Evaluating sustainability in materials management – case mobile handset manufacturers

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ABSTRACT

Manufacturers' materials management strategy is increasingly highlighted as a source of competitive advantage and, at the same time, is under stakeholder pressure to become more environmentally sustainable. Restricting legislation on substance use and extended producer responsibility (EPR), such as the RoHS and WEEE directives in the EU, increased consumer awareness in sustainability and environmental issues and improvements in the performance of competitors in terms of more environmentally friendly products being launched onto the market are forcing manufacturers to re-evaluate and develop their operations related materials management.

This study sets out to identify the strategic elements of a sustainable materials management strategy by studying relevant operations management and environmental management literature and to develop a model for evaluating the sustainability of materials management strategy. Metrics for evaluating the sustainability of the identified strategic elements will be produced as part of this model. Another objective for the study is to use the model empirically to evaluate the level of sustainability of materials management strategy in five mobile handset manufacturing companies operating in the European market. The data used for this research is extracted from the companies' published reports and other external published sources and compiled in the form of case studies focusing on the companies materials management activities.

Sustainable sourcing, product eco-design and product recovery and end-of-life management are identified as the strategic elements of sustainable materials management in this study and used as the basis of the qualitative evaluation model. Simplistic metrics for each of these elements are provided in the form of checklists of selected issues for evaluating company involvement in the identified strategic elements. The model produced is a three dimensional evaluation model incorporating the results of each metric checklist on their own axis. The position of the subject company on each of dimensions determines the level of sustainability of the company's materials management strategy.

The empirical application of the model shows that there is relatively high involvement in sustainable materials management in the mobile handset manufacturing industry. Companies proved to be most involved in product eco-design whereas product recovery and end-of-life management operations are still rather limited to companies participating in the collection and recycling of end-of-life products without reintegrating materials back into the forward channel.

Keywords: materials management, sustainable operations, mobile handset manufacturers
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Materiaalihallinnan kestävän kehityksen periaatteen mukaisuuden arviointi – case matkapuhelinvalmistajat

TIIVISTELMÄ

Materiaalihallintastrategian merkitystä valmistavien yritysten kilpailuedulle korostetaan kasvavissa määrin samaan aikaan kun ulkoiset sidosryhmät luovat yrityksille paineita kehittää toimintojaan kestävän kehityksen periaatteen mukaisemmiksi. Rajoittava lainsääntö liittyen vaarallisiksi luokiteltujen ainesosien käyttöön ja tuottajavastuuseen (EU:n alueella voimassa olevat RoHS- ja WEEE-direktiivit), kuluttajien lisääntynyt ympäristötietoisuus ja kilpailijoiden parannukset ympäristöystävällisten tuotteiden suunnittelussa ja tuonnissa markkinoille pakottavat yrityksiä arvioimaan ja kehittämään omia materiaalihallintaan liittyviä toimintojaan.

Tämä tutkimus pyrkii määrittämään ne strategiset osa-alueet, joilla on merkitystä kestävän kehityksen mukaisen materiaalihallintastrategian kannalta tutkimalla asian kannalta olennaista kirjallisuutta, ja kehittämään mallin, jota voidaan käyttää yrityksen materiaalihallintastrategian kestävyyden arviointiin. Mallia varten kehitetään mittaristo aiemmin määriteltyjen strategisten osa-alueiden arvioimiseksi. Tutkimuksen toinen tavoite on soveltaa kyseistä mallia käytäntöön arvioimalla viiden Euroopan markkinoilla toimivan matkapuhelinvalmistajan materiaalihallintastrategiaa kestävän kehityksen periaatteen mukaisuutta. Tutkimuksessa käytetty aineisto on kerätty yritysten julkaisemista raporteista ja muista ulkoisista lähteistä, ja siitä on koottu tapaustutkimusraportit, joissa keskitytään yritysten materiaalihallintaan liittyviin toimintoihin.

Tutkimuksen tuloksena kestävän kehityksen mukaisen materiaalihallinnan strategisiksi osa-alueiksi määriteltiin kestävän kehityksen mukaiset hankinnat, ekologinen tuotesuunnittelu sekä käyttöikänsä ylittäneiden tai muuten käytettyinä palautettujen tuotteiden takaisinotto ja käsittely. Jokaiselle osa-alueelle määriteltiin yksinkertaistettu, valikoiduista asioista koottu tarkistuslistan omainen mittaristo osa-alