tool in the past and I think now because of public awareness and because of pressures from environmental groups these commitments will be a voluntary commitment, policed by the public and by environmental groups, so corporate responsibility is actually meaning an awful lot more and is developing into voluntary commitments.' (Mr. Christopher Murphy, Deputy Chief Executive, The Chartered Institution of Wastes Management)*
Management awareness	*1*	*'As one of the world's largest IT companies, HP's greatest impact on the environment is through our products.* ***HP is committed*** *to providing products and services that are environmentally sound throughout their life cycles. Environmental impacts occur at every stage of the product life cycle: from product design, through manufacturing and transport, to use by customers and, finally, disposal at the end of a product's life'. (Memorandum by Hewlett Packard)*
Employee awareness	*2*	*'We believe that sustainable approaches to waste reduction* ***requires a change in attitude****. In particular, there needs to be a greater appreciation that the efficient use of resources is not only desirable but that the decisions of individuals can make important contributions to improving the efficiency of resource use.'(Memorandum by Envirowise)*

Competition	*4*	*'The drivers have been **commercial** as well as environmental but they have had significant benefits. '(Mr. David Workman, Director General, British Glass Manufacturers' Confederation)*
Company's culture	*3*	*'I happen to have had quite a lot of experience of dealing with **Japanese** companies when I was in government and with parties over here and visiting them in Japan. I will not repeat the examples that I referred to in our evidence last week but, quite apart from any long term government measures, they always seem to me to have had a very high emphasis on getting their costs down, using their employees in little circles in the business to come up with suggestions and so on in a way which is rather unusual in **British business**. It is surprising to me, as there is profitability at the end of all this.' (Lord Crickhowell, House of Lords)*
Legislation	*15*	*'….so I think that these kinds of situations are starting because they are being **driven by the directive** in the legislation that says they have to take responsibility for these things, but there are only a few parts of industry where that is happening.' (Dr Norman Swindells, Chairman, Sustainable Development Group, The Institute of Materials, Minerals And Mining)*
Material price fluctuation and availability	*5*	*'You probably know that for every kilogram of aluminium that is processed you need 6 kilograms of bauxite. In other metals it is much, much higher. We are **rapidly running out of many of the most important minerals**. As a chemist, in 80 to 100 years' time a significant proportion of the Periodic Table will not be available to us unless we start to do a better job of capturing and reusing our resource.' (Dr Michael Pitts, Priorities Manager, Chemistry Innovation Knowledge Transfer Network).*

Validation

Rejection

Factor/Influence	***Occurrences***	***Sample quotes***
Legislation	*2*	*'Government as the regulator and its agencies as enforcers should first ensure that waste laws are practical in application and simple to understand. Industry views should be listened to and UK competitiveness protected. Like manufacturers' good design, legislation should be tested for unintended consequences. Once laws are passed they must be correctly enforced, those who comply often have to invest heavily whilst those who do not comply escape both investment and too often enforcement.' (Memorandum by The Society Of Motor Manufacturers And Traders Limited)*

6.2.2 Factors that influence the choices of strategies

None of themes under factors that influence companies to choose types of strategies were rejected but in fact all were confirmed. Below are the quotes taken from the House of Lords report to show the confirmation.

Confirmation

Factor to choose	***Occurrences***	***Sample quotes***
Cost reduction	*2*	*'.... I think it is true for all of our companies that environmental performance and sustainability is right up at the top of the agendas of all the companies, but it goes hand in hand with* ***cost efficiency****.' (Mr. Andrew Clack, Environmental Affairs & Corporate Social Responsibility Adviser, Panasonic UK Ltd)*
Product's type	*5*	***'Glass is 100 per cent infinitely recyclable****, not just once, it can be* ***recycled*** *time and time and time again and the infrastructure exists in the UK to handle it.' (Mr Rick Hindley, Chief Executive Officer, Alupro)*
Management	*2*	*'We believe that sustainable approaches to waste*

awareness		*reduction require a **change in attitude**. In particular, there needs to be a greater appreciation that the efficient use of resources is not only desirable but that the **decisions of individuals can make important contributions** to improving the efficiency of resource use.' (Memorandum by Envirowise)*
Customer requirements	*7*	*'Another barrier to realising resource efficiency within your own process in your part of that supply chain is the **customer requirements**. Often what we find with our members is their customer is saying, "We want this product and we want it made in this way." You have to follow that criterion. It is very difficult for these companies to change their process because of the customer requirements. The customer requirements are king, so if they can even see **resource efficiency opportunities t**hey might not be able to effect that change. That is what we are finding.' (Mr Gareth Stace, Head of Environmental Affairs, EEF The Manufacturers' Organisation)*
Legislation	*4*	*'Another driver is **existing regulatory requirements**. For example a **particular type of material used** for packaging might have less environmental impact compared to the use of another material. However the end product might not comply with food hygiene laws.' (Memorandum by EEF The Manufacturers' Organisation)*
Available technology	*5*	*'Innovations in chemistry have a huge part to play in reducing waste in downstream sectors. The construction industry is an example of a sector where increased use of sustainable materials and design for ease of dismantling and separation could have a huge impact in reducing waste. **New chemical technologies** will be needed to achieve this such as new adhesives and high-performance insulating materials from sustainable sources.' (Memorandum by Chemistry Innovation Knowledge Transfer Network and the Chemical Industries Association)*
Company's image and social responsibility	*8*	*'Particularly looking at the case of Philips, for example, who in their latest **sustainability report** have actually identified that ten per cent of global revenue now is from*

		*their so-called **green flagship products**, of which one of the strategies they use is materials reduction.' (Martin Charter, Director, Centre for Sustainable Design , the University College for the Creative Arts)*
Company's culture	*3*	*'Firstly, the difficulty with SMEs is there is a lack of internal resource to drive those changes through. That same lack of internal resource may mean that they cannot manage an external programme either, so if somebody comes in, the SME may say, "That is all very well. You are going to do it for us but I have to find the time to manage it", there is also **frequently a belief** that "I do not really need you because I can do it all myself".' (Mr. Jonathan Davies, Environmental Industries Commission)*

6.2.3 Constraints

All constraint themes resulting from the study were confirmed with the evidence from the House of Lords. However from the House of Lords evidence, several additional constraints surfaced. Among the issues raised were SME's issues; and regulation, standards and legislations constraints.

Among issues of SMEs are that the ***company size*** is too small to get attention and influence suppliers on green practices, they lack resources such as funds and time to address sustainable issues on their own. They are also lacking awareness and knowledge on legislation and how to implement sustainable strategies. The SME's although always excluded from the regulatory framework have an accumulative effect according to Ecodesign Centre Wales. This particular theme was in the researcher's list of themes but was taken out before validation as it only represented a problem in one company. Due to this constraint being cited many times in the House of Lords report, the researcher decided to take this theme as a significant constraint.

Regulation, standards and legislation is the barrier most commonly mentioned by the interviewees in the House of Lords report (not surprisingly, given the remit of the Inquiry). The stated issues with the regulation, standards and legislation are: there are some cases of conflict among regulations that make the manufacturers confused as to which one to follow because meeting one legislation sometimes makes products fail to meet another standard. Another reason is that the narrow definition of waste makes it difficult to reuse the useful by-products. The current policies, regulatory and legal frameworks are also criticised as they seem to confuse and do not support the development of better and more sustainable products and processes.

Confirmation

Constraint	***Occurrences***	***Sample quotes***
Design constraints	*16*	*'The function of a designer and the function of a producer of a product is to design something that is fit for purpose, and we have to accept that because consumers want to buy products that are fit for purpose and functioning, and that is where the* ***design constraints*** *are.' (Professor Sue Grimes, Centre for Environmental Control and Waste Management, Imperial College London)*
Measurement and target	*6*	*'Many of the solutions would not be immediately foreseeable beforehand; some of it was actually to recognise that what they were throwing away had a commercial value. That had not occurred to them, and it had not occurred to them because they do not see it because of the* ***lack of measurement*** *within their processes.' (Mr Michael Glass, Chief Executive Officer, Process Industries Centre for Manufacturing Excellence)*
Decision making	*13*	*'I would like to add to and support Ms Bickerstaffe's point there. I think that* ***we need to have a balance*** *between recycling where it is economically and environmentally beneficial and not focus on all packaging material having to be recycled. There will be a balance in the spectrum of materials where at some point we will have to say, "No, these very small yoghurt pots", for example, "to collect and recycle them is really just not worth the effort. We will be much better burning them and taking the energy back". Again, it is this* ***big picture piece, to make that decision****.'(Dr Forbes McDougall, Environmental Manager, Proctor & Gamble)*
Supply chain and supplier constraints	*8*	*'No. It would be very difficult here because we have a much more* ***diverse supply chain****, a very different mechanism for collection. We generally have a very unsegregated waste recovery chain which makes it very difficult to do that.' (Mr Arnold Black, Network Director, Resource Efficiency Knowledge Transfer Network)*

Product's types	*9*	*'The barrier to the wider adoption of both processes is the variability of the waste streams, and the risk of contamination. We have yet to devise processes that can reliably produce raw materials of the required quality from the general waste streams. This is made more complicated by the tendency to increase* ***the complexity of materials used in industry*** *in order to gain other benefits in performance and environmental impact. For example, modern window glass is frequently coated to give additional benefits such as self-cleaning properties or control of solar gain. From the point of view of recycling this is a contaminated material which is extremely difficult and costly to clean up.' (Memorandum by Chemistry Innovation Knowledge Transfer Network and The Chemical Industries Association)*
Organisational barriers	*13*	*'I think there are already quite a few mechanisms, but as I see it first of all I deal with many manufacturing companies and I would say that the single biggest barrier to reducing waste or improving anything is the* ***lack of awareness amongst the senior people*** *in the business of the real potential for improvement. Many are carrying on doing things the way they have always done and have not been particularly receptive to learn. One can offer advice but it is of no value unless it is actually implemented and something is done with it, and we do not have a nation of implementers when it comes to business, I would say.' (Mr. Michael Glass, Chief Executive Officer, Process Industries Centre for Manufacturing Excellence)*
Manufacturing processes constraints	*5*	*'Manufacturing and* ***business practices are often inherited****, or have developed in an ad hoc way. Small companies may not be aware that more resource-effective processes exist. However, finding out may be beyond their scope.' (Supplementary memorandum by Dr Claire Barlow, Senior Lecturer, Institute for Manufacturing, University of Cambridge)*
Recyclability	11	*'But the problem we have is that the* ***materials available from the recycling stream are not in high enough quantities*** *to make it viable for us to use. We are trying at this moment to clarify a stream of plastic that is useable. Obviously when we make a mould, that mould is designed*

		*for a specific plastic requirement and specific plastic properties—melt-flow index, and all that sort of thing. We have found that we cannot get a big enough supply to make it effective for us to change. We can get 10 or 15 tonnes, but when you talk, as Ab said, of a minimum of 1,000 to 1,200 tonnes to make it reasonable for us to change a mould to accept recycled material. We have in the past used significant volumes of materials, and certainly on previous models have used a significant amount of PET from plastic bottles, but, unfortunately, the newer trend of televisions, which are the flat panel TVs, tend to require a different quality of plastic, and therefore we have had to move away, back to high impact polystyrene—**we cannot source the material to the volumes we require to meet that demand**.' (Mr. Peter Evans, Senior Manager Environment, Sony UK Ltd)*
Employee constraints	*1*	*'In much of the work of Envirowise, changing behaviour is key to improving the efficiency of resource use and the consequent reduction of waste. It is our view that few people understand how to use the "waste hierarchy" within their approaches to decision-making. In addition, **very few people in business seem to appreciate** the need to reduce resource use or that their purchasing decisions have an effect on the use of resources. Even people who do want to reduce resource use may not have information on how to do it.' (Memorandum by Envirowise)*

Additional Themes

Constraint	***Occurrences***	***Sample quotes***
Company size	*12*	*'SMEs typically have little influence on the supply chain, up or down. They can rarely improve their market potential by being actively "green". (Supplementary memorandum by Dr Claire Barlow, Senior Lecturer, Institute for Manufacturing, University of Cambridge)* *It is important to distinguish between SMEs and big businesses in their capacity to react to the waste agenda. SMEs rarely have the human or economic resource to*

		*invest in developing new solutions. Rather, **buried in supply chains** and, all too often, in fire-fighting mode, they can only react to the demands of clients, legislation, and increasing costs of energy and waste management.' (Memorandum by Social Environmental Enterprise And Design Foundation)*
Regulation, standard and legislation	*10*	*'A major problem for the reuse and recycling industries lies in the **legal definition of waste**. In some situations, a perfectly acceptable reusable by-product of waste treatment will still be regarded as waste requiring any user to have a waste management license.' (Memorandum by Professor Sue Grimes, SITA and Royal Academy Professor of Waste Management, of the Centre for Environmental Control & Waste Management, Imperial College, London)*

6.2.4 Accelerators

All accelerators are confirmed by evidence from the House of Lords report. Only one accelerator was rejected by some evidence, but also confirmed by other interviewees. The accelerator ***close relationship with supplier*** was rejected by interviewees representing the chemical industry as this accelerator does not act on their industry. The researcher did not take this as a true or full rejection because the researcher found in the report that this is not true for other industries. In the report, the evidence shows car manufacturers have a very good supply chain relationship, and the manufacturers use the supply chain to influence good practices. Moreover this accelerator is confirmed seven times at various places in the report.

Confirmation

Accelerator	***Occurrences***	***Sample quotes***
Management awareness and knowledge	*1*	*'In **proactive companies** sustainable design has got an appropriate position in functionality value creation processes.' (Memorandum by Philips Consumer Electronics)*
Available technology	*7*	*'On behalf of the chemistry using industry, we see chemistry as one of the **enabling technologies** for solving a lot of the issues, it is underpinning technology. We have*

		many examples on our `roadmap'. We have a sustainable technologies roadmap on the Chemistry Innovation website which lists many different examples in different sectors where ***sustainable technology*** *or green design principles have been applied.' (Dr Michael Pitts, Priorities Manager, Chemistry Innovation Knowledge Transfer Network)*
Suppliers	*7*	***'Suppliers can influence*** *manufacturers by demonstrating that using more sustainable materials, or using materials more sustainably, will improve their business. This might be through cutting their costs, being able to improve product functionality and performance, helping them meet regulatory obligations at minimum effort or minimum cost, or by enhancing customer profile. This requires very active interaction between customer and supplier. In some sectors, such as automotive with its Tier 1 and Tier 2 suppliers, supply chains are very closely linked together. .....(continued)... For example, recently Ford in Europe wanted to reduce the waste generated by metal cutting machinery in the production of engines. Part of the problem were the lubricants and cutting oil used in the process, and by working closely with their lubricant supplier the supplier was able to develop a vegetable oil based lubricant which had both superior performance and superior environmental impact. As a result, Ford was able to realise significant savings in their engine plants. It is generally easier for a manufacturer to influence their suppliers than the other way round.' (Memorandum by Chemistry Innovation Knowledge Transfer Network And The Chemical Industries Association)*
Employee awareness	*1*	*'We believe that sustainable approaches to waste reduction require a change in attitude. In particular, there needs to be a greater appreciation that the efficient use of resources is not only desirable but that the* ***decisions of individuals can make important contributions*** *to improving the efficiency of resource use.' (Memorandum by Envirowise)*
Company's culture	*4*	*'You can also look to Nissan and the automotive sector for these key aspects of waste reduction during production and the stripping out of costs, because some*

		of these have become international leaders in production efficiencies, so they have probably got both aspects. We were talking earlier about the need to put all of these aspects of design, production efficiency and end-of-life take-back together. Some of these ***Japanese*** *companies are among the best at connecting these features.' (Professor Simon Pollard, Cranfield University Centre for Resource Management and Efficiency.*
Lean production system	*9*	*'The earlier point about* ***lean is very appropriate here.*** *It works well within factories and it comes from the Japanese worrying about waste rather than efficiency. It tends to be operational and those thought processes can perhaps be extended either end up to the design and outside the factory as well. There is a worry that lean approaches are just seen as operational and not changing the rules of the game. The other bit is new processes'. (Professor Mike Gregory, Head, Institute for Manufacturing, University of Cambridge)*
Product types	*1*	*'There has been a move away from aluminium into something which is called CPET, which is a form of plastic, because again it is lighter weight. The reality is that the foil container is infinitely recyclable whereas the CPET container is very difficult to recycle.' (Mr. Rick Hindley, Chief Executive Officer, Alupro)*
Environmental standards and ISO 14001	*3*	*'Most major plants now are either operating to, or are likely to become accredited to,* ***ISO 14001****, which is the environmental system which we tend to use in our industry, and that is bringing huge benefits.' (MR DAVID WORKMAN, Director General, British Glass Manufacturers' Confederation)*
Communication	*2*	*'... from a corporate point of view, we have a Nissan green programme which is to promote recovery, re-use and recycling and that Nissan green programme is used externally but it is also used as a* ***communication*** *internally to encourage all of the staff, in whatever role—design, manufacturing or administration—to reduce waste.' (Mr. Jerry Hardcastle, Vice-President, Vehicle Design and Development, Nissan Technical Centre*

		Europe)
Environmental target from top management	*2*	*'With the rise of sustainability up the agenda globally, waste is **higher up the agenda** in the big multinational companies now than it has ever been.' (Dr. Forbes McDougall, Environmental Manager, Proctor & Gamble)*

Rejection

Accelerator	***Occurrences***	***Sample quotes***
Suppliers	*1*	*'In other sectors where materials may be used in a very wide range of applications, the supply chains have been less closely linked and there has been less involvement by suppliers in innovations of the customer. At the moment, for sectors like chemicals, it mostly happens when a customer has a driver to be more sustainable.' (Memorandum by Chemistry Innovation Knowledge Transfer Network And The Chemical Industries Association)*

6.2.5 Benefits

All themes under benefits were confirmed and rejected in the report. This is because different industry sectors expect and experience different benefits from the implementation of Material Efficiency strategies.

Confirmation

Benefit	***Occurrences***	***Sample quotes***
Reduced cost	*7*	*'There are a number of ways that we can reduce waste and they are quite often related to the reduction of weight and also a **reduction of cost** as well.' (Mr. Jerry Hardcastle, Vice-President, Vehicle Design and Development, Nissan Technical Centre Europe)*

Validation

Reduced waste and environmental impacts	*6*	*'Clearly, manufacturing methods and designs that maximise resource efficiency will tend to **reduce waste** production.' (Memorandum by Environment Agency)*
Reduced virgin and incoming materials	*14*	*'Recycling waste, or "cradle to cradle" thinking, can turn waste streams into important **feedstocks** for industry.' (Memorandum by Chemistry Innovation Knowledge Transfer Network and The chemical industries association)*

Rejection

Benefit	***Occurrences***	***Sample quotes***
Reduced cost	*4*	*'**Materials recovery is not in itself an economic goal**. If it were, and all the fiscal and regulatory framework to the economy was geared to that happening, then, of course, companies would find extremely ingenious ways, I am sure, of reclaiming materials. At the moment we have a situation in this country with aluminium, which is worth several hundred pounds a tonne on the resource market, where we manage to recover only about 50 per cent of what goes into drinks cans, despite having doorstep recycling schemes and other things. That is simply because we have not organised or wanted to get that material back. There is a market for it but there is a disjunction between feeding that market and the systems of recovery.' (Ms. Julie Hill, Green Alliance)*
Reduce waste and environmental impacts	*1*	*'When you think of everything from toys through to the very large servers that we make that run air-traffic control systems, for example, they are very different beasts. We find, quite interestingly, that a lot of the environmental impact within the IT sector—particularly when we look at computers, laptops, printers—is in the **use phase** rather than in materials selection, and that is why we have been concentrating very much within our*

		design for environment programmes on energy efficiency within our products. We do that across our product range but we also work on materials and dematerialisation and other things. I just wanted to demonstrate that not all electronic products are the same and so we see different peaks of environmental impact at different points of the product life-cycle.' (Dr Kirstie McIntyre, Head of Takeback Compliance, Hewlett-Packard and a Member of APSRG)
Reduced virgin and incoming materials	*1*	*'We were talking before about why **we are not getting enough materials**. There are plenty of materials being collected by local authorities but they are mixed and the economics of unmixing them renders them economically impossible to do anything with later on.' (Dr Kirstie Mcintyre, Head of Takeback Compliance, Hewlett-Packard and a Member of APSRG)*

6.2.6 Practices

Almost all practices (which are 16 in total) that were chosen as significant by the researcher are supported by evidence from secondary data. Only one, which is the practice of ***selection and employee training***, has no evidence in the report. As a result this theme will be dropped from significant theme list. From 16 practices, four others were rejected but were confirmed at various places in the report. These themes were rejected by certain sectors only as the factors/practices are not apply or are not suitable to them. This shows that the practices are chosen by companies depending on the suitability to the industry which is related to the type of products and materials used.

Confirmation

Practices	***Occurrences***	***Sample quotes***
Material and waste recovery	*7*	*'Ford is proactive in its use of **recycled**, renewable and low life-cycle impact materials and we are looking at ways of increasing use where appropriate.' (Memorandum by Ford Motor Company)*
Design	*23*	*'Better **design** and a more knowledgeable use of materials and manufacturing processes can minimise the creation of waste.' (Memorandum by The Institute Of*

		Materials, Minerals And Mining (IoM3))
Relationship with suppliers	*5*	*'We issue a purchasing green guideline from Nissan to all of our **suppliers**, so we tend to ask them to take responsibility for their own waste and recycling. Nissan as a company just does not like waste.' (Mr. Jerry Hardcastle, Vice-President, Vehicle Design and Development, Nissan Technical Centre Europe)*
Relationship with customer	*5*	*'Latterly, **our customers** are becoming far more aware in terms of how vehicles are actually produced, not just what comes out of the pump in terms of fuel consumption, but they are now looking for us to provide information about how you minimise those things.' (Mr. Peter Stokes, Vehicle Compliance Manager, GS Product Technical Group Services, Volkswagen Group United Kingdom Limited and Chairman of the Consortium for Automotive Recycling (CARE))*
Efficient use of material	*3*	*'In the area of the catalyst, for example, for emissions control, those have precious metals on them which are necessary for the function of the catalyst, but we would try and **minimise** the amount of precious metal required in order to get the exact performance, which of course stops you using the precious metals in the first place and also makes it easier to recover them because there is less of them at the end of the process. They are just a few of the ideas; there are many more ideas if you would like to hear more.' (Mr. Jerry Hardcastle, Vice-President, Vehicle Design and Development, Nissan Technical Centre Europe)*
Use tools, techniques, environmental programmes and standards	*2*	*'There is another manufacturer which my Lord Chairman has been closely associated with over the years who has halved the amount of waste per tonne of product produced in the last five years. The drivers have been commercial as well as environmental but they have had significant benefits. Most major plants now are either operating to, or are likely to become accredited to, **ISO 14001**, which is the environmental system which we tend to use in our industry, and that is bringing huge benefits.' (Mr. David Workman, Director General, British Glass*

		Manufacturers' Confederation)
Environmental target and objectives	*3*	*'We have what we call a sustainability report, which is a separate **report** from our financial report. You ask for figures. For 2006/2007 we converted 95.72 per cent of all raw materials to final product, so it is more of a description of transition. Of that remaining piece 2.36 per cent was recycled, so overall a relatively small amount goes to waste because waste is money.' (Dr. Forbes McDougall, Environmental Manager, Proctor & Gamble)*
Measurement and audit	*2*	*'We do use a wide range of **metrics**. We manufacture over 100 different product lines, so 100 different brands, for example. Each of those brands will have a range of different multiples, whether it is small bottles, medium sized bottles or big bottles. We compile and publish data to cover the whole of our business.' (Dr. Forbes McDougall, Environmental Manager, Proctor & Gamble)*
Select employee, encourage and train employee	*0*	*No evidence*
Product service system	*7*	*'There are examples of lots of companies who have been looking at **leasehold** products for a number of years—Xerox is an example, in photocopiers. That has been a very successful business model. In fact, a lot of companies in that sector have then managed to bring the products back, refurbish them and resell them at the same sale price as the original product price. That is an excellent business model. You have companies like Interface, floor tiles, exploring this route as a business model. '(Dr. Frank O'Connor, Director, Ecodesign Centre Wales)*
Prolong product's or material life	*8*	***'Product life extension** is one way of reducing the consumption of resources—the consumption of energy through manufacturing, shipping and distribution—but indeed does imply an equivalent reduction in turnover.' (Dr. Jonathan Chapman, Senior Lecturer in 3D Design,*

		University of Brighton)
Manufacturing and machine efficiency	*7*	*'In terms of production waste, one key area is that we would design a component so that it can be made with the* ***least amount of waste material****. This is things like the blankings, so that when you are blanking something out of steel you would try and make the shape so that it can be nested in a pattern that does not waste material. That is one thing that we might be asked to do.' (Mr. Jerry Hardcastle, Vice-President, Vehicle Design and Development, Nissan Technical Centre Europe)*
Implement sustainable strategies	*2*	*'Our members take their responsibility for the environmental impacts of their products seriously, including availability and end of life impacts of raw materials, and, where possible, strive to re-engineer processes and use* ***resources more efficiently****, and thereby reduce their costs.'(Memorandum by EEF, The Manufacturers' Organisation)*
Lean production system	*9*	*'Certainly there is the concept of better design, environmentally sensitive design, better selection of materials, opportunity for concepts such as product lightweighting, and design for disassembly; in other words designed to improve opportunities for remanufacturing. In terms of production and manufacture, there are opportunities with respect to* ***lean*** *manufacturing and dematerialisation; and concepts such as the six sigma concept, which is about production performance and reliability.' (Professor Simon Pollard, Cranfield University Centre For Resource Management And Efficiency).*
Reduce packaging materials	*5*	*'From the aluminum packaging perspective, our industry has been heavily involved for a long time* ***in reducing the thickness*** *and the weight of packaging.' (Mr. Rick Hindley, Chief Executive Officer, Alupro)*
Legislation compliance	*2*	*'****We did not want to put ourselves at risk*** *by finding out if we would be punished but clearly the enforcement programme was quite harsh and we have only just submitted and had our evidence approved for 2006 where*

		we did meet the target, but BERR were very methodical and demanded to see the evidence of actually meeting that target.' (Mr. Steve Franklin, Senior Manager, Environment Group, The Society of Motor Manufacturers and Traders Limited)

Rejection

Practices	***Occurrences***	***Sample quotes***
Material and waste recovery	*7*	*'..when you get this mixed selection, mixed bag of products back, it is very difficult, as my colleagues have said,* ***to pull out enough to feed*** *into a manufacturing process to really make a difference.' (Dr. Kirstie McIntyre, Head of Takeback Compliance, Hewlett-Packard and a Member of APSRG)*
Design	*3*	*'That is always a fear: that people will try and meet the legislation by introducing a bit of technology at the end of the product's life to extract the material rather than thinking about: "Let's go back to the starting point and change the design to make it better at the start". Unfortunately, I think it is the way that companies will cost things. They do not cost the whole life of the product when they design it; they design to the manufacturing cost and then worry about the end-of-life costs if there is some legislation there. So it is* ***not looked at comprehensively at the start of the design process****.' (Dr Tracy Bhamra, Reader in Sustainable Design & Research Co-ordinater, Department of Design & Technology, Loughborough University)*
Product service system	*2*	*'I do not think there are other sectors moving in this direction at all. In fact, it is the reverse. I have certainly spoken to one electronics retailer and they have said that every year fewer and* ***fewer of their products are worthy of repair****. It is getting to the stage now where even things like washing machines are becoming increasingly irreparable.' (Dr Tim Cooper, Centre for Sustainable*

		Consumption, Sheffield Hallam University)
Prolong product or material life	*3*	*'In this way, it is clear that the "design for durability" paradigm has important implications beyond its conventional interpretation, in which product longevity is considered solely in terms of an object's physical endurance—whether cherished or discarded. In this sense, it can be seen that durability is just as much about desire, love and attachment, as it is fractured polymers, worn gaskets or blown circuitry. It therefore appears clear that there is little point designing physical durability into consumer goods, if consumers lack the desire to keep them.' (Memorandum by Dr Jonathan Chapman, Senior Lecturer in 3D Design, University of Brighton)*

6.3 Refined Themes

From the validation it is found that none of the significant themes were truly rejected but all of them except one were supported. If there were any rejections, the researcher always found supporting evidence from within the same report. In fact almost all themes including the ones that had not been selected by the researcher as significant themes (which were dropped before the validation stage) were also confirmed. Although these themes were supported, the researcher decided not to include all of them as final themes due to reasons explained in Chapter 5. However, only a selected few were taken into the significant list as these themes were heavily supported by evidence found in House of Lords report. Also, the researcher decided to drop one theme which is not supported but not rejected, as an act to be selective and careful in producing the final list of significant themes. Figure 6.1 shows the refined themes resulting from the validation. Validation evidence shows that the research conducted by the researcher is highly relevant to the current situation in UK industry.

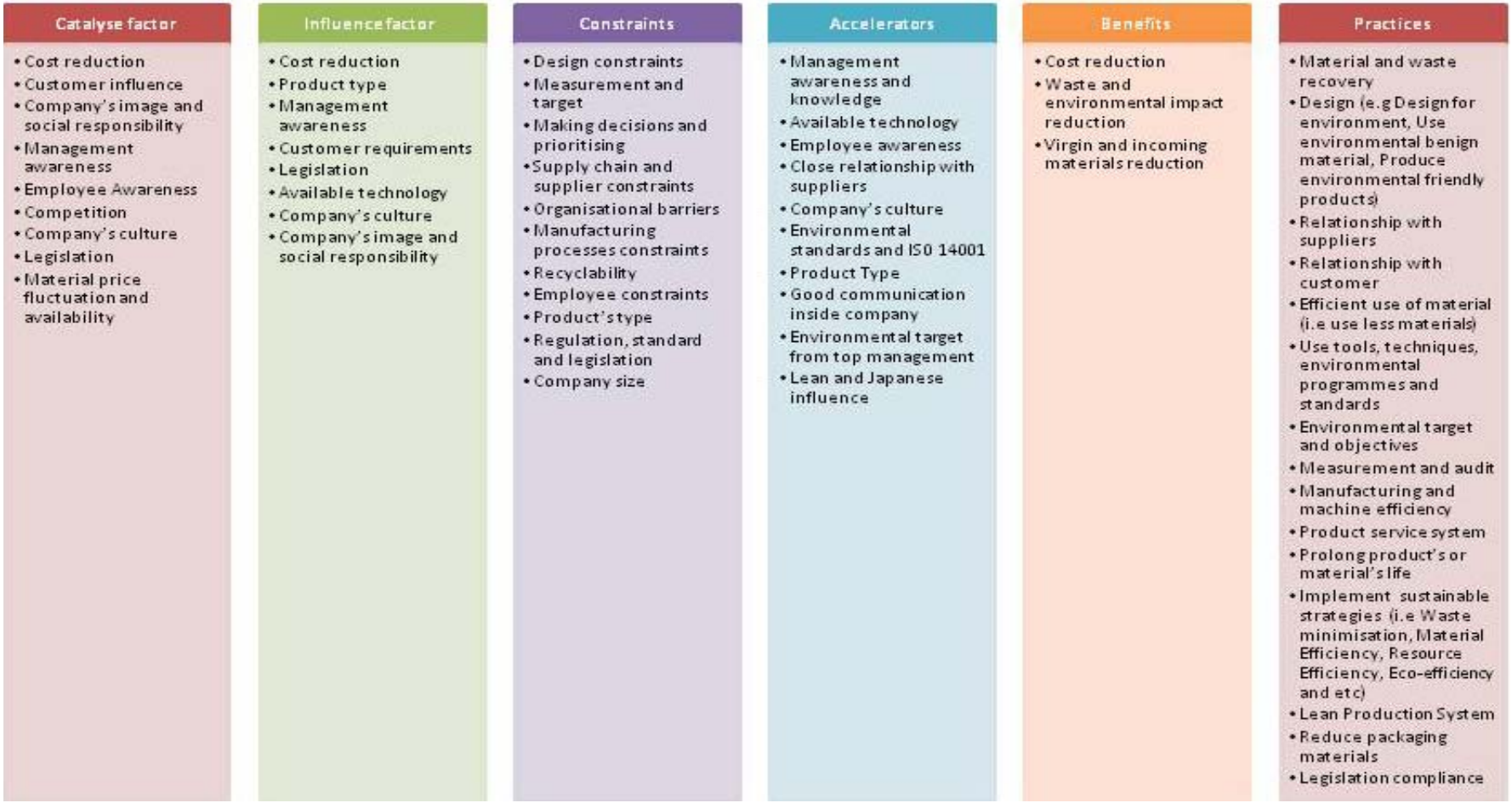

Figure 6.1 Refined themes after validation

6.4 Chapter Conclusions

This chapter shows how the researcher performed validation both during data analysis and while finalising its findings. The themes presented above indicate clearly that almost all themes resulting from the research were supported by highly reliable secondary opinions. The secondary opinions are in the form of written evidence based on an inquiry by the House of Lords on waste reduction. The confirmation of most of the themes shows that the research conducted is highly credible and reliable. Findings from this chapter are part of the overall findings emerging from this research. A more detailed summary and a discussion of the overall findings are presented in the next chapter.

7 DISCUSSIONS

This chapter discusses the research findings derived from both study and the literature review. Findings from study are derived from cross-case analysis which were carefully validated and have been discussed in the previous two chapters. These findings are then discussed in the context of answering research questions. Other findings emerged from the studies and are presented, and overall findings will be discussed based on research objectives and by reference to literature.

7.1 Research Questions Addressed

In this section the findings are selected, interpreted and discussed in order to answer each of the Research Questions determined in the beginning of this study. Below are the Research Questions answered using the findings which emerged from the study.

7.1.1 Answering Research Question 1

Do companies use Material Efficiency strategies?

The evidence in this research indicates that **companies in UK do practice Material Efficiency strategies** although it is not clear how extensively they implement the strategies. It is evidenced from the study that **all companies perform waste minimisation** and work towards higher strategies such as Material Efficiency and Resource Efficiency. The higher the strategies that they try to practice, the more constraints and complexity they have experienced. The willingness to continue trying more complex more strategies is motivated by the same factors which influenced them to choose the types of strategies in the first place. These two types of factors will be discussed in later sections. **It is found that all companies are reacting to pressure, but some companies are more proactive than others**. Most companies are pressured to have some form of strategies in response to threats such as customer requests and pressures; material price and availability; legislation and competition. It is found that companies that practicing lean production are more proactive. The study also reveals that small companies have harder constraints in reacting to the pressures to have reduced waste and material usage. The companies also experienced varying constraints which depends on type of products produced, type of material used and waste produced. More details on constraint will be explained when answering research question 3.

Answers:

- Companies do practice Material Efficiency strategies.
- All companies investigated have at least done waste minimisation strategy.
- Some companies investigated are more proactive in reacting to pressures.
- It is found from the study that companies which practice lean production are more proactive in implementing Material Efficiency strategies.
- There is evidence to show that smaller companies have a bigger challenge in implementing Material Efficiency strategies.

7.1.2 Answering Research Question 2

Do companies use these strategies but call them something else?

From the study, it is found that the strategies used by manufacturing companies consist of various tactics, based mainly on ease of implementation and result orientation regardless of their names. It is observed that **each manufacturer tends to give their own names** or labels and use a specific combination of strategies, techniques or tactics that are known and available to them. These strategies, techniques and tactics are typically similar or can be part of those four main strategies (Waste minimisation, Material Efficiency, Resource Efficiency and Eco-efficiency) found in literature. Although most of them do not use specific names; they are comfortable in referring to them as an act of reducing waste or materials. However, if they have to give a name in order to refer to and communicate those strategies, they are comfortable using their own labels that employees can understand. For example, labels used are closed to actions such as 'Revert strategy' which refer to strategy of recovery materials by "reverting" the waste back into the processes. Each company is using a different name to the others although the concept is similar. **They certainly do not use any of the phrases such as Material Efficiency, Resource Efficiency and Eco-efficiency**, and were often puzzled by the terms when introduced to them by the researcher. They are less puzzled by the term Waste Minimisation because it is straightforward.

When most interviewees were shown the list of strategies, their responses were that they may recognise some of the names given especially the simpler strategies. However for more complex and higher strategies they usually do not know exactly what these strategies mean. When the researcher showed the design engineer of Company 3 the list of strategies name, he responded by saying *'Material Efficiency? Well, I can understand that one. It's the simplest and most obvious: The most efficient use of our resources. Material Productivity? We don't use that phrase because [Linda] described earlier*

about how to get more shelves out of a bit of cheaper steel. It is common sense: use a language that everyone can understand!'

Answers:

- Companies used various achievable tactics.
- Each company investigated tends to give their own names for the strategies they use.
- They certainly do not use any of the phrases Material Efficiency, Resource Efficiency and Eco-efficiency.

7.1.3 Answering Research Question 3

How do companies use Material Efficiency Strategies?

To answer the question of how the companies use Material Efficiency strategies, the researcher used all the sub-questions at the sub-sections below to look at what type of strategies exist in practices as compared to literature, how could they use the strategies, what is the constraint, what are the benefits and what are the accelerators that help them to practice the strategies.

7.1.3.1 Sub-question 3a

What Material Efficiency strategies exist in practices?

There are many strategies and tactics used by manufacturing companies. This research found that the strategies used by companies are more straight forward, common sense and tactical regardless of their name. The researcher listed the most significant practices and tactic by companies namely:

1. Material and waste recovery
2. Design (e.g. Design for environment, Use environmental benign material, Produce environmental friendly products)
3. Relationship with suppliers
4. Relationship with customer
5. Efficient use of material (i.e. use less materials)
6. Use tools, techniques, environmental programmes and standards

7. Environmental target and objectives
8. Measurement and audit
9. Manufacturing and machine efficiency
10. Product service system
11. Prolong product's or material's life
12. Implement sustainable strategies (i.e. Waste minimisation, Material Efficiency, Resource Efficiency, Eco-efficiency etc)
13. Lean production system
14. Reduce packaging materials
15. Legislation compliance

The meaning and discussion of these strategies and tactics were presented in detail at section 5.2.5 of Chapter 5.

7.1.3.2 Sub-question 3b

What Material Efficiency strategies exist in literature?

There are many manufacturing sustainable strategies available in literature. In this research, the researcher grouped all related strategies as Material Efficiency strategies as there is a lot of confusion in definitions and practices and they are difficult to label clearly. Among the strategies that are very closely related, other than the main four [i.e. Waste Minimisation, Material Efficiency, Resource Efficiency and Eco-efficiency], that the authors mention are Clean production, Dematerialisation, Material Reduction, Resource Productivity, Material Production, Pollution Prevention, Product Service Systems, Ecological Footprints, Ecological rucksacks, End of life strategies, Environmentally Conscious Manufacturing, Design for Environment and much more. There is also a range of target and measurement techniques such as Zero Emissions Systems, Direct Material Inputs and Intensity of Use etc.

7.1.3.3 Sub-question 3c

What benefits do these companies achieve?

There a several benefits found by researcher which was achieved by companies but only three benefits are significant;

1. Cost reduction

2. Waste and environmental impacts reduction

3. Virgin and incoming materials reduction

Cost reduction

Reduced cost is the top benefit found in the study. Evidences from data imply that companies could achieve cost reduction as a result from thorough implementing Material Efficiency strategies. Evidence shows efficient use of materials, reduced cost and reduced waste. Cost is reduced because less material becomes wasted, thus less virgin and new materials are needed. Recycled waste when fed into production will reduce the cost of buying materials and cost of treating waste whereas cost and waste reduction goes hand in hand.

Waste and environmental impacts reduction

The second most reported benefit experienced by companies is waste reduction. Segregated "waste" can be turned into resources by a material recycler and sell to other party. Realising they can get profit from their waste, companies put an effort into segregating their waste to get higher prices. For some companies however this is not a priority they are trying not to produce waste at the first place, realising not to produce waste is more cost efficient. Less material waste means that the company is saving money from buying less virgin material. This benefit is also extended to the packaging. By discussing with suppliers how they might pack products and parts sensibly, they can help to reduce packaging waste. Reduced waste is not only manifested as a reduced cost of materials but also as a reduced cost of treating the waste and, less obviously, as a reduced energy cost associated with producing that material.

Virgin and incoming materials reduction

Due to reduce waste and material usage, companies get benefits by buying less virgin or new materials as virgin and new materials are more expensive compared to recovered materials. They mixed materials for production from the supply which are recovered from waste. Companies do realise that it is costly to produced waste but some waste is in inevitable as waste has been produced due to several reasons. Recovering waste and mixing it with new materials will save money on purchasing new materials. This will greatly benefit companies from which waste could be recovered and products can be produced using recycling waste. This is however not practiced by all companies due to some constraints which will be discussed under difficulties faced by companies. For some companies the great benefit is that turning the recycled waste into resources can reduce the problems of material scarcity which companies then could avoid other problems such as price and material supply fluctuation.

7.1.3.4 Sub-question 3d

What difficulties did they meet when implementing Material Efficiency strategy?

Many constraints and barriers which were experienced by manufacturers were reported in this investigation. The significant constraints experienced by companies are:

1. Design constraints
2. Measurement and target
3. Making decisions and prioritising
4. Supply chain and supplier constraints
5. Organisational barriers
6. Manufacturing processes constraints
7. Recyclability
8. Employee constraints
9. Product type
10. Regulation, standard and legislation
11. Company size

Design constraints

Design is playing important role in manufacturing products. Customers purchased products because the products were designed to fit the purposes and as it is expected by customers. Design constraints could mean difficulties and barriers experienced by companies in designing products in order to minimise waste and environmental impacts especially during production and customer use phase. There are many constraints that are related to design faced by companies as strongly evidenced from the study. Among the difficulties found are *a) Customers expect the product to be functional and also attractive whereas green products should better or at least on par with the non green products; b) Design constraints by product functionality and performance; c) Product must meet health and safety standards or other requirements, for example due to this many healthcare products cannot use recycled materials; d) Products whose technology and style quickly changes also give a lot of constraints to designer. The design has to be balanced with the need to cater the product's short life span and the*

concern about reducing waste at customer use phase; e) Recyclability is an issue to the designer as designing products that are easily recycled sometimes conflicts with other requirement such as health, safety, functionality and thus designing for recyclability alone is not trivial.

During the validation more evidence emerged from the House of Lords inquiry which highlights the problems on designers are such a lack of knowledge of sustainability issues and materials, and what choices are available to them. Other constraints faced by the designer is that the customer is the master and thus there is nothing much they can do if the company or customer requested them to design a product to prioritise other requirements and not the product's sustainability.

'Availability, cost, fitness for purpose and aesthetic considerations will influence material choice above many environmental issues. This makes the selection of products and materials a complex decision making process, often requiring compromise to achieve the best overall results. For example, an environmentally preferred material may cost more or be difficult to obtain; whereas a less "green" material might have excellent workability and fire resistance qualities.' (Memorandum by the Environmental Industries Commission (EIC), in the House of Lord Report on Waste Reduction, 2008)

Measurement and target

Measurement and target setting is a common management tool and is often used in Material Efficiency strategies. Consistent with findings from analysis done during literature review, it is found that measuring waste, Material Efficiency and environmental impacts are difficult. Measuring both waste and Material Efficiency strategies effectiveness are proved to be not easy and most of the time not achievable. Measuring true environmental impacts on different types of material used also proved difficult. When there is no measurement, setting achievable targets is also difficult. Measuring waste is not an easy task as the same measures cannot be used for different materials. For example, some materials are measured by weight, but others are by volume and so forth.

'The weight-based targets we have heard about do cause a problem in this. Of the seven different types, only the very high density plastics are recycled, types one and two. The weight-based target discourages low density plastic recycling. We possibly need targets based on the environmental impact, toxicity or volume.' (Dr. Michael Pitts, Priorities Manager, Chemistry Innovation Knowledge Transfer Network, in the House of Lord Report on Waste Reduction, 2008)

For products that used mixed materials this is more difficult. As measurement is a way to base action on, failure in measuring can lead to ineffective actions. However there is an example of one company that does not measure because they consider that it will

waste valuable time that can be used to invent ways to reduce waste and efficient use of materials. They use an analogy of this as the Formula one car driver, you drive so fast you hardly be able to check your speed meter.

Making decisions and prioritising

Choosing among alternatives of strategies to reduce waste, material usage and environmental impacts proved difficult for the manufacturers due to problems with measurement. Based on this study, most companies complain that it is difficult for them to know which decisions are better in term of reducing environmental impacts. Reducing material weight can be seen as reducing the amount of material used, which no doubt will reduce material usage and reduce waste but this not guarantee to reduce overall environmental impacts. Cost is the first factor that is considered by companies in prioritising choice. Other than cost, lack of information and guidance on making choices are among the difficulties faced by companies. Other constraints are customer requirements and a manufacturing process that requires them to choose certain strategies above others. Customers sometimes pressure companies to opt for certain Material Efficiency strategies such as reduced packaging, where the requirement was ill informed causing more negative impacts towards the environment.

Supply chain and supplier constraints

The supply chain and suppliers can constrain companies' efforts to practice Material Efficiency strategies. Based on evidence there are many difficulties faced by companies, among them are: *uncooperative suppliers* and *limitation with overseas supplier.*

Uncooperative supplier faced by companies can cause real problems if they did not really cooperate in the supply of the materials as needed. Product's type and company's size also sometimes contribute to the factor that the supplier is not being cooperative. Small companies complain that they are too small and insignificant in the long supply chain and that their requests usually have not been entertain.

This problem becomes worse when dealing with overseas suppliers where standards and practices are different. It is not difficult to request that a supplier comply with certain environmental standards within the UK, but will become a problem when involving suppliers overseas especially if the supply chain is long. Companies also sometimes have no control over packaging as packaging decisions are not included during purchasing.

Big companies usually can put greater pressure on the supplier to comply with their request. Big companies would manage to do an environmental audit and tracking the source but this is not easy for small companies. What matters to suppliers is the profit, so they were usually not willing to comply with small companies as the profit from them is small.

Organisational barriers

Management and organisational barriers such as problems with company's culture, behaviour and communications are significant constraints. Among problems reported from the study is an environmental manager having difficulty convincing management and employees on implementing the Material Efficiency strategies. Finance sees material efficiency as a waste of money as its monetary benefits could not been directly. Communication also a great barrier as the lack communication between management and employees would cause any strategies implemented to fail.

Problematic management can cause employee problems. Among problems relating to organisational management revealed from this study are management lack of awareness and support, traditional thinking and an inherited traditional working culture where department decisions and data are separated. These in turn will cause employees to be unwilling to learn, to be resistant to change and lack awareness.

'I think there are already quite a few mechanisms, but as I see it first of all I deal with many manufacturing companies and I would say that the ***single biggest barrier t****o reducing waste or improving anything is the* ***lack of awareness amongst the senior people*** *in the business of the real potential for improvement. Many are carrying on doing things the way they have always done and have not been particularly receptive to learn. One can offer advice but it is of no value unless it is actually implemented and something is done with it, and we do not have a nation of implementers when it comes to business, I would say. It is true, of course, only for some and I would not like to generalise and give that impression of everyone, but I do think that is part of the problem.' (Mr Michael Glass, Chief Executive Officer, Process Industries Centre for Manufacturing Excellence, in the House of Lord Report on Waste Reduction, 2008)*

Manufacturing processes constraints

Most manufacturing processes are inherited and thus contribute to waste and inefficient material uses. Undesignated manufacturing flow that cannot support Material Efficiency strategy can give problems. There is evidence at one company that employees complain that they are under pressure to cope with production targets and at the same time they are expected to clean the machine so the metals swarf is not mixed up. The value of mixed metal swarf is practically worthless. For products which use expensive materials such as Titanium, the companies seek to produce uncontaminated Titanium swarf. However, machining Titanium using a non-dedicated machine is a challenge as this then needs to rely on employee discipline to clean and segregate the swarf carefully. Other issues relating to manufacturing process is that in certain processes, waste is sometimes inevitable.

'Some processes are inherently less wasteful of energy or material than others. But changing a process normally has implications for capital investment in equipment, so there are huge barriers to radical change.' (Supplementary memorandum by Dr Claire Barlow, Senior Lecturer, Institute for Manufacturing, University of Cambridge, in the House of Lord Report on Waste Reduction, 2008)

'The two parts to this (on altering production process to improve waste reduction) are existing and new processes. If you have existing processes, it is much more difficult to mess about with them.'(Professor Mike Gregory, Head, Institute for Manufacturing, University of Cambridge, in the House of Lord Report on Waste Reduction, 2008)

Recyclability

Recyclability is one big constraint for a company who chooses recycling strategy. Among the difficulties of recycling gathered from the investigation are: *difficult to separate waste, recycling material in-fluctuation* and *material downgrading*.

It is not easy for a manufacturing environment to manage fluctuating recycled material supply into their factory (due to on-off supply of the original waste materials into the recycling system). Some recycled materials suffered downgrading thus it is actually been down-cycling rather than recycling. Downgrading material has its own limitation when supplies are fed the into production process. Both in-fluctuation and downgrading of material supplies gave challenge for companies to manage. Thus the companies usually put only a low percentage of recycled supplies into production to make sure this allocation has been meet, as different percentages of recycled material used will affect the aesthetics requirement by customer, also will affect other aspects such as health and safety.

Companies which use a lot of metals have fewer of these problems. Metals are easily recycled and will not downgrade. The only issue is to segregate it carefully so it will become high grade waste that can be sold at higher price to a metal recycling company.

Employee constraints

No matter how bright ideas come from top management, how much budget is put aside to embark on sustainable strategies, employees are the ones that have to perform the actions. There is evidence that employees that are not disciplined in performing these strategies or just do not care will make implementation of strategies difficult. This problem however was reported at companies that are having problems with management and company culture. Companies that have reported least constraints with employees are usually the ones that have innovative and proactive management where good communication is the key. All this evidence pointed to the overall picture that employee behaviour and other issues related to employees can constrain Material Efficiency and other related strategies.

Product type

Some products are more complex compared to others. There are huge varieties of products in the market. Some are made from advanced and mixed materials, some are made from basic and simpler materials, some have short life and change quickly following the trend, some are designed to last for decades. These are the factors that influence companies on practicing Material Efficiency strategies. Products that are produced by mixed materials and advanced materials are more difficult as advance technology and techniques are needed to reduce their waste. This is the same for products that produce toxic waste during manufacture. Types of products produced also have implications such as its size, life cycle and whether it is a fashion lead product. Products that change quickly due to fashion and also due to the quick change or fast pace in technology can also give problems.

Company size

Small-medium size company could face more difficulties compared to their bigger counterparts. Other than evidence found by the researcher in the study, there is considerable evidence and emphasis placed in the House of Lords inquiry into Waste Reduction on problems faced by small companies. Based on evidence from House of Lords, small companies are usually lack resources such as people, time and money, to be able to have Material Efficiency strategies. Other problems are to influence customers and supplier to cooperate with their strategies. The companies also have problems to route their waste in a more sustainable manner due to lack knowledge and support (as there is not sufficient weight/volume to be of interest to a recycling company).

Regulation, standard and legislation

According to Professor Sue Grimes, a major problem for the reuse and recycling industries lies in the legal definition of waste. In some situations, a perfectly acceptable reusable by-product of waste treatment will still be regarded as waste requiring any user to have a waste management licence. The evidence also came from The Institute of Materials, Minerals and Mining.

'The term waste is a general term which if applied to materials can create negative implications which do not assist reuse or recycling. It would be more appropriate to consider material that is not the primary output to be classified as by-products. These by-products should only be considered to be waste if they are not utilised further or are sent to a disposal facility.'

The policies, regulations and other legal frameworks also sometimes acted as barriers rather than accelerator to the implementation of sustainable strategies.

'The current policies, regulatory and legal frameworks seem to confuse and do not support the development of better and more sustainable products and processes. There is evidence that the main emphasis in the UK is on avoiding risk, which is inimitable to innovation. For example, the legislation that provides enhanced capital allowances for installing specified types of environmental devices seems to be too restrictive as new types of products do not qualify because they are not defined in the lists that are part of the legislation.'(Memorandum of the Institute of Materials, Minerals and Mining, in the House of Lord Report on Waste Reduction, 2008)

7.1.3.5 Sub-question 3e

What actions did they take that helped the implementation succeed?

There are many actions and technology that help companies' increase rapidity or accelerate the implementing of Material Efficiency strategies. It is found that answers for ***sub questions d*** and ***e*** point to the fact that some constraints and accelerators are mirrored to each other. For example, factors related to employee, suppliers, environmental standards, product type, company's culture can be constraints if these variables are problematic but can be accelerators to companies if they are fine. The researcher had selected top accelerators listed as below:

1. Management awareness and knowledge
2. Available technology
3. Suppliers
4. Employee awareness
5. Company's culture
6. Environmental target from top management
7. Environmental standards and ISO 14001
8. Product type
9. Good communication inside company
10. Lean and Japanese influence

Management awareness and knowledge

The study shows that management awareness and management knowledge is one significant factor that helps with the Material Efficiency strategies implementation. This is an interesting finding because it shows that without management awareness and knowledge on sustainability and what it offers to companies it is impossible to implement sustainability and for any sustainability strategies to succeed. Management

awareness can be seen through their commitment in the form of the company's social responsibility, amount of efforts and also support for the Material Efficiency strategies implementation in companies. With the strategies from top down, it is communicated to the whole company and resources are allocated. Proactive and innovative management always strive to finds ways to support and to make the strategies work.

Available technology

It is evident from the study that advanced technologies help accelerate the Material Efficiency and other related strategies implementation. Examples of the technology are efficient machines, prototyping machine, advance coolant management systems, technology to segregate waste, and to recover waste. Availability of advanced materials that is more environmental benign also contributed to acceleration of the implementation of Material Efficiency strategy.

Suppliers

The supplier is also the biggest accelerator. Having a close relationship with suppliers, having suppliers that are proactive and which practice green strategies, can be factors that helps with companies' implementation of sustainable strategies. This works both ways, companies can influence or pressure suppliers and suppliers also can influence companies to practice green strategies. Evidence shows companies have been influenced by suppliers' requests, practices and suggestions. A close relationship also helps companies influence and place specific requests to suppliers in order for companies to practices the strategies themselves.

Employee awareness

Employees can play a large part by not resisting new practices introduced to them and help to accelerate the process. Employee awareness, however, relates closely with management awareness and the company's culture. High management awareness and a supportive company culture can increase employee awareness. If employees are aware of the cost of waste and its implications, coupled with management awareness, support and good communication, this can no doubt accelerate any strategies implemented. There is evidence from the study that employees gave better suggestions than an outside consultant to improve Material Efficiency strategies. These suggestions are taken seriously by companies which treat employees' views and suggestions as important. These are happening at companies that have a very proactive management.

Company's culture

A company's culture can not only act as a constraint but also as accelerator to the implementation of Material Efficiency strategy. This study shows that having a supportive company culture not only encourages them to have Material Efficiency

strategy but also helps smooth the implementation. The cultural components include management principle, management decisions, employee behaviour etc. A culture that does not help with the implementation can be a great constraint. One company provided a good solution in response to a constraint associated with an employee by providing training to all employees especially new employees, to imbed new practices and hope that old problematic practices and behaviour will be eliminated. One company owned by a Japanese company where lean working culture is at highest importance shows better Material Efficiency practices.

Lean production system

Lean practices and Japanese management culture influences are found to accelerate Material Efficiency strategies. There is a lot of evidence from study and from the report of the House of Lords inquiry that proved this factor is one of the drivers. Lean is a practice that eliminates all sort of waste. The company which already practices lean manufacturing most probably will strive to eliminate material waste and this will be easier for them because the company culture and practices are designed to help elimination of all types of waste.

Product types

Types of products help accelerate Material Efficiency strategies implementation. Types of product produced determined types of materials used and type of waste produced. From the study it was observed that some companies produced simpler products and some used less mixed materials. Some products were produced which used materials that easy recycled compared to others. Also some products produced easy recyclable waste and less toxic waste compared to others. This contributed to the types of strategies chosen by companies and accelerates its implementation. A good example is a corrugated board company which used only paper as material resource and the waste produced also paper without any printing on it. These paper wastes are sent back to paper mill and recycled back into resources to feed into the production. These are mixed with the virgin material without any complexity. Unlike many other materials which need certain percentage of virgin and recycled materials to be mix in order to achieve required standard material for product. Furthermore, for this type of material, there is almost zero toxic waste produced.

Environmental standards and ISO 14001

Environmental standards and programmes such as ISO 14001 and clean production can help speed the implementation of Material Efficiency strategies. Evidence from the study shows that ISO 14001 helps companies select suppliers and help companies to embark on new environmental programmes.

'An important step in encouraging organisations to change their behaviour is putting into place an appropriate standardisation framework. ISO 14001, a standard aimed at helping organisations put into place an effective Environmental Management System has now been in existence for over 10 years. ISO 14001 is an internationally agreed approach to managing all aspects of a business that relate to its impact on the environment, and the implementation of this has enabled companies and organisations to reduce this impact, whilst, as a direct result, reducing costs' (Memorandum by BSI British Standards, in the House of Lord Report on Waste Reduction, 2008)

Communication

This factor is very closely linked to the company management and culture. Efficient and effective communication exists when there is two-way communication between management and employees. Companies which have environmental targets and objectives together with effective communication will send signal about how important it is for a company to achieve material strategies.

Environmental target from top management

Environmental objectives and targets are important to drive any Material Efficiency strategies towards achieving the company's target. Environmental strategy that is fixed and cascaded down to employees from top management helps with effective communication and can provide a vision or target for everyone to work towards.

Answers:

- Many strategies and tactics are practiced by manufacturers.
- There are many strategies mentioned in the literature.
- Investigated companies achieved three main benefits.
- There are 11 significant constraints experienced by these companies.
- There are 10 significant accelerators experienced by these companies.
- It is found that constraints and accelerators often mirrored each other.

7.2 Other Findings

These findings do not directly answer the research questions but they emerged during data analysis and were felt to be of interest. Here they are presented as additional findings. They are in the areas of:

- The factors that catalyse a company to implement Material Efficiency strategies
- The factors that influence choice of strategies
- Findings on sustainable manufacturing strategies comparing models from literature review and from industrial practices
- The working definition of Material Efficiency

7.2.1 The factors that catalyses a company to implement Material Efficiency Strategies

From the study there are many factors that motivate companies to have Material Efficiency strategies. However there are only nine (9) factors that were found to be significant in this study. Interestingly the top three factors are related to company ability to maintain existence and to compete. Legislation, although it is significant, it is interestingly found among the bottom reasons for companies to implement Material strategies. Below is the list of top nine motivating factors for companies to implement Material Efficiency strategy. These most significant factors are listed as below:

1. Cost reduction
2. Customer influence
3. Company's image and social responsibility
4. Management awareness
5. Employee awareness
6. Competition
7. Company's culture
8. Legislation
9. Material price fluctuation and availability

Cost reduction

Cost reduction is the most popular motivation for companies in deciding to have some form of strategy in tackling material inefficiency and waste. As is having some form of

Material Efficiency strategy which not only saved money in dealing with waste but also saved materials from being wasted, thus leading to reduced cost. Companies can make some profit by selling their waste to recyclers, and reduce cost by using less material to begin with. Most companies that put cost reduction as a main factor that influenced them to adopt sustainable strategies are companies which are using: a*) scarce and expensive materials; b) types of materials whose waste is easily identified and separated or c) types of materials whose waste is not easily recyclable into the production process.* Although cost is not the primary motive, it certainly adds weight to the decision by companies to adopt Material Efficiency strategies. If the strategies did not reduce overall cost, this might discourage companies from performing Material Efficiency.

'I think it is something that all companies and all countries go through. I started work in the chemical industry and it was about the time when we were starting to understand the full cost of waste. You started to look at the cost of lost raw materials as well as the actual cost of the waste. SMEs are now learning that as well. That parallel can be seen in other countries.' (Dr Liz Goodwin, Chief Executive, WRAP, in the House of Lord Report on Waste Reduction, 2008)

Customer influence

Customer pressure or customer influence is among the reasons that motivated companies to adopt Material Efficiency strategies. Customer influence can be in form of customer specifications, supply chain pressure and market pressure. Increase in customer awareness on environmental and waste problems pressures companies to respond to this request. Companies will try to fulfil customer requirement as long it is still cost effective to them. Any decisions they made will need to balance with cost.

Competition

Competition is no doubt a significant factor that caused companies to implement Material Efficiency strategies. Due to competition to attract customers, companies are trying to deliver what the customer wants by following market trends. Among the customer trends are environmental friendly products.

Management awareness

Management awareness is a factor that is related to company culture which motivates companies to have sustainable strategies. Without management awareness and support, any strategies will fail to materialise and have a desired impact. Management awareness can encourage companies to seek information and knowledge in order to be able to make informed decisions in taking up any type of strategies.

Employee Awareness

Employee awareness is related to company culture which nevertheless plays a key role in leading some companies to decide to implement Material Efficiency strategies. Companies which have a good company culture is more open to employee suggestions were usually are also the one which had an element of employees driving the changes. The awareness of employees can be seen when they voluntarily give suggestions to improve processes. Employee awareness together with management's awareness and effective communication will influence companies' decision to have Material Efficiency strategies. These examples point to the fact that company culture is an important driver that motivates companies to subscribe to Material Efficiency strategies.

Company's culture

Company culture is the term given to the shared values and practices of the employees which no doubt has a big role in motivating companies to have sustainable strategies. From this study, at least four examples were found showing that company culture motivates companies to implement sustainable strategies. Three examples are of Japanese management cultural influence and the other one a family type culture; all of these companies had a strategic interest in the role of their business in society.

Company's image and social responsibility

Company's image and social responsibility are among the factors that motivate manufacturers to adopt Material Efficiency strategies. It is not clear whether this is a true cause of change or one that was recognised as a benefit and used to help persuade the whole company to change. Having awareness that green practices will portray a positive image of the company can motivate the company to have Material Efficiency strategies.

Legislation

Complying with legislation is one of the reasons which motivate companies to implement Material Efficiency strategy. By implementing Material Efficiency strategies, companies can avoid legislation and regulation penalties from producing persistent waste and negative environmental impacts.

Material price fluctuation and availability

This is the significant factor that motivates companies which uses expensive materials, scarce materials and materials that are prone to price fluctuation. By using Material Efficiency strategies the companies can minimise material waste and use waste material as a feedstock into production. Companies which use a lot of metals can cooperate with the recycler to overcome a materials supply problem. This is possible when companies

segregated waste and supply the waste to the recycler. The recycler which is also a supplier will process and promise a good price and better supply of materials to companies.

7.2.2 The factors that influence choice of strategies

There are eight most common factors that influence companies in choosing strategies' type. Several factors are the same factors that motivate companies to have strategies. Other than motivating companies to implement strategies, these factors also influence the type of strategies that would be suitable for companies. Cost reduction has once again become the top factor which influences companies to choose types of strategies. These most common factors are listed as below:

1. Cost reduction
2. Product type
3. Management awareness
4. Customer requirements
5. Legislation
6. Available technology
7. Company's culture
8. Company's image and social responsibility

Cost reduction

Cost is the most important factor that influences decisions of companies to implement any strategies inside the companies. Cost influences this decision in two ways. Firstly, by encouraging and deterring companies in choosing specific strategies due to cost reasons. This is due to the fact that the cost of running the technology that enables strategies may be expensive. Secondly, the strategy is giving or not giving a cost benefit after that investment has been made. The resources invested can be human, time and/or money. Cost is the first and the top factor to consider as this is an obvious criterion used to communicate and measure the success of any chosen strategy. For example, the annual cost of removing waste from a factory is an obvious target for improvement and can readily lead to a focus on waste diversion from landfill and waste minimisation becoming the main focus of activity. In such a company the opportunity for eco-efficiency may not even be discussed.

'Given estimates by Envirowise that 80 per cent of the cost of a product over its life-cycle is in-built at the design phase and that manufacturing companies can save up to 1 per cent of the turnover by implementing waste minimisation initiatives, it is no surprise that companies are increasingly focusing their attention in this area.' (Memorandum by

EEF, the Manufacturers' Organisation, in the House of Lord Report on Waste Reduction, 2008)

Product type

The product referred to in this discussion is the physical product which the customer purchased as a 'finished goods' which was produced using raw materials. Thus *product type* in this investigation refers as different product which:

a) produced using different type of material;
b) produced using different mix of raw material;
c) undergoing different type processes and;
d) as a result produce different types of material waste, toxic and environmental impacts.

From this research it is found that different types of these attributes influence decisions made by companies in choosing the type of strategies and techniques. Among decisions to be weighed by companies are: *cost; available technology; data* and *supported system* e.g. waste recycling provided by local council etc.

Management awareness

From the study it shows that management awareness influences the decision on types of strategies. Many examples from the research shows management play a big role as they are the key persons making decisions in a company. Thus their level of awareness on having Material Efficiency strategies in the companies and level of awareness of the impact of having them or not having them on the companies and on the environment influence in any level of decisions they made. Among of these decisions are decision on investing resources to have the strategies, decisions on how to be proactive in finding solutions for implementing specific strategies, being receptive to employee suggestions and many more. Also based on evidence from the interview data and the House of Lords data and from the observation the researcher made it can be concluded that when management is more aware of the pressures and opportunities they are more likely to seek information to enhance their knowledge over the matter. Thus in turn, is more likely to lead to a positive decision to implement a Material Efficiency strategy. This finding on management awareness is supported by evidences found in the House of Lords report.

Customer requirements

This study shows that the role the customer plays not only by motivates companies to implement strategies but what types of strategies companies choose. Customer requirements can influence companies' decision in choosing types of strategies in two

ways. First it may restrain companies' choices in design and manufacturing processes; and secondly may push companies to be creative in finding ways to produce products. Choices are restrained because companies not only have to deliver products or services that fulfil its actual performance and functionality but also fulfil customer expectation on environmental performances. Creativity in producing products or services means that the company is pushed to seek alternatives to produce products that deliver both environmental and actual performance. Examples of a current alternative is by offering service or maintenance contracts (called Product Service Systems) rather than sell-and-forget contracts so customers either return back the products (so the materials can be recovered) or keep the product for longer.

Legislation

Findings from this study point to the significance of legislation as a factor influencing type of strategies companies select. Existence, non-existence and type of legislation influences type of strategy chosen by companies. It is also influence amount of effort put in by companies on realising Material Efficiency strategies. Types of strategies and efforts they choose in responding to these can be categorised as either defensive or proactive acts towards legislation. Proactive companies do not wait until it is threatened by penalty, legislation, or regulation imposed on their sectors before reacting. Defensive companies will react when threaten by legislation, and the type of strategies chosen are the ones that can minimise the threat.

Available technology

This factor influences the companies' decision on choosing type of strategies by using current technology. Technology can be in form of advanced equipment, tools, machines, techniques, knowledge and advance materials to tackle waste material wastage. Available technology gives choices of strategy for companies to choose, makes the difficult alternatives easier, for example a research currently is looking for smart materials[8] which make the disassembly for recycling easier.

Company's culture

Company culture does influence the way companies look at things, handle problems in day-to-day activities and practices. This can influence the type of strategy chosen by determining the impact of the strategy to minimise waste and material and environmental on the practices and how far the company will imbed them into practices.

[8] Smart Materials' is materials that form part of a smart structural system that has the capability to sense its environment and the effects thereof and, if truly smart, to respond to that external stimulus via an active control mechanism. (The Institute of Materials, Minerals and Mining, 2003: p.5)

Company culture influences the decision on how money and time should be spent and this of course influences the decision on the type of strategy e.g. lean culture.

Company's image and social responsibility

Companies which put company image and social responsibility as important choose strategies that communicate this to stakeholders so that this can be seen. It is found from this study that companies are seeking ways to project an image as an environmentally responsible company and show that they have social responsibility but at the same time make sure they can benefit from it.

7.2.3 Material Strategies Evidence Comparisons from the Literature Review and Industrial Practices

There are many sustainable strategies mentioned in literature. The authors have identified four strategies most commonly described in the literature - namely Waste Minimisation, Material Efficiency, Resource Efficiency and Eco-efficiency. The strategies from literature review critical analysis, which has been done at section 2.3, has been discussed and compared. The criterion of each strategy that has been identified through literature has also been put in the table (see table 2.6 at Chapter 2).

The characteristics of those strategies identified and displayed in the table will probably vary when applied to real practices. Although this research is not specifically designed to validate the table characteristics and comparisons the researcher has made, much comparison can be made based on available evidences both from primary and secondary data. Primary data is companies' interview data that the researcher collected and secondary data is from House of Lords inquiry report into Waste Reduction. Among these four strategies, the criterion of the **definition, scope of implementation, practically and compatibility** found in the literature were compared to companies practices and shown at table 7.1. Quotes are selected from primary and secondary data to strengthen the argument, though the absence of a directly referring quote is not an indicator of lack of support in the data.

Definition

In terms of **definition,** the interviewees can define waste minimisation efficiency and Material Efficiency with their own words compared to Resource Efficiency and Eco-efficiency. The strategies' name and definition of Waste Minimisation are easily understood by interviewees. The term Material Efficiency is not much heard by the interviewees but is also easily understood by them. Resource Efficiency was less known to them compared to Eco-efficiency which is more familiar because of its popularity.

'For Waste minimization and Material Efficiency, they both on the same track … I think ones goes hand in hand with the others… so Material Efficiency…hmmm…we are

always looking at different ways of….let say cutting down on the actual amount of material we use within a product. So I believed that by cutting down the amount of material using, we are efficiently cutting down wastage and everything that goes with it. So again if it is not processing the material… you are not turning, cutting it and milling it in…you are not produce much waste, so again there is not so much to recycle and…the reform basically.' (Value Engineer 2, Company 1)

'*Waste minimization could , I would see two ways…minimising the way of minimising the amount of…If we can reduce the amount of materials that we need to start with to achieve a given of one tonne output and that will be minimise the amount of material you have to buy to achieve a given engine.'(Value Engineer 1, Company 1)*

As answered at Research question 2, most companies are not interested in these names and definitions but in how they can achieve the target to reduce environmental impact in the best way without it costing too much.

Scope

From the literature, the researcher assumed that companies which implement waste minimisation have limited influences along the supply chain compared to the highest strategy in the spectrum which is Eco-efficiency. For the scope of implementation, it was found from the study, that most practices observed in the data and in companies studied match with the conclusions made by the researcher, as displayed in the table 7.1.

Although it was proven that the scope for higher strategies, such as Eco-efficiency, is wider compared to the lower strategies such as Waste Minimisation, however the data shows that ***system boundaries*** of the supply chain are not very wide for all strategies along the spectrum, which is limited for Waste Minimisation to Material Efficiency and only getting slightly bigger to end of spectrum (Eco-efficiency). All the strategies can penetrate limited supply chain boundaries upstream and downstream due to several constraints which have been discussed in earlier sections. It is true as displayed in the table that systems boundaries are limited and wider towards Eco-efficiency but in practice it is not easy to widen the scope of system boundaries due to several constraints.

The system boundaries that companies are trying to work within are based on companies' decisions. For example, if they choose to minimise waste and material usage as a preferred strategy, they are more likely to request specific help from material and waste-contracting suppliers but less likely to engage with product design to minimise waste and material usage during customer use. Other companies are deliberately including the customer use, and any waste created during use, as part of their strategy. The system boundaries for Material Efficiency strategy that companies intend to cover are slightly wider than Waste Minimisation, as companies practising it

are trying to influence the supplier upstream. This is done by trying to influence suppliers on material purchasing decisions to minimise waste and material usage and also to try sustaining material sources for sector's future use. It is found that the system boundary for the strategies implementation is also slightly wider for both Resource efficiency and Eco-efficiency. Companies who practice Resource efficiency and Eco-efficiency are trying to influence suppliers' and customers' practices with greater efforts through the supply chain pressure and product design.

'They have now started to supply other customers. They now has boxes that they has made that thing goes to customers and their boxes then come back to them. So that's something that they….It is good, it is really colonised across pollination that you just kind of (inaudible) you insight a little bit.' (Head of Sustainability, Company 4)

Externalities arise when actions by producers or consumers cause unintended effects on others which could be positive or negative. Evidence from the study shows that all four strategies influence externalities. Both Waste Minimisation and Material Efficiency strategies can influence externalities but are limited compared to Resource Efficiency and Eco-efficiency. If minimum material waste entered the waste stream which then minimised persistent waste then this would be good for environment in the long term and also would minimise wastage of natural resources. Although waste recovery technology is used these technologies cannot recover waste significantly. Based on evidence from literature review there is only 0.02% waste recovered (from total 100% material and resources extracted) after customer use. The companies could concentrate on waste recovery during the production stage but this is also proven unattainable. From the study, there is no concrete evidence that shows the highest strategies can influence externalities in a greater way compared to the lowest strategies. But companies which have an Eco-efficiency strategy are confident they are influencing externalities by their efforts in terms of minimising waste, material usage and environmental impact.

'Our strategy is eco-efficiency strategy, the whole concept; the whole thing is about improving environmental performance and the impact of environment so the eco-efficiency is built in.' (Environmental Manager, Company 3)

In the study, for ***level usually used*** the strategies were found implemented at product, process and services level. Several companies have selected only several product and process for strategies implementation. Few companies have run company-wide sustainable strategies. The investigation is done in mostly manufacturing companies so there is no other evidence to support whether the four strategies were used in any other services or level (e.g. national, regional).

On ***depth of issues*** which involves deeper investigation and efforts on certain issues to realise the strategies, evidences proves that the depth of issues to be tackled are deeper (varieties) for higher strategies. However, it is found that companies which claim

having Eco-efficiency have implemented a set of smaller strategies and tactics which involves simple measurements for each. This is done not only in the hope of covering deeper issues to be tackled but also to cover wider concerns, influence wider boundaries and externalities. Companies which implement higher strategies have to use advanced technology, invest in research and development, and time in realising the strategy. This is, however, accelerated by other factors (e.g. company knowledge and type of products).

As proven by evidence found during investigation, ***concerns*** for four types of strategies are different in which Waste minimisation has a fewer concerns compared to Eco-efficiency strategy. As the companies didn't label strategies and tactics they used as Waste Minimisation, Material Efficiency, Resource Efficiency and Eco-efficiency, the concerns of companies while practicing strategies and tactics (they may use different names) has been used by the researcher to categorise the strategies they used into one of these four strategies. Figure 7.1 shows the concerns scope which relate to the types of strategies companies practice. There is evidence of a whole range of concerns found during the study which include impact of waste, resources for future use, environmental impacts and society well being.

'….really the company family were thinking of resources being global resources as well not just resources available to the company so be careful with energy, be careful with earths precious resource if you like and that's going back until 1990s before a lot of this really became….' (European Environmental Manager, Company 5)

As for a ***utility assess*** from the study it is found that most assessment and measurements are based on simple calculations such as on weight, monetary and percentage. These measurements show waste reduction, money spent on research and development, emissions and to show Material Efficiency. The most advanced percentage and ratio calculation is on 'material coming in' over the 'material becoming products'. For companies claiming to have Eco-efficiency or companies who have strategies to tackle wider concerns (that Eco-efficiency strategies do), it is found that these companies actually have a set of various simple strategies and tactics; and the utility assessment used are those simple measurements on weight and volume.

'Currently waste reduction targets are set in both tonnage and/or percentage terms.' (Mr Bob Lisney, Director, LRL Consultancy Services ltd, in the House of Lord report on Waste Reduction, 2008)

Practicality

In term of the strategies' practicality it is found that practicing the four strategies is not easy. It is proven that the easiest is waste minimisation and the difficulties are greater for the higher strategies.

Qualitative and quantitative aspects of strategies can contribute to levels of difficulty in setting **targets and measuring** against them. For almost for all of the strategies, measuring the effectiveness is problematic. As argued in the literature review chapter, the measurement effectiveness of the manufacturing sustainable strategies is highly debatable especially on measuring environmental impacts. The method of calculating environmental impact using a tool such as LCA is known to be ineffective and problematic. The easiest measurement is on Waste Minimisation and the most difficult is on the Eco-efficiency. From the study, smaller companies which have got no time and resources to perform tracking and measuring, measuring waste for them is a challenge, especially for companies which have no waste and material tracking system in place. For big companies which can allocate resources and have lean system in place, this is much easier.

'On the differentiation, it is size really. The large companies may have dedicated staff to examine this (on measurement and strategies). They are probably also registered on a variety of EMAS schemes. They probably have a corporate social responsibility report and so forth. All of these draw attention to what they are doing and are a driver to improve them.' (Mr Jonathan Davies, Chair, Waste Working Group, Environmental Industries Commission, in the House of Lord Report on Waste Reduction, 2008)

There is no standard measurement to measure all types of waste. Other than a system such as a tracking system and lean production that can support measurement there are many other factors that accelerates the measurement and overall implementation of sustainable strategies. It is found in the study that it is very difficult for companies to measure how effective their efforts were. Although it is found that companies claimed having Eco-efficiency strategies keep statistics detail and tracking of all material purchase and waste. These practices however require resources and commitment in terms of manpower, discipline, time and money. When measurement gets complicated some of them refuse to measure but insist that are trying their very best to achieve the Eco-efficiency target. These accelerators have been discussed extensively in section 7.1.3.5. From the study it was found that companies which implement highest strategies have wider and deeper scope of implementation compared to the lowest strategies. For measurement, companies practicing Waste Minimisation use percentage, weight, monetary, for Material Efficiency companies use calculations such as 'material used' to 'buy material' ratio and Eco-efficiency use.

Based on conclusions made from literature analysis, the author found that the **indicator effectiveness, data availability, technical feasibility** and **communication and actions** are all impacted by how easy or difficult it is to measure each strategy. These criteria are all interrelated. An effective indicator (showing clear, reliable and positive improvement) depends on measurement and also needs available data. For implementation we need to have technical feasibility which in turn needs measurement, data to communicate and base actions on. The ability to translate a strategic intent into

actions is in turn affected by indicator effectiveness, measurement and communication. Based on evidence from the study, these assumptions were supported.

There is a lack evidence that showing how ***effective*** are the measurement of those strategies and tactics applied by companies.

'Life-cycle analysis is inevitably an extremely complex business and things which appear to be technocratic details such as systems boundaries and allocation of impacts between different co-products and so on can make an enormous difference to the outcome of the analysis. It can completely reverse the conclusions you get in the comparison of two products in some cases.'(Mr. Malcolm Fergusson, Senior Fellow, Institute for European Environmental Policy, in the House of Lord Report on Waste Reduction, 2008)

Most companies investigated have limited ***data*** on waste, material, resources and other environmental impacts to do measurement and to base decisions on in order to guide actions. Most companies have only basic data on waste such as waste recovery rate, energy consumption and other monetary measurements. Not many companies have data other than those basic data, for example, on emissions and advance calculation on environmental impact.

'*The information is out there but it is very confusing and I think that is the problem. If you are a small organisation, a small company, where do you go to get the right information for what you are trying to do or your production process? That is the barrier. You might know what you need to do, but sometimes you do not know how to action it and achieve it.' (Mr. Gareth Stace, Head of Environmental Affairs, EEF The Manufacturers' Organisation, in the House of Lord Report on Waste Reduction, 2008)*

Communication is difficult if the former criterias such as data, measurement and indicator are problematic. For Waste Minimisation and Material Efficiency communication is done by showing cost and waste reduction. This is hard enough as measuring waste and cost reduction are additional tasks on top of existing tasks to reach production targets, delivery times and customer request.

For the strategies' ***technical feasibility***, based on interviews, it is found that it is more difficult to implement any sustainable strategies if the companies lack a support system or existing accelerator in spite of difficulties implementing higher strategies. The evidence shows there are companies which implement higher strategies but which also try to treat Eco-efficiency and waste reduction as day-to-day activities. In contrast some companies only do Waste Minimisation but fail to achieve the companies' target on waste reduction. There are a few explanations on this which can be related to the accelerators which have been discussed at section 7.1.3.5.

Even though implementing these strategies is not easy and its indicator effectiveness is debatable, all of these strategies do ***guide actions*** in a positive way to certain degree. Since most actions are based on monetary saving, weight-age and percentage, their full effectiveness is not known. Most companies do guide their actions based on monetary and tonnes reduction. These will help most with the Waste Minimisation and Material Efficiency implementation as its measurement is more direct and involves less dimension or concerns.

Compatibility

Lastly on the ***compatibility*** of the definition and real practice, what is assumed from literature is proved correct. For example, there are measurement problems experienced by companies investigated especially for companies which try to implement higher strategies that look at material, resources, environmental impacts and beyond.

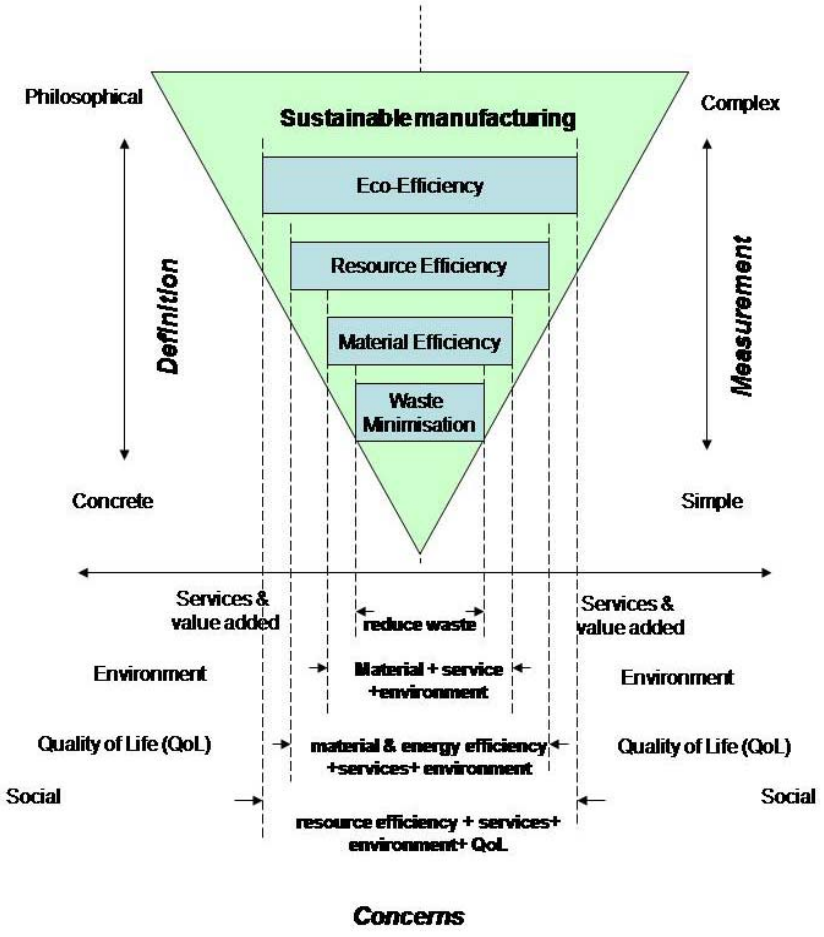

Figure 7.1 The hierarchy of sustainable manufacturing strategy

Whatever strategies companies choose in the spectrum from either Waste minimisation or Eco-efficiency; they will experience constraints such as on supplier and supply chain and measurement complexity. For the supplier and supply chain constraint, a bigger company may have a greater advantage influencing suppliers. Companies which cannot influence suppliers have to choose tactics such as to educate and influence customers or find other ways that best suit them. The companies which have wider concerns are the ones that are trying to work towards achieving Eco-efficiency (although some of them do not use the term Eco-efficiency).

'…my initiative to really redouble our efforts and making stuff in this country because important was that was a nonsense hmmm I said it was a lot been said then about a decline of British manufacturing its all in early 90's recession and the so in response to an article in FT, an letters that followed from it, I wrote a letter following that letter in

that article talking about the problems that we had getting suppliers to take us seriously in this country because we wanted decent quality and we are small and all of those things.' (Managing Director, Company 4)

'But we had to educate them, in early days it was quite difficult because it was whole different mindset for them.' (Managing Director, Company 4)

Conclusion for this section

Evidence gathered from the study support most of the claims that are put in the table 7.1 (previously table 2.6 at chapter 2). There is no evidence that rejected the claims. Some of the analyses were not rejected nor supported as this research is an exploratory research and the aim was not to test or to validate assumptions build up from literature.

Although most of the analysis is supported from the study there are many underlying issues regarding the comparisons made. The strategies and its characteristics are just a surface analysis. There are many factors involved in implementing those strategies. As brought forward by researcher at earlier sections, there are many issues involved in implementing the strategies such as motivations, factors that influence choice of strategies and accelerators for implementation. The companies also will face different constraints and benefits depending on several factors i.e. type of product produced, company size, company culture and much more.

Table 7.1 Evidences from industry are used to support comparison of four sustainable manufacturing strategies

Criteria / Concepts		Waste Minimisation	Material Efficiency	Resource Efficiency	Eco-efficiency
Definition	*Types*	Concrete	Concrete	Concrete	Philosophical
	Orientation	Goal oriented	Action oriented	Action oriented	Measurement oriented
	Focus	Effect-waste	Cause- material	Cause- resources	Cause/effect – Resources/pollution
	Main goal	Reduce waste and pollution Reduce cost	Efficient use of resources (both material and energy) Reduce waste and pollution	Efficient use of resources Reduce waste and pollution	Efficient use of resources, Reduce waste and pollution, Quality of life Earth carrying capacity
Scope	*Systems Boundaries*	Limited–downstream✓	Upstream-downstream ✓	1)Do not cover upstream and downstream activities ▫ 2)Cover upstream and downstream by measuring MIPS ✓	Claimed to cover upstream-downstream by addressing all stages of product life-cycle - but seen as debateable- ✓
	Influence Externalities	Limited✓	Yes✓	Yes✓	Yes - supposedly big influence ✓
	Level usually used	Process✓ , Company ▫and National ▫	Process✓, Product✓	Product▫, Company▫ and National▫	Product✓▫▫ ,Company✓▫▫and National▫
	Depth of issues to be tackled to achieved goal	Relatively easy✓	Potentially difficult✓	Difficult✓	Very difficult ✓
	Concerns (e.g economy, ecology)	Limited✓	Limited ✓	Broad✓	Broad ✓
	Utility Assess	Weight, volume, cost✓	Functionality/services ✓▫▫	Unit of value added▫	Unit of value added ✓▫▫
Practicality	*Measurement and Target*	Direct/simple✓ Quantitative ✓▫▫	Potentially complicated✓▫▫ - Quantitative✓	Complicated✓▫▫ Qualitative▫; Quantitative▫	Complicated✓▫▫ Quantitative✓ and Qualitative▫▫
	Indicator Effectiveness	Yes ✓	Potentially difficult	Difficult✓	Very Difficult ✓
	Technical Feasibility	Yes ✓	Potentially difficult	Difficult✓	Difficult ✓
	Data Availability	Easy	Potentially yes▫▫	Difficult✓	Difficult✓
	Easy of Communication	Yes✓	Potentially yes✓	Potentially yes▫	Difficult✓
	Does it guide actions	Yes✓	Potentially yes✓	Potentially yes✓	Debateable ✓▫▫
Compatibility	*Between goal and measurement*	Yes✓	Potentially yes✓	Potentially yes▫	No – difficult to determine on earth's carrying capacity, Limited, Does not effectively address the issue of toxicity ✓

✓ Supported ▫ Not supported/ no evidences ▫▫ Interesting for discussion

7.2.4 Working definition of Material Efficiency

Based on the data and synthesis from this research, the researcher has developed a working definition to help guide this and future studies. Thus, from this study, the researcher proposed a working definition of Material Efficiency as those manufacturing practices which are actively co-ordinated and implemented with the aim to:

- Use of less materials per product made, and/or;
- Generate less waste per product, and/or;
- Use less energy to make each product, and/or;
- Select materials that reduce impact on the environment (e.g. less toxic, recoverable, recyclable, and disposable).

For the purpose of this research it is assumed that the company is practicing a Material Efficiency strategy if the company is practicing or considering the use of tactics to achieve any or all of the targets listed above. It is not the intention of this study (due to time limitation and complexity of the measurement and efficiency issues) to investigate the effectiveness of tactics the companies employed to be able to achieve those targets.

7.3 Remarks on Other Interesting Findings

There are a few other interesting findings which emerged from this research that have potential for further investigation. Some of these findings were incorporated into main findings and into sections about other findings but these have not been emphasised enough. This section will briefly highlight these findings but limitations of the research boundaries, time and scope do not permit those findings to be further investigated and concluded.

From this study, the data shows that **companies which practice lean manufacturing are more active in implementing Material Efficiency and related strategies**. These companies are also the ones that strive to implement higher strategies such as Eco-efficiency. In terms of resources, these companies invest time, their workforce and money in researching ways to achieve higher Material Efficiency, Resource Efficiency and lower the environmental impacts. It is observed that there is a synergy between lean manufacturing and green practices. This prompts questions such as do companies need a lean attitude towards high cultural, systematic and team-work to achieve sustainable practices?

It is observed from the data that **big companies have fewer problems influencing suppliers** to practice or to fulfil the company request in order to practice sustainable strategies. This evidence is supported by House of Lords data.

It is observed that **SME companies have bigger problems influencing suppliers** to practice or to fulfil the company request so the company can practice Material Efficiency strategy. This evidence is also supported heavily by House of Lords' data.

'It is important to distinguish between SMEs and big businesses in their capacity to react to the waste agenda. SMEs rarely have the human or economic resource to invest in developing new solutions. Rather, buried in supply chains and, all too often, in fire-fighting mode, they can only react to the demands of clients, legislation, and increasing costs of energy and waste management.' (Memorandum by Social Environmental Enterprise and Design Foundation, in the House of Lord Report on Waste Reduction, 2008)

Measurement is a big problems and the biggest constraint for most companies. Companies having lack resources found difficulties to measure waste, Material Efficiency and resources. For companies to be able to effectively measure waste, material resource and Eco-efficiency, they need system in place, discipline and time which is very scarce. This is because companies have to concentrate on meeting a production schedule and solving day-to-day problems and issues. There is evidence that shows companies do not have time to identify, let alone research, the technology to solve problems related to waste and Material Efficiency. To solve the issue of resource and Eco-efficiency is very difficult for them. This is again mostly experienced by small companies, and this is heavily supported by evidences from the House of Lords' data.

'The point is getting air time with the senior people in small companies. They are extremely busy. If it is not on their list of top three jobs today, they are probably not going to get round to it.' (Professor Mike Gregory, Head, Institute for Manufacturing, University of Cambridge, in the House of Lord Report on Waste Reduction, 2008)

'From the small business angle it is feasible to design out waste but most small businesses are looking to survive for tomorrow, next week, next year.' (Mr John Holbrow, Chairman of the Environment Committee, Federation of Small Businesses, in the House of Lord report on Waste Reduction, 2008)

Successful companies included sustainability practices as normal practices and a compulsory aspect of design. Practices and tactics that contribute to waste reduction, improved Material Efficiency and reduce environmental impact comes as natural and effortless as the system to support the strategies is already in place.

'Our strategy is eco-efficiency strategy, the whole concept; the whole thing is about improving environmental performance and the impact of environment so the eco-efficiency is built in.' (Environmental Manager, Company 3)

'Sustainability should be included as a completely "normal" aspect of design. In the same way that "good" design at the moment has to address aspects like functionality

and aesthetics, it should also address sustainability as a matter of course. Too often "sustainable" design is still being taught as a speciality subject rather than as integral to the core design syllabus.' (Memorandum by Green Alliance, in the House of Lord Report on Waste Reduction, 2008)

Based on the critical literature review made by the researcher, it was found that there are missing links in sustainable strategies. There has been and still is much emphasis on recycling and tactics in reducing waste after it has been produced. There is also emphasis on Eco-efficiency, Resource Efficiency and Waste Minimisation strategies. In terms of resources there are emphases on energy and CO2 reductions. The missing link is that **there is not enough emphasis on Material Efficiency** or on material the impacts on environmental and resource availability. Attitudes towards materials are not equal to attitudes over other resources such as energy and water or attitudes over other environmental impacts such as CO2.

'In changing attitudes and behaviours over waste, we feel it is essential to move the debate from "outputs" to "inputs". In energy and water, people and government talk about the resource being used—i.e. the input—but when it comes to materials, the terminology most often used is waste—the output. We would urge the Committee to consider the benefits of changing attitudes to help people to focus on resource use rather than simply waste reduction.'(Memorandum by Envirowise, in the House of Lord Report on Waste Reduction, 2008)

'*We feel that there is currently too much focus on waste. The waste hierarchy is a sensible approach to reducing and managing waste but could equally be applied to resources. The majority of environmental impact from most resources comes from their production and use, rather than their disposal. If waste policy were refocused on reducing material intensity, it could lead to a more efficient economy.' (Memorandum by Envirowise, in the House of Lord Report on Waste Reduction, 2008)*

Although many tactics and strategies are **not fully achievable companies are still doing it**. This is because the companies have experienced benefits and also experienced more pressure to be more sustainable. Pressures are greater now compared to a few years ago.

'Because we look at prevention as being aligned with, say, zero waste. It is a philosophy, we would all like to get to that stage, but it is not achievable at the present time so let us look at something which is achievable.' (Mr Christopher Murphy, Deputy Chief Executive, The Chartered Institution of Wastes Management, in the House of Lord Report on Waste Reduction, 2008)

From the literature it was found that an estimated 93% of most resources become waste during the industrial process (including resources extraction phase). This shows that

manufacturers must and can play a bigger roles being in the middle influencing the supply chain upstream and downstream, and influencing its customers. Decisions made and practices by these companies would contribute to or reduce significant amounts of waste and resource use.

'Industry has a significant role to play in waste prevention and using waste as a resource wherever possible. Manufacturers are not only producers of waste, but will be providing the solutions to many of the challenges that are faced in reducing waste.' (Memorandum by EEF, the Manufacturers' Organisation, in the House of Lord Report on Waste Reduction, 2008)

The scenario in the manufacturing industry in UK currently shows that many companies are doing and practicing Material Efficiency and related strategies, whether it is the simplest Waste Minimisation or higher strategies such as Eco-efficiency. This is despite the view that manufacturing companies experience a lot of constraints and difficulties doing this, as the efforts and knowledge over this matter is incoherent and confusing (as admitted by academics and government representatives in the House of Lords inquiry report into Waste Reduction, 2008). The essence is that companies are doing the strategies, whether being pushed into it by legislation or voluntarily due to competition, because they recognize that these efforts will give benefits to them. Although many companies share certain constraints, the situation is not the same for all manufacturing companies. Company size and type of materials used in production have an impact over the constraint experienced by companies. History also dictates what materials; machineries, production system companies have been used, and can therefore limit how easy it is to change Material Efficiency performance. History also dictates company culture and thinking. Companies which have the intellectual capacity deal with these problems if they want it to, in a similar way to how they tackled production efficiency previously.

On Material Efficiency practices, although the companies came up with various tactics and strategies, there were few promising strategies and tactics that the researcher found that companies should focus upon. One may comment that most of them are common sense and are already practiced widely by manufacturing companies. However just like energy, material efficiency is becoming an important focus and its everyday practice not well understood in the literature. Material inefficiency and waste will be reduced if manufacturers can convert material waste to resources and reduce waste in both the production and customer use phases. These can be done by producing quality products, design for x, influence suppliers' behaviours, influence customers' behaviours and improving systems to get materials that can be reused back. All these tactics can be combined, and one way of doing it is by offering services to customers and not products (termed Product Service Systems). Product Service Systems have a big potential in improving material efficiency as the product and the system could be designed in such a way that it increases the chance for the manufacturers to get their materials back and

manage its supply as a feedstock. This would reduce dependency on customer awareness to sort and return the material into the proper systems.

7.4 Reflections on Research

First of all, the researcher would like explain why the **term Material Efficiency** sometimes referred to specific Material Efficiency strategies and at other times refer to all manufacturing sustainable strategies investigated in this research. The literature done by the researcher has highlighted that Material Efficiency is at the core of every sustainable manufacturing strategy, thus the researcher believed the Material Efficiency strategy existed in all those strategies. Terms for strategies in this area are not yet clear; some terms have been used interchangeably. This view is shared by other academics when asked during House of Lord inquiry on waste reduction on the difference between the terms.

'Chairman: What is the relationship between waste reduction and material efficiency or resource efficiency and how do you link those?'

'It is part and parcel of a holistic or generalistic view of prevention. Prevention or minimisation will include specific targets, resource use, awareness-raising, it is all implicit in this generalistic term which is prevention or minimisation.' (Mr Christopher Murphy, Deputy Chief Executive, the Chartered Institution of Waste Management, in the House of Lord report on Waste Reduction, 2008)

There are some issues and concerns that could affect the research's results. The data were collected using semi-structured interviews. During the interview sometimes interviewees talk about some things in more detail than others. During an interview lasting from 40 minutes to 90 minutes at most, it is impossible to cover all aspects of Material Efficiency practices in company. Thus it is possible some factors that not mentioned by the interview exist in the company. The author has to assume that if it is not mentioned during the interview, the factors are not significant to the company. The results are more to reflect what emerged from the data rather than what really exists in one particular company. To overcome this weakness, the cross-case study and validation were done to highlight the themes, its pattern and significance. As this is an exploratory research, the findings are not to test the theory rather working towards theory building.

Sustainability research has not had a long history. Although ideas on sustainability sprout as early as 30s but the intensity on this research is fairly recent. Research in sustainability is influenced by different areas such economics, environmental, science, manufacturing and management. Thus, the literature papers from these different areas have different priorities. These papers argued on different stance, which of course challenges the researcher.

'Knowledge in the field is chiefly based on empirics, although can be consolidated into some general principles and design rules. Real fundamental research in this field is lacking, because the field is new and for new research projects, universities have to rely on external sponsors (which are mostly interested in applied rather than in fundamental research).' (Memorandum by Philips Consumer Electronics, in the House of Lord report on Waste Reduction, 2008)

Doing research on topics which have combinations of research methods such as phenomenology, exploratory, case study, qualitative data and qualitative analysis is a great challenge to researcher. As this research starts with almost no theoretical framework and assumptions; this then caused difficulty in setting barriers while investigating. Conversations with people from industries were usually very interesting and there is danger to prolong the conversations and found interesting things that less related to the topic.

Doing qualitative research methodology and methods is challenging for manufacturing management area as these methods are considered new for the researcher in the management school let alone to the researcher in the manufacturing school where experiments, simulations and quantitative methods are dominant. In the 1980's and 1990's, the qualitative research became more multidisciplinary in focus moving beyond qualitative research's traditional disciplinary roots of anthropology, sociology, and philosophy (Denzin *et al*, 2005). However, in doing this research, not all qualitative methods are suitable to manufacturing management subjects. It requires the researcher to adopt certain methods to tailor to the needs of new subjects. Being in the experiment, modelling and quantitative research world it is easy to look at the qualitative data with a quantitative view. The researcher sees these challenges as a tool for learning as an obstacle the research progress. Qualitative methods are increasingly popular in the Manufacturing, Engineering and Technology Management community. The Annual EPSRC Research Methodology Workshop for Manufacturing and Technology Management which has been held for 17 successive years at the University of Cambridge has regarded qualitative methods to be equal to quantitative and experimental methods.

Qualitative research offers opportunities to forward new knowledge in this area through investigating the knowledge from different angles and provides a depth and description of what is happening in industry from the practitioners' views. This could be done because qualitative research involves understanding the meaning that individuals give to the phenomenon inductively (Creswell and Clark, 2007). This could not be done using other approaches such as experimental, simulation and quantitative methods.

As the **methods are not well known in manufacturing research**, the research methods chapter is heavily described the philosophy of research, ontology and epistemology choices to justify the relevance of qualitative research to this type of study.

7.5 Chapter Conclusions

This chapter presents discussions on findings. Findings are put as an answer to Research questions. There are other findings that emerged from the study which do not directly answer the research questions, but offer a body of knowledge surrounding the list of objectives set out to be investigated. In the later sections of this chapter the remarks on the interesting ideas/findings and reflections on research is discussed. This research presents new findings on:

1. List of significant factors that catalyse companies to have Material Efficiency strategies.

2. List of significant factors that influence decision on choosing type Material Efficiency strategies.

3. List of significant constraints experienced by companies to implement and while implement the Material Efficiency strategies.

4. List of significant benefits gained by companies for implementing Material Efficiency strategies.

5. List of significant accelerators that help with implementing strategies.

6. Comparison that shows the spectrum of four types of sustainable manufacturing strategies is presented as table 2.6 and 7.1, and is also shown in the form of an hierarchy which shown in Figure 7.1.

7. Compares the table to real practices in industry.

8. Working definition of Material Efficiency strategy.

The table below shows the summary of findings from the research

Research Questions	***Summary of findings***
RQ1 Do companies use Material Efficiency strategies?	▪ Companies do practice Material Efficiency strategies ▪ All companies have at least done waste minimisation strategy ▪ Some companies are more proactive in reacting to pressures ▪ Smaller companies have bigger challenges in implementing Material Efficiency
RQ2 Do companies use these strategies but call them something else?	▪ Companies used various achievable tactics ▪ Each manufacturer tends to give their own names ▪ They certainly do not use any of the phrases Material Efficiency, Resource Efficiency and Eco-efficiency
RQ3 How do companies use Material Efficiency Strategies?	
a) What Material Efficiency strategies exist in practices?	A list of tactics has been provided: 1. Material and waste recovery 2. Design (e.g. Design for environment, Use environmental benign material, Produce environmental friendly products) 3. Relationship with suppliers 4. Relationship with customer 5. Efficient use of material (i.e. use less materials) 6. Use tools, techniques, environmental programmes and standards 7. Environmental target and objectives 8. Measurement and audit 9. Manufacturing and machine efficiency 10. Product service system 11. Prolong product's or material's life 12. Implement sustainable strategies (i.e. Resource Efficiency, Waste Minimisation, Material Efficiency, Eco-efficiency etc.) 13. Lean Production System 14. Reduce packaging materials 15. Legislation compliance

Discussions

b) *What Material Efficiency strategies exist in literature?*	i.e. Clean production, Dematerialisation, Material reduction, Resource Productivity, Material Production, Pollution Prevention, Product Service Systems, Ecological Footprints Ecological rucksacks, End of life strategies, Environmentally Conscious Manufacturing, Design for Environment and much more. There are also a range of target and measurement techniques such as Zero Emissions Systems, Direct Material Inputs and Intensity of Use etc.
c) *What benefits do these companies achieve?*	1. Cost reduction 2. Waste and environmental impact reduction 3. Virgin and incoming materials reduction.
d) *What difficulties did they meet when implementing Material Efficiency strategy?*	1. Design constraints 2. Measurement and target 3. Making decisions and prioritising 4. Supply chain and supplier constraints 5. Organisational barriers 6. Manufacturing processes constraints 7. Recyclability 8. Employee constraints 9. Product types 10. Regulation, standard and legislation 11. Company size
e) *What actions did they take that helped the implementation succeed?*	1. Management awareness and knowledge 2. Available technology 3. Employee awareness 4. Suppliers 5. Company's culture 6. Environmental standards and ISO 14001 7. Product types 8. Good communication inside company 9. Environmental target from top mgt 10. Lean and Japanese influence
Other Findings	***Summary***
The factor that catalyse company to implement ME strategies	1. Cost reduction 2. Customer influence 3. Competition

	4. Company's image and social responsibility 5. Management awareness 6. Employee Awareness 7. Company's culture 8. Legislation 9. Material price fluctuation and availability
The factors that influence choice of strategies	1. Cost reduction 2. Product type 3. Management awareness 4. Customer requirements 5. Legislation 6. Available technology 7. Company's culture 8. Company's image and social responsibility
Sustainable manufacturing strategy spectrum table (Table of comparison of four main manufacturing sustainable strategies)	Refer to table 2.6 at page 29.
The hierarchy of sustainable manufacturing strategy	Refer to page 31 and 187.
Working definition of Material Efficiency Strategy	Refer to section 7.2.4 at page 190

8 SUMMARY AND CONCLUSIONS

This chapter reviews the aims and objectives; summarises the research process and research findings. In this chapter, the researcher will present the contribution of this study to academia and what are its implications to industries. The researcher will show the limitations and opportunities which arise from this study. Overall, this chapter shows what the researcher has done, found, learned and understands and what others can benefit from it.

8.1 Reviewing the Aim and Objectives

The aim of this research was developed at Chapter 1, which states as below:

To establish an insight into Material Efficiency strategy as discussed in the literature and as practiced in the real world. By presenting this work, other researchers and practitioners can gain knowledge and understanding as this study will characterise and categorise strategies that fall under Material Efficiency concepts.

This research aim has been achieved by completing the following three research objectives which was also established in Chapter 1. The objectives of this research were:

- To review critically substantive literatures, company practices and other secondary resources in relation to:
    - the concept of Material Efficiency including its rationale, origins and attributes;
    - the rationale, origins and attributes of related strategies similar to Material Efficiency;
    - related sustainability issues.
- To identify the key characteristics of different Material Efficiency strategies.
- To categorise Material Efficiency strategies.

8.2 Summary of Research Process

As this research is in a relatively new subject area and is phenomenological and exploratory, there is no conceptual or theoretical framework to guide the research. This research consists of two main stages. Stage one was a critical literature review that resulted in comparing and positioning Material Efficiency strategy among published,

important sustainable manufacturing strategies in the UK. From these findings, interview questions and themes of investigation in companies for stage two were generated. Stage two was data collection in industry to investigate companies' Material Efficiency real practices.

As a process of enquiry and investigation which aims to contribute to the body of knowledge, this research has been carefully planned and designed using systematic and valid methods. The research is carried out through multiple cases studies. Sixteen (16) semi-structured interviews from ten (10) companies have been conducted, which consist of nine (9) manufacturing companies and one (1) retailer. In addition the researcher has had access to high quality secondary data from the House of Lords Inquiry into Waste Reduction. These additional data was used to validate findings and to support the synthesis process.

Data analyses were conducted in three stages, firstly within case analysis, secondly cross-case analysis and thirdly validation. Thematic analysis is an approach used in data analysis which can be applied both within cases and in cross-case study. Validation was improved using secondary data taken from the House of Lord report on waste reduction inquiry. The final process in this research was synthesis, which used primary and secondary data to work towards the conclusions.

8.3 Summary of Research Findings

The findings of this research are summarised below:

1. It is found that companies in UK are using Material Efficiency and related strategies as a tactic to reduce material waste, material usage and environmental impacts.

2. The strategies' names that companies used are not necessarily the same as those used in literature. Companies used names that communicated well to their employees and management.

3. Companies gained benefits implementing Material Efficiency and related strategies.

4. Companies experienced difficulties in implementing these strategies.

5. Companies found specific accelerators that helped with their implementation.

6. There are a set of factors that commonly motivated companies to implement Material Efficiency strategies.

7. There are set of factors that influence companies in choosing which type of Material Efficiency strategy to adopt.

8. The factors 3-7 above are interrelated, and influenced by the context of the company.

9. Various authors on different manufacturing sustainability strategies related to Material Efficiency are compared and contrasted in a table using key characteristics.

10. Four different sustainable manufacturing strategies, including Material Efficiency, are positioned in a proposed hierarchy.

11. A working definition of Material Efficiency strategy is proposed.

8.4 Contributions to Theoretical Knowledge

In the literature, it was highlighted that few other studies had addressed issues such as the motivation, challenges and the benefits achieved by companies when practicing a range of strategies and tactics available in sustainable manufacturing. However, no literature can provide an overview of sustainable manufacturing strategy especially on material efficiency practices in UK manufacturing context. Previous studies by various researchers were not addressing factors such as motivation, accelerators, constraints, benefits and practices in one single investigation on UK manufacturers. They either reported one or two factors such as practices (see Côté *et al*, 2006; Finnveden *et al*, 2005 and Khanna *et al*, 2009), or motivation and constraints (see Young, 2001, as cited by Côté *et al*, 2006; Vernon *et al*, 2003; Garcia *et al*, 2008). There were also researchers who looked at the relationship between the strategy implementation and outcomes, such as Chapple *et al* (2005) and Yu *et al* (2009). The nearest study was an exploratory study by Gottberg *et al* (2006) which presented motivations, drivers and constraints experienced in the European lighting sector in performing Eco-design. However this is limited only to Eco-design and to the lighting sector, which is one of many strategies in sustainable manufacturing, and only looking at design practices rather than operations. On highlighting the importance of Material Efficiency, there was a study by Lilja (2009a) who found that in the future the trend will shift from Waste Prevention to Material Efficiency and Eco-efficiency in Finland. However this study takes the view of policy makers in Finland and is not grounded in findings from industry. It is stressed here that no studies have been identified that compared the four main sustainable manufacturing strategies and highlighted the significance of problems of Material Efficiency strategy being tackled in order to make sure the three other strategies and sustainable manufacturing are achievable. There were also no other studies found that show the various factors and attributes that relate to success, which were grounded from data collected from UK industry. In this single study, the findings show insight into real practices.

In conclusion, it is emphasised that there are no similar studies that can fill the gaps investigated by the researcher, thus emphasising the value of this study in adding to the current literature in this area. The academic contribution to knowledge made by this thesis has been to explore the concept of Material Efficiency strategies, related strategies and its surrounding attributes. This investigation on the topic gives contribution to knowledge in five ways:

Firstly, the study makes a significant contribution through a critical literature review that compared the different published sustainable manufacturing strategies. Clear comparison among these strategies is useful to identify the strategies' characteristics and issues surrounding their implementation. This review, definitions and critical comparison provides better understanding of the sustainable manufacturing strategies. This study provides a useful starting point for those wishing to undertake research in this area.

Secondly, this study contributes to substantive knowledge on Material Efficiency practice through providing a list of factors on motivations, on choosing strategies, on accelerators, on benefits, on constraints and by comparing practices in industry. There is no similar study determining these factors for Material Efficiency related strategies done in UK. There is currently a lack of evidence on how companies are coping with the sustainability pressures and how companies practicing Material Efficiency strategies and related sustainable manufacturing strategies. This study gives an insight into the strategies practiced by companies, and into the benefits and issues surrounding the implementation.

Thirdly, the comparison between published views on Material Efficiency and its related sustainable manufacturing strategies with the real practices in UK industry give a contribution to substantive knowledge. This helps academics steer future research into the direction that can help industry in realising the objective of reducing waste, material usage and overall environmental impacts in a practical and achievable manner. Thus the critical comparisons made in literature compared with real practices can give insight to the challenges and issues in implementing those strategies.

Fourthly, this study highlights the importance of addressing materials before it becomes waste. In term of tactics used the research community and government bodies have overly emphasised other strategies such as recycling which only tackle a small part of the problem, and does not significantly reduce the waste. The research community and government bodies also overly pay attention to other types of resource such as energy and other type of waste such as CO2. This may be because they are clearly important in tackling climate change, but also because they are simpler to tackle than material efficiency. Thus insights from material efficiency research may give a fresh direction into solving problems through increased understanding and practice, in order to prevent materials becoming permanent waste.

Fifthly, the study provides a contribution to substantive knowledge by identifying and positioning the Material Efficiency strategies among other sustainable manufacturing strategies, using the hierarchy and the strategy spectrum. This contribution may help the research community by providing some structure to a currently confusing and complex topic

8.5 Research Limitations

This section discusses the limitations on both research protocol and research findings.

8.5.1 Limitations of the research protocol

On gathering evidences from data, the research activities have followed the stages of data collection, analysis and synthesis. The methods of data collection and data analysis however are subject to issues that need to be highlighted.

First, the data was collected using a semi-structured interview which the questionnaire was designed in a way so that it could collect rich information. However this method has a disadvantage as its sometimes inclined towards having a lengthy interview as communication gets interesting. This in turn could contribute to longer and painstaking data analysis. It is easy to miss some important points that can alter the findings. This problem is known as the problem of anecdotalism which is explained in Bryman (2001) and Silverman (2004). This happens when the researcher tends to draw findings from clear or apparent phenomenon and less attention is given to less clear (or even contradictory) data.

Second, the researcher had wished to design questionnaires more carefully which would easily steer the communication to its greatest benefits. This however requires careful planning and knowledge during designing and selecting questions. This could not be fully achieved as the researcher understanding of methods was not very profound during the early designing data collection stage. Designing questionnaires in a way that could ask questions in many ways can help to cover the researcher's lack of skills (if any) in interviewing subjects. Interviewing requires skills to probe and build rapport which could be improved by experience and practice. Lacking these may result in missed opportunities in uncovering useful information.

Third, the *thematic analysis* method has its own challenges. Thematic analysis reveals findings to a certain extent from a very rich set of data. Much deeper findings could be generated using other methods such as grounded theory and other techniques. These methods could be used to show the relationship of variables, thus a pattern can be built. Generating relationships and patterns will be useful to work towards theory building. This could not be done due to time limitation because qualitative research is time consuming. Doing thematic analysis requires researcher to have interpretive skills, to perform consistently, have the ability to connect the themes and be extra diligent.

All the limitations above could be improved as the researcher's skills and experience improve over time. Due to this research being the first qualitative research project for the researcher, many limitations were expected due to lack of prior knowledge and experiences when this research project was executed.

8.5.2 Limitation of the research findings

This research has investigated Material Efficiency practices and its related strategies at ten companies. This research has investigated companies without selecting the attributes of the companies other than choosing preferably manufacturing companies which practice Material Efficiency and any related strategies. Thus these findings are limited to providing an insight into general Material Efficiency practices without detailing the influences of the different variables. These variables may give different results and findings of the study would give greater impact e.g. type of constraints experienced by smaller companies versus type of constraints experienced by bigger companies, type of constraints experienced by companies categorised into type of materials they used and so on. As explained in the section above this can be done but it was not done in this research due to time limitation and would probably need more case studies. As has been highlighted before there is limited time to do the extensive analysis because of the study's scope and time. However the findings generated from this study are highly significant and original as the process to generate the findings to this extent were already arduous and lengthy.

8.6 Opportunities for Future Research

Research in Material Efficiency can be considered to be at a very initial stage. This is only an exploratory research thus there are many opportunities for conducting further research in this field. The current research can be viewed as an attempt to explore this field by providing insight and direction for future research in this topic.

This research has investigated Material Efficiency practices and its related strategies at ten companies without choosing the sectors. In term of company size, companies which participated in this research were mixed, some of them are small size companies and some of them are large international companies. Companies which participated in this research were also chosen without selecting the type of specific sectors, without choosing the types of materials companies use as an input or types of products that the companies produced. As found in this study there are some different sets of issues experienced by manufacturers, influenced by factors such as company's size, available technology and type of material used, type of products and so on. Future research can therefore replicate this study by grouping the case studies into different variables, such as grouping into sets of large companies versus set of smaller companies, or on different sectors, different types of product produced and materials used. The patterns of findings

will without doubt, offer deeper insight into new knowledge as these variables may yield different results.

Other than opportunities for future research in Material Efficiency topics, there are many other research opportunities around the topic that need to be addressed. This research highlights problems with measurement and indicator effectiveness, and more research is needed to pursue issues with measurement, including gaining a better understanding of both quantitative and qualitative indicators. Data from this research shows that very few companies are willing to practice higher strategies such as Resource Efficiency and Eco-efficiency because of the lack of workable "efficiency measure(s)". Offering a solution to this issue through a better understanding of measurement will be a tremendous help to both practitioners' and academics in implementing sustainable strategies.

Research on improving manufacturing process and systems to support material efficiency and waste recovery is needed. Many manufacturers are having problems segregating and recovering waste into production due to several reasons. These are problems with manufacturing process, technology limitations and also there is lacking a supporting system (e.g. local recycler or local council). More research to address this issue is needed to help manufacturing companies work towards achieving sustainability practices.

Generally there is a lack of accessible data relating to the life cycle impact of materials that manufacturers and designers could use to measure and to base decisions on. They also lack support and guidance from government agencies in selecting product type that have less impact on the environment. Without understanding the overall environmental impacts it is impossible to fully quantify the benefits derived from a more efficient use of materials. Although providing a database which contains data on materials and their associated environmental impact is would be very difficult and would require time, something should be done to provide the information so that designers and manufacturers could refer to it in order to practice successful manufacturing sustainable strategies.

Currently there is not much evidence that suggests that designers, material scientists, manufacturers, people in service and customers communicate with each other specifically in order to produce material efficient and environmental friendly products. This could lead to these individuals making decisions limited to their knowledge. An example of this is designers with minimum knowledge and information on materials and environmental impacts would design product that according to them is environmental friendly but actually it is not. Research should be done to enable these people to communicate during sourcing, choosing materials and manufacturing process, designing products, manufacture and offering services that have emphasis on materials and their environmental impacts.

8.7 Implications for practitioners

In order to understand how Material Efficiency and sustainable manufacturing strategies help to reduce waste, material usage and environmental impacts, manufacturers need a fresh insight into what strategies are available, how these strategies can help and which strategies suits them. This research provides knowledge and guidelines to practitioners in three ways:

Firstly, it focuses companies' attention on the importance of tackling material efficiency and waste at source.

Secondly, it gives an insight into other companies' practices, accelerators, constraints and benefits. Through this, manufacturers can learn good practices and overcome difficulties from other people experiences and potentially build better programmes themselves.

Thirdly, the comparison table and the figure that shows the position of each strategy along the spectrum of sustainable manufacturing hierarchy can give rough guidelines on available strategies and its characteristics. These can help companies during implementation about which direction to consider and what difficulties they could expect.

Overall academic research on Material Efficiency will impact upon practitioners as it addresses the fundamental resource which is waste. In the past the ability of nature to continue to create new materials and to absorb our waste was not questioned, but this situation will not continue and we have to learn how to be much more efficient, both now and in future.

'... the only thing I would possibly ***say that it is refreshing that academia is actually looking into raw material utilization*** *because its…raw material…we sell our [product] and we will negotiate to sell our [product] that we are going to sell in 3, 4, 5, 6, 10 years time, so we need to understand the cost of that in 4,5,10 years time. Unfortunately a lot of the cost of our [product] is driven by elements costs and elementals cost is like share prices. One day they go up, next day they come down.'(Value Engineer, Company 1)*

8.8 Research Conclusions

Material efficiency is of utmost importance to ensure that the supply of materials, especially materials extracted from earth, is available for the manufacturing industry to continue operating now and in the future. Manufacturers need to change their way of doing business, the way their products are designed and how they manufacture their products. From the study, it can be seen that manufacturers in the UK are aware of the need to use materials more efficiently, mostly due to competitive factors such as cost,

company's image and customer pressures. It is recommended that manufacturers should make themselves more aware of the long term benefits of practicing Material Efficiency as the way they operating now could impact the way they are doing business and their future existence. Evidence from the literature review shows that high percentages of materials are wasted during extraction and production. Manufacturers are in the middle of a supply chain and are better positioned to influence decisions on upstream and downstream activities. These decisions could reduce waste and environmental impact significantly. The long term benefits of Material Efficiency as evidenced in the literature review are the ability to reduce a high percentage of waste, use less earth resources and have less environmental impact, such as toxicity, due to materials waste.

There are many tactics that can be employed by manufacturers in all functional areas such as design, manufacturing, sourcing, services and at an overall business level. In design, a company needs to include sustainability while designing the product development process using concurrent engineering philosophy. The design stage plays a key role as most of the cost and the environmental impact are determined at this stage. Tactics that can be employed by manufacturers are; design the products and services that have less environmental impact, use less materials and produce less waste. This can be achieved by influencing suppliers and customers to take part in joint activities and so influence their behaviours and actions. Manufacturers can also prolong material life by using several tactics such by offering a product service system and performing design for x.

In terms of manufacturing strategy, manufacturers should concentrate on employing tactics and using technology to promote efficient use of materials to increase manufacturing and machine efficiency. Although there are challenges in changing manufacturing process as many process are inherited, there are many things that can be done to change how the company operates. It is expected that the target of having energy efficient materials and resources are quickly becoming as important as manufacturing efficiency in the future.

Overall at the management level, the company should make its plan to implement Material Efficiency strategies clear, communicate environmental targets and objectives to employees, encourage employees to identify waste sources and have a system such as Lean production in place.

In practicing the tactics and strategies of Material Efficiency during sourcing the material, the manufacturer should have a strong relationship with suppliers to be able to request their support for strategies and standards practiced by the company. Without the support of suppliers and without the recycling network it is almost impossible to practice successful Material Efficiency strategies. The companies also should have thorough systems that can support implementation inside the companies. This research indicates companies that have a good working culture, proactive management, good

relationship with suppliers and have lean production system in place are more successful in implementing Material Efficiency strategies. Customers play a big role as the products and services exist because of them.

Based on the experiences of the participating companies in this study, accelerators such as management awareness and knowledge, technology and employee awareness could help with implementation. Constraints such as design, measurement, and decision making (due to lack of information and measurement problems) need to be understood by companies and are good areas for researchers to improve. Although types of constraints and accelerators differ from business to business, many accelerators and constraints gathered are common and are a useful guidance to manufacturers.

Material Efficiency strategies could be used by manufacturing companies to minimise waste, maximise material usage and use environmentally benign material through:

- practicing these strategies in production;
- designing a product in such a way that supports those strategies in production, after sales service and even after life;
- take into account of material efficiency when sourcing and purchasing materials;
- take consideration of material efficiency when designing manufacturing process;
- influencing suppliers to adopt these strategies;
- influencing and causing customers to support those strategies by using material efficient products.

It is highly recommended that manufacturers prepare and adopt a Material Efficiency strategy as early possible as the pressure to reduce waste and environmental impact will definitely not decrease. It is predicted that materials efficiency will be increasingly needed as the demands on products increase as materials resources are declining. Thus is a good strategy for manufacturing companies in order to be competitive to get ready for more pressures to come.

'We are only just beginning to consider how to design for recycling, and until forceful economic or regulatory drivers are in place here in the UK, we will not refine our understanding of product life-cycles or develop world-class academic expertise to take us into a ***better material world.****' (Memorandum by Green Alliance in the House of Lord report on Waste Reduction, 2008)*

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APPENDIX

APPENDIX 3.1: INTERVIEW QUESTIONNAIRES

Semi-structured Interview and list of sustainable manufacturing strategies

Interviewer to introduce herself, explain purpose of the interview, assures confidentiality, ask permission to record. Also briefly explains what the research is all about and give definition of Material efficiency.

Questions

1. Could you please tell me what is your job role?
2. What is your company doing to improve material efficiency?
3. Why do you think the company is doing this? (e.g. customer request, legislation, material cost, landfill cost)
4. How wide is it practiced across the company?
5. How widely is it practiced across the lifecycle (from material extraction to landfill)
6. Does it involve suppliers? (If yes, how do suppliers get involved in this strategy?)
7. Does it reach customers? (If yes, how can the customer contribute to it?)
8. What is the evidence of success?
9. Why did your organisations choose this specific strategy?
10. Why do you think that the strategies succeeded/failed?
11. Please tell me how the strategies are incorporated in the product design/manufacturing processes?
12. How do you know the strategy is working?
13. Are any measurement tools used?
14. Do you think these tools work? And why do they work/fail?
15. Do your companies practice these tactics (similar ones)? (showing the list)
    - using less material
    - re-use, re-cycling materials
    - materials substitution to more environmental friendly materials (easy to dispose, recyclable, less toxic)
    - material substitution to less energy intensive materials

- sharing of resources/materials with other business unit inside or outside the company (multiple use)
- servicising/ leasing
- innovation through design to use more efficient materials.

16. The literature lists the following strategies (showing the interviewee the list)
17. Have you heard of these?
18. What do you think these mean? (showing the main three strategies)
19. Are such practices used inside your company?

    - If so, how?

20. Does your company intend to widen the strategy or/and opt for bigger strategies?

List of Strategies (some of the strategies appear in literature)

Material Efficiency

Waste Minimisation

Material reduction/dematerialisation

Eco-efficiency

Resources Efficiency

Resource Productivity

Material Productivity

Pollution prevention

Integrated Product Policy

Product Service Systems

Materials Input per Unit Services

Ecological Footprints

Factor 4/Factor 10/Factor X

Ecological rucksacks

Direct Material inputs

Intensity of Use

Zero Emissions Systems

Clean production

End of life strategies

Symbiosis

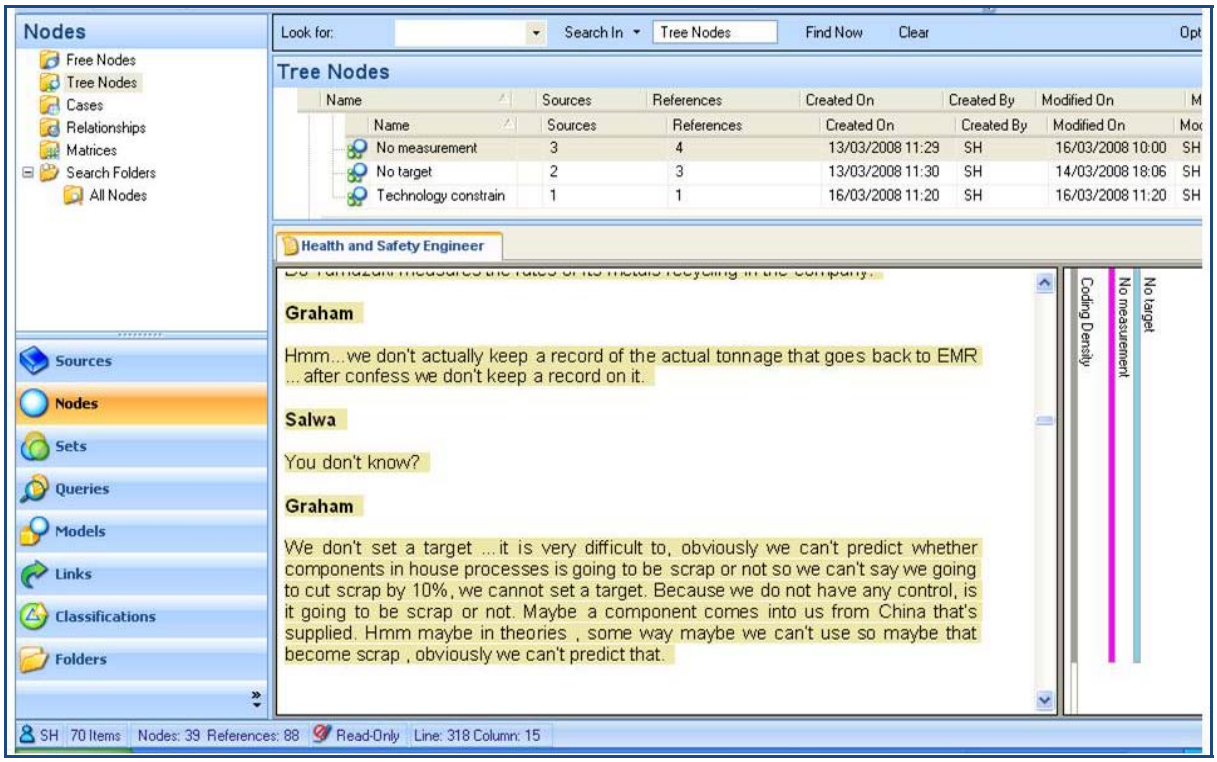
Design for Environment

Environmentally Conscious Manufacturing

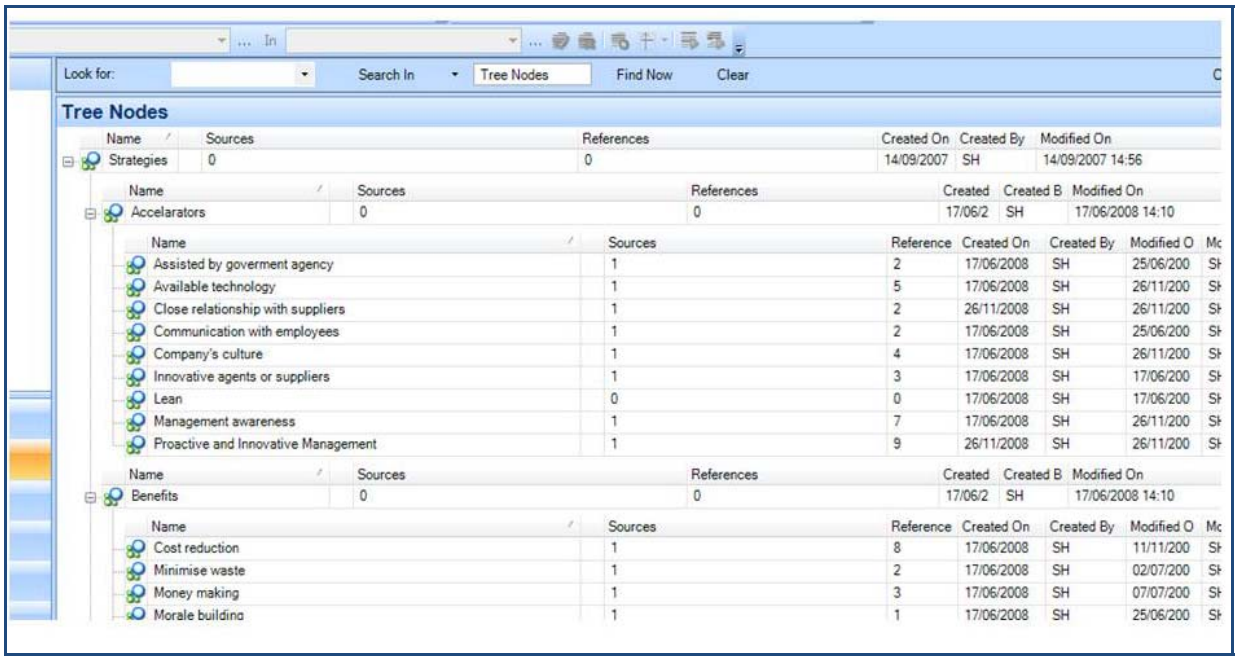
Recycling/Re-use/Remanufacturing

APPENDIX 4.1: EXCERPT FROM NVIVO ANALYSIS

Example of coding process during within-case analysis using NVivo 7 shown by picture below:



Example of codes or nodes built during within-case analysis using NVivo 7 shown by picture below:



APPENDIX 5.1: EXCERPT OF SUMMED INDICES TABLE

	Cases										Weight
Factors that catalyse to have strategies	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**Out of 10**
Employee Awareness		✓	✓		✓			✓			4
Management awareness		✓	✓					✓		✓	4
Company's image and social awareness and responsibility	✓	✓	✓			✓	✓			✓	6
Company's culture		✓				✓		✓		✓	4
Cost reduction	✓	✓	✓	✓		✓	✓		✓		7
Increase production efficiency		✓		✓							2
Customer influence	✓	✓	✓	✓			✓	✓			6
Creative employees								✓			1
Material prices and availability	✓								✓		2
Competition			✓	✓		✓	✓				4
Legislation	✓						✓				2
Vision and target					✓					✓	2
Reduce product weight	✓										1
Health issues		✓									1
Reduce waste and environmental impacts									✓	✓	2
Product type							✓				1
Reduce incoming and virgin materials						✓					1

APPENDIX 5.2: COMPREHENSIVE LIST OF THEMES

Comprehensive list of themes resulted from Cross-case analysis: Themes with weight-age

Factors that catalyse to have strategies

1. Cost reduction (7)
2. Customer influence (6)
3. Company's image and social responsibility (6)
4. Management awareness (4)
5. Employee Awareness (4)
6. Competition (4)
7. Company's culture (4)
8. Legislation (3)
9. Material price fluctuation and availability (2)
10. Reduce waste and environmental impacts (2)
11. Vision and target (2)
12. Employee selection (1)
13. Increase production efficiency (2)
14. Suppliers influence (1)
15. Reduce product weight (1)
16. Health issues (1)
17. Product type (1)
18. Creative employees (1)
19. Reduce Incoming and virgin materials (1)

Factors that influence choice of strategies

1. Cost reduction (6)
2. Product type (6)
3. Management awareness (Proactive and innovative) (5)
4. Customer requirements (4)
5. Legislation (3)
6. Available technology (3)
7. Company's culture (3)
8. Company's image and social responsibility (3)

9. Employee awareness (proactive and creative) (2)
10. Material availability and prices (2)
11. Competition (2)
12. Relationship with suppliers (2)
13. vision and target (2)
14. Production efficiency (1)
15. Business models (1)
16. Light weighting (1)
17. Organisational barriers (1)
18. Innovative suppliers and employees (1)
19. Health and safety (1)
20. Company's common Sense (1)
21. Waste reduction
22. Relationship with customers (1)
23. Dislike performing measurements (1)

Constraints

1. Design constraints (customer expectations, product's functionality, performance and safety) (5)
2. Measurement and target (4)
3. Decision making (4)
4. Supply chain and supplier constraints (4)
5. Product's type (3)
6. Organisational barriers (management, communication and culture constraint) (3)
7. Manufacturing processes constraints (3)
8. Recyclability (segregation, down-cycling, downgrading, volume)(3)
9. Employee constraints (3)
10. Customer expectations on green products(2)
11. Business systems constraints (2)
12. Useful waste as resources (no where to go) (2)
13. Cost constraints (1)
14. No assistance from government agency (1)
15. Material substitution constraints (1)

16. Business model constraints (1)
17. Some waste is inevitable (1)
18. Company size (1)

Accelerators

1. Management awareness and knowledge (proactive and innovative) (7)
2. Available technology (5)
3. Suppliers - Close relationship with suppliers, suppliers have green practices(5)
4. Employee awareness (innovative and proactive) (4)
5. Company's culture (4)
6. Lean and Japanese influence (3)
7. Product types (3)
8. Environmental standards and ISO 14001 (3)
9. Good communication inside company (3)
10. Environmental target from top mgt (3)
11. Government assistance (2)
12. Relationship with customer (2)
13. Available resources (people and R&D budget) (2)
14. Tight employee selection (1)
15. Knowledge sharing (1)
16. Simple measurement (1)
17. Product's life (1)
18. Clear definition on strategies

Benefits

1. Reduced cost (8)
2. Reduced waste and environmental impacts(6)
3. Reduced virgin and incoming materials (4)
4. Need vision or target (2)
5. Saving time and improve production efficiency (2)
6. Competitive (1)
7. Ready to changes (agile)(1)
8. Material supply (1)
9. Comply to legislations (1)

10. Avoid market fluctuation (1)
11. Morale building (1)
12. Improve company's image(1)

Practices

1. Material and waste recovery (10)
2. Design (Design for environment, Use environmental benign material, Produce environmental friendly products) (8)
3. Relationship with suppliers (7)
4. Relationship with customer (influence customer)(7)
5. Efficient use of material (use less materials) (6)
6. Use tools, techniques, environmental programmes and standards (6)
7. Environmental target and objectives (6)
8. Measurement and audit(6)
9. Select, educate and train employee (5)
10. Product service oriented (5)
11. Prolong product's or material's life (4)
12. Manufacturing and machine efficiency (4)
13. Implement sustainable strategies (RE, WM, ME, EE and etc)(4)
14. Just In Time, Lean and Toyota Production System (3)
15. Reduce packaging materials (3)
16. Legislation compliance (3)
17. Use common sense (2)
18. Housekeeping(2)
19. Choose and use technology (2)
20. Knowledge sharing (2)
21. Environmental awareness (2)
22. Invest on design (2)
23. Seek assistance from government (2)
24. Give strategy a name that communicates to employee (2)
25. Waste Data and waste tracking (2)
26. Use improved recyclability materials (1)

APPENDIX 6.1: MEMBER CHECKING EXCERPT PAGE

Page	Evidences	Member checking	Researcher	Missed	Coded Similarly	Exact
1	And we got them all in the canteen, and said "What we are looking at is the processes, what can we do?" And it was not a professor and it was not a lecturer that came up with the ideas. It was the guy on the machines that came up with the ideas and we put the process together.	Communicate with employee	Social responsibility and company's image Employee awareness or suggestions		1	
	We sent out a spec to four different organisations on the outside and ask if they were willing to come in and help us and only one was willing to come and help us on the full specs. And that was the company called Ampthill Metal Company AMC. They came…. they came in and helped us to set up the systems. They came in and helped us to talk to employees. It is very rare for us for an outside company to come in and want to get involved with the employees and help us research the different materials that we are using…..	Uncooperative supplier Relationship with supplier	Close relationship with supplier Innovative agents or suppliers	1		1

APPENDIX 6.2: EXCERPT OF COMPANY INTERVIEW

Interview with Safety, Health, Environmental and Quality Manager of Company 8.

-continues-

Researcher

So it's trigger by cost?

SHEQ Manager

Yes, so far waste is going up, because we report to division every month for our wastage. They then start to say "your waste is going up; you need to do something about it because it's costing you x amount of pound per month"

Researcher

So when did this awareness or pressure by parent company start? Was it recent or …

SHEQ Manager

No, it is always been there, it is always because. ..hmm the problem in corrugated industry is over capacity hmm what you have to make sure is you run very efficiently, you run very fast, you have to keep up next day delivery hmm and making sure that the customer isn't let down on quality and services. Hmm that is how you maintain the business because there is no loyalty in this kind...if a prices increases goes to mine, if the customer doesn't like it ...they move to somebody else. Because they can because it is over capacity. But if we are quiet, and somebody else is busy, if they put their price up, they will go quiet and we go busy.

Researcher

You were saying about the machine, is it more efficient now compared to before. Was it a request by a company so that the machine supplier designs to be more material efficient?

SHEQ Manager

Hmm it is not so design to be more material efficient just the technology gets better. Hmm I supposed yes that the side consequences of that is yes you can run nearer to the core and stuff, you can run faster , you can…but it is more new machine is built for speed , they are.

Researcher

So, none of the waste here is going to landfill?

SHEQ Manager

Not of the process no. It is all recycled. All got put into piles and get sent out to the paper mills.

Researcher

Is this practiced widely in company? Are all employees aware of the strategy?

SHEQ Manager

Yes, one the way it is done is they get bonus based on waste. If they can keep the waste down, they will get money at their back pocket. And that is the way a big motivator (laughing). It is so yeah.

Researcher

How wide it is practiced across the life cycle? When you choose the supplier, did you ask for ISO 14000 certification and stuff?

SHEQ Manager

No, what tend to happen is because we part of bigger group, the XXX group, paper deals were done covering thousands of tons of paper. And generally it comes down to price. It is hmm a but a lot of times paper mills without the penetration from us haven't got 14000 because of the (inaudible) of in the 80's which in vain forest being hacked to pieces to make reels paper .The first paper company that we had knowledge of which got 14000 was the Brazilian one. It was so they actually done a lot themselves to improve their marketing sort to show they are environmentally friendly.

Researcher

So other than Marks and Spencer, are many of your customers really concern about this?

SHEQ Manager

Yeah, what I meant what was tend to happen in the past is that there has been a movement away from what we called virgin fibre paper to recycled and I mean probably in the early 90s to mid 90's hmm there was a new type of paper that we started to used which is what we called test liner, it is high quality test liner .Almost have the same finish and look as a craft liner which is the treat pulp (inaudible). There was a big movement towards complete recycle material. We used a lot less virgin fibre paper now and what we had done the much higher percentage now that can be recycle…

Researcher

Is it because everybody is doing the same or is it the company does some research and comes up with more innovative product?

SHEQ Manager

No, there were general within the corrugated industry, there has been a very big push to use more and more recycle material hmm because they were import so we can make it in this country , we can't make craft paper in this country but we can make recycle material

Researcher

So, is the material you get from fresh supply or are you taking recycling material?

SHEQ Manager

We take recycle materials as well, we probably 30% virgin material along a side and 70%

recycle material in our store.

Researcher

Is it from same suppliers or different suppliers?

SHEQ Manager

Different suppliers, we have about 30 paper suppliers supplying us because we have the thing like the brown craft and then you got the thing what we called white top craft hmm and you got the different test liner and different fluting medium and because we use probably about 100 thousand tons of paper a year, also it is difficult for one person to supply us all grades. So have a lot of different people supply all different grades to us.

Researcher

If there anything that the company try to communicate to the customer to influence the customer instead of the customer influencing you?

SHEQ Manager

Yeah…we promote like when we have these new materials, we do a big promotion on it to show the benefit that moving away from a craft liner hmmm not just environmental benefit but also there is cost benefit but to show them even though it is recycle material it is a strong as a virgin fiver craft material. And then they can move to that, you get the cost saving and also the environmental friendly and it is easier for us in some way to get it much shorter notice because it is mainly in this country. The mills probably making it once, twice a week so we can have it here probably in couple of days. If we are going to order from America or Brazil or something it is going to take about 6 weeks to get here.

Researcher

So do you measure the waste you saved…the company reduces the waste, do you measure the waste?

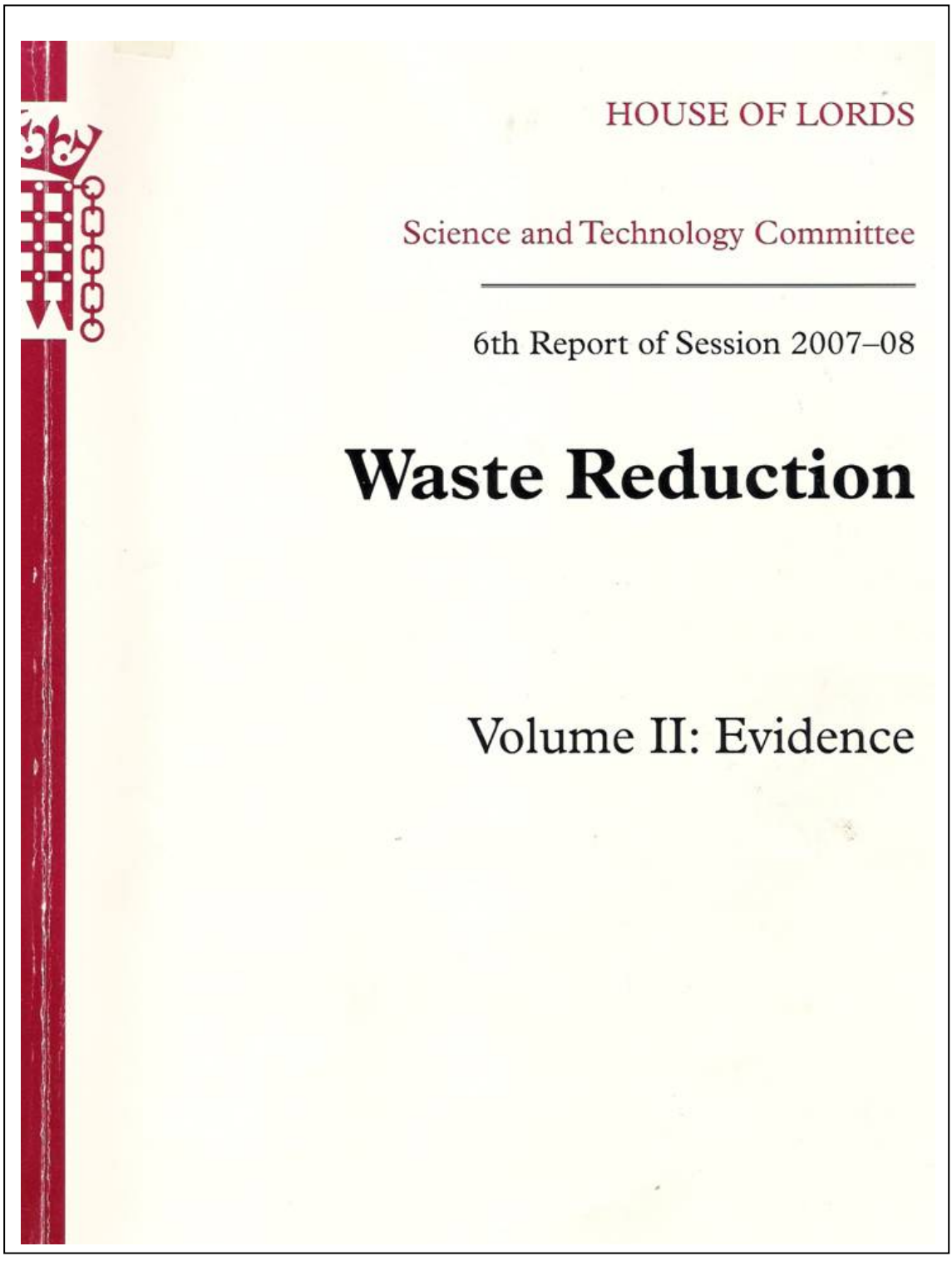
SHEQ Manager

Yes, we measure the waste on weekly basis, we do and hmm it is quite simple (inaudible), we know how many tons go into the machine and we know how much waste goes out because all have to be weight. And it just one divided by the other. So it is percentage to material. It is.

-continues-

APPENDIX 6.3: HOUSE OF LORD REPORT ON WASTE REDUCTION

Appendix 6.3i: House of Lords report into waste reduction cover page (Volume 2: Evidence)



HOUSE OF LORDS

Science and Technology Committee

6th Report of Session 2007–08

Waste Reduction

Volume II: Evidence

APPENDIX 6.3ii: House of Lords' Members and Declarations of Interest

Members	**Declared Interests**
Lord Bhattacharyya	None
Lord Crickhowell	None
Lord Haskel	Honorary President, Environmental Industries Commission Honorary President, Materials UK Honorary President, TechniTex
Lord Howie of Troon	Fellow, Institution of Civil Engineers
Lord Lewis of Newnham	President, Waste Management Industry Training and Advisory Board Associated with Committee of Veolia
Lord May of Oxford	None
Lord Methuen	None
Lord O'Neill of Clackmannan	President, Specialist Engineering Contractors' Group
Baroness Platt of Writtle	None
Earl of Selborne	Non-Executive Director (designate), Green Rubber Chair, Funders Board, Living with Environmental Change Programme
Baroness Sharp of Guildford	None
Lord Sutherland of Houndwood	None
Co-opted Members	None
Professor Stephen Evans	Professor of Life-cycle Engineering, Cranfield University Board Member, Centre for Sustainable Engineering Partner, RiverSimple Partnership Former employee, Martin-Baker Engineering Academic collaborations with: BRE, Ford Motor Company, Nissan, Biffa, BERR (the Department of Trade and Industry), EEF, Philips, Oakdene Hollins, EPSRC and TSB

APPENDIX 6.3iii – List of Participants

The following witnesses gave evidence. Those marked with a * gave oral evidence:

Organisations	**Participants**
Aluminium Federation	Mr Will Savage
Aluminium Packaging Recycling Organisation	Mr Rick Hindley and Mr Cal Bailey, NG Bailey
Balfour Beatty and Ciria , BAN Waste	Mr Mike Barry, Marks & Spencer Dr Tracy Bhamra, Department of Design and Technology, Loughborough University
Biffa	* Mr Peter Jones, Boots; BREW Centre for Local Authorities
British Glass Manufacturers' Confederation	* Mr David Workman
BSI British Standards	* Mr Marcus Long
Building Research Establishment:	* Ms Gilli Hobbs * Mr Stephen Carter, Unilever
Centre for Environmental Control and Waste Management, Imperial College London	* Professor Sue Grimes
Centre for Research and Development, University of Brighton	* Dr Jonathan Chapman
Centre for Resource Management and Efficiency, Cranfield University	* Professor Simon Pollard
Centre for Sustainable Consumption, Sheffield Hallam University	* Dr Tim Cooper
Centre for Sustainable Design, University College for the Creative Arts	* Mr Martin Charter
Chartered Institution of Wastes Management	* Mr Christopher Murphy, Chemical Industries Association
Chemistry Innovation Knowledge	* Dr Michael Pitts

Transfer Network	* Dr Robert Chilton, National Consumer Council * Mr Andrew Clack, Panasonic UK
Department for Business, Enterprise and Regulatory Reform	* Mr Tony Pedrotti * Mr Malcolm Wicks MP
Department for Environment, Food and Rural Affairs	* Ms Joan Ruddock MP * Mr Neil Thornton
Department for Innovation, Universities and Skills	* Dr David Evans * Mr Ian Pearson MP
Design Council	* Mrs Lesley Morris
Ecodesign Centre Wales	* Dr Frank O'Connor
EEF, The Manufacturers' Organisation	* Mr Gareth Stace, Electronic Producers Environmental Policy Forum
Environment Agency	* Ms Tricia Henton * Ms Liz Parkes
Environmental Industries Commission	* Mr Jonathan Davies * Mr Merlin Hyman
Envirowise	* Dr Martin Gibson
Essex County Council	* Mr Peter Evans, Sony UK * Mr Malcolm Fergusson, Institute for European Environmental Policy, Ford Motor Company, Forum for the Future
Green Alliance	* Ms Julie Hill * Miss Hannah Hislop * Mr Jerry Hardcastle, Nissan Technical Centre Europe
Hewlett-Packard	* Dr Kirstie McIntyre * Mr John Holbrow, Federation of Small Businesses

Industry Council for Packaging and the Environment	* Ms Jane Bickerstaffe
Institute for Manufacturing, University of Cambridge	* Dr Claire Barlow * Professor Mike Gregory
Institute of Materials, Minerals and Mining	* Dr Norman Swindells
Institution of Chemical Engineers	* Mr Malcolm Wilkinson
Laing O'Rourke	* Mr Chris Sexton
Local Authority Recycling Advisory Committee	* Dr Andrew Craig
LRL Consultancy Services	* Mr Bob Lisney * Mr Brian McCarthy, TechniTex , Mike Read Associates, Milled Carbon, Nappy Alliance
National Industrial Symbiosis Programme	* Mr Peter Laybourn, North London Waste Authority
Oakdene Hollins and the Centre for Remanufacture and Re-use	* Mr Nicholas Morley, Office of Government Commerce
Philips Consumer Electronics	* Professor Ab Stevels
Process Industries Centre for Manufacturing Excellence	* Mr Michael Glass
Proctor & Gamble	* Dr Forbes McDougall
Research Councils UK	* Dr Peter Hedges
Resource Efficiency Knowledge Transfer Network	* Mr Arnold Black
Resource Efficient Design Initiative, De Montfort University	* Miss Lizzie Dutton * Miss Holly McCain
Salvation Army Trading Company and the Nonwovens Innovation and Research Institute	* Mr Paul Ozanne

Scottish Environment Protection Agency	* Ms Lesley Seymour, Buro Happold
Social Environmental Enterprise and Design Foundation	* Ms Clare Brass
Society of Motor Manufacturers and Traders	* Mr Steve Franklin
South East England Development Agency on behalf of England's Regional Development Agencies	* Mr Peter Stokes, Volkswagen Group UK
Sustainable Development Commission	* Ms Sue Dibb * Mr Andrew Lee * Mr Andrew Swain, Aggregate Industries * Mr Jeremy Tait, Market Transformation Programme
Technology Strategy Board	* Dr John Whittall, Tesco
Vitsoe	* Mr Mark Adams
Waste and Resources Action Programme	* Dr Liz Goodwin * Mr Martin Wheatley, Local Government Association * Mr Alan Wheeler, Textile Recycling Association
Women's Environmental Network	* Mr Rainer Zimmann, Arup

APPENDIX 6.3iv – Questions used by House of Lord Committee

The House of Lords Science and Technology Select Committee has appointed a sub-committee, chaired by Lord O'Neill of Clackmannan, to look at sustainable approaches to waste reduction. The inquiry will focus on the first level of the waste hierarchy, waste reduction, and will look into ways in which products and production processes can be made more sustainable and therefore produce less waste.

The Committee invites evidence on the following questions. Witnesses are encouraged to focus on those issues of which they have particular knowledge or experience - submissions are not required to cover all questions.

Better design and the use of materials

- What role can better design and materials play in minimising the creation of waste? Are there any barriers to how knowledge in this area can best be translated and applied?
- What factors influence the use of materials? In what way do considerations of sustainability feature in the selection of most commonly used materials?
- To what extent do product designers and engineers take into account the availability and the end-of-life impacts of raw materials?
- What impact does the development of new materials have on design? How much interaction is there between material scientists and designers?
- Can better designed products offset the increase in consumption?
- Are there any other gaps in knowledge and how are they being addressed?

Business framework

- Does the current policy, regulatory and legal framework support and incentivise the development of better, more sustainable products and processes? How is the framework communicated to businesses and what is the level of awareness and understanding among businesses?
- How central is sustainable design to business thinking? What initiatives are in place to encourage this and are they meeting business needs?
- What other measures can promote a focus on waste reduction among businesses?
- What lessons can business learn from international experience?

Government policy

- What is and should be the role of Government in addressing the issue of waste reduction?
- How does Government policy link up with European strategies and action plans?
- What lessons can be learnt from other countries—within the EU and globally?
- Consumer behaviour
- How can better product design be used to effect a change in consumption patterns and behaviour?
- What role do marketing strategies play in influencing more sustainable design?
- Are there any gaps in knowledge in this area?

Skills

- How is sustainable design integrated into the design syllabus?
- To what extent are considerations of sustainable waste reduction part of broader industrial training courses.

APPENDIX 6.3v – Excerpt page of oral evidence

RECOVERY AND DISPOSAL

SMMT is of the opinion that only waste recovery that is environmentally sound should be undertaken. The energy consumed and consequent CO_2 emissions produced can only be justified where worthwhile substitution or efficiency levels are reached.

END OF WASTE

SMMT consider that the reclassification of waste as a secondary raw material once it reaches a standardised specification is correct. This has been achieved with the PROVE project for recycled plastics. Whether a market exists or not does not affect the product, and should not be a criterion for deciding whether it is still waste or secondary raw material, markets for recycled materials have to compete economically with virgin material. The incentive to recycle efficiently to reduce cost and the fluctuation of virgin material price will impact markets differently over time.

SMMT would prefer that existing engineering standard processes and bodies determine the quality criteria required rather than use the comitology procedure.

February 2008

Examination of Witnesses

Witnesses: MR STEVE FRANKLIN, Senior Manager, Environment Group, The Society of Motor Manufacturers and Traders Limited, MR JERRY HARDCASTLE, Vice-President, Vehicle Design and Development, Nissan Technical Centre Europe, and MR PETER STOKES, Vehicle Compliance Manager, GS Product Technical Group Services, Volkswagen Group United Kingdom Limited and Chairman of the Consortium for Automotive Recycling (CARE), examined.

Q674 ***Chairman:*** Good morning, gentlemen. Perhaps, Mr Franklin, you could introduce yourself and your colleagues can do so along the line.

Mr Franklin: Yes, thank you very much, good morning. My name is Steve Franklin and I head up the Environment Department of the SMMT; I have been there for eight years, predominantly taken on to look after the ELV legislation implementation in the UK. I have had a total of 45 years in the motor industry, manufacturing predominantly, but a little bit of product development.

Mr Hardcastle: Good morning, ladies and gentlemen, I am Jerry Hardcastle, I am the Vice-President for Vehicle Design and Development at Nissan Technical Centre Europe, based in Cranfield, UK. I have responsibility for other offices in Barcelona, Brussels, Bonn and Moscow. From a business point of view I have a reporting line to Nissan Europe and from a functional point of view I have a reporting line to the global research and development function, Nissan Technical Centre, in Japan.

Mr Stokes: Good morning. My official job title is Vehicle Compliance Manager for Volkswagen Group in the United Kingdom. My relevance to this Committee is that it was my job to ensure that our group met the end-of-life vehicle responsibilities and, as part of that, became chair of the Consortium for Automotive Recycling which was formed in the mid-Nineties to tease out and work with a lot of the issues that we have now put to bed enabling the End-of-Life Vehicle Directive to function in the UK, so my experience is more on the recycling end rather than my colleagues' which is on the design.

Q675 ***Chairman:*** That is very helpful, gentlemen, thank you. This morning we recognise that at least two of you will be talking on behalf of your companies, and we will see you about complaints we have about your vehicles later on. As far as Mr Franklin is concerned, I imagine you will be able to range over the subject as best you can.

Mr Franklin: I would like to think that we can cover the whole remit if necessary, yes.

Q676 ***Chairman:*** Perhaps we could start with you, Mr Hardcastle. To what extent can better design and novel materials be used to reduce waste in the automotive industry? Can we start with the design end as it were?

Mr Hardcastle: There are a number of ways that we can reduce waste and they are quite often related to the reduction of weight and also a reduction of cost as well. For example, we would use a particularly high strength steel, sometimes up to 980 megapascals. If you use a steel like this it is actually difficult to manufacture with, difficult to weld, difficult to form; however it allows us to delete additional brackets and it allows us to use thinner material, so therefore at the end of the vehicle's life there is less material that needs to be recycled. We can also use a ultra high modular plastic for the bumper; in that case we could delete some of the bracket trays and the aluminium supports that might be behind the bumper, and that would of course reduce the weight and reduce the cost, but it also deletes some metal parts that then do not have to be wasted or recycled. In the area of the catalyst, for example, for emissions control, those

APPENDIX 6.3v – Excerpt page of oral evidence (continued)

have precious metals on them which are necessary for the function of the catalyst, but we would try and minimise the amount of precious metal required in order to get the exact performance, which of course stops you using the precious metals in the first place and also makes it easier to recover them because there is less of them at the end of the process. They are just a few of the ideas; there are many more ideas if you would like to hear more.

Mr Stokes: I would agree with my colleague. One thing that is worth pointing out, and I am sure you are aware, is that the design end of building a car is intrinsically tied to the tail-end and the way the vehicle is actually treated. The way that the vehicle is shredded at the end of its life has a direct influence on how you build it at the beginning of its life. To illustrate that, a couple of examples: in the mid-Nineties one manufacturer was making plastic bumpers which were a plastic skin which was filled with a liquid foam and there were metal brackets set into that. Once the foam hardened it actually bonded to the plastic skin and bonded to the metal brackets which, when the vehicle was shredded, meant that you had a mix of materials that was very difficult to separate, very difficult to recycle and would more than likely end up in landfill. Moving away from those techniques of using dissimilar materials for making a component means that you end up with something which can fragmentise easily and is subsequently easier to recycle.

Mr Franklin: There are many computer-aided techniques now for designing components that are very materially efficient—Nastran is an example of computer-aided technology where we can eliminate material and get down to absolutely the minimum requirement of material to be used and then get an efficient design. For instance, if you were looking at crash performance, you could actually simulate that very effectively and put in high-strength steels instead of heavier mild steels in particular areas, so the design aspect at that point becomes crucial.

Q677 ***Lord Methuen:*** May I ask a question about the shredding process? Have you semi-dismantled the car by this time, so you have taken the bumpers off and other plastic components and you are shredding the individual components rather than the whole thing?

Mr Stokes: No, it is economically impractical to do that, so the bare minimum of hand dismantling actually takes place, which would be the removal of fluids and the removal of what the directive calls hazardous substances—batteries and mercury components, those sorts of things. The vehicle is then crushed and shredded and then the materials subsequently extracted from that.

Mr Franklin: If I could just add something to that, something like two million ELVs are disposed of in the UK every year although at the moment the DVLA is only recognising about a million. That is the equivalent of about seven Nissan factories worth of production, but we have 1400 authorised treatment facilities (ATFs) actually disposing of the vehicles, so the logistics of moving the stock around are not quite so good. Although, yes, you could take off plastic bumpers and plastic components, the logistics of getting them all together at the dismantling stage do not really tie up unless you have got a moulder right next door to you, so we tend to look at it going to the shredders, and there are only about 35 shredders in the UK so you get better logistics of recovering material.

Q678 ***Lord Haskel:*** What happens to the other million?

Mr Franklin: We would like to think that the other million were correctly disposed of but there are some issues that you may be aware of with the DVLA at the moment. Central to the ELV legislation is a certificate of destruction; every vehicle entering an ATF should be issued with a certificate of destruction. The DVLA has not implemented that in quite the way we would have liked it to have done in terms of there is an ability to make some self-declaration of scrapping the vehicle on a V5, therefore it does not end up logged with a Certificate of Destruction (CoD). This is something on which we and DTI (now BERR) have made continuous representations to them.

Q679 ***Baroness Sharp of Guildford:*** How far is there recycling of parts as they go along? The modularisation of motor cars in this way means that rather than dents being pushed out there is a tendency to just take off the door and put a new door on or take off the bumper and put a new bumper on. How far is there any recycling of these parts as they go along?

Mr Franklin: There are some insurance schemes that recognise the use of using recycled parts. They are in their infancy but there is an opportunity; if you say "I do not mind having recycled parts put on my vehicle if and when I damage it" then you can have that done. The repairability is one of the major things that we look at. As the vehicles become more complex in their design the repairability issues do become quite severe: we are using adhesives now, we are using different forms of joining technology and there is so much integrity in the build of a vehicle now—its crash protection et cetera—that it has to be very carefully looked after when repairing crash damage.

Q680 ***Lord Crickhowell:*** On repairability, as seen from the car owner/driver's point of view, there are some changes which seem to make things worse rather than better—no doubt there are good reasons why those changes have happened. For example,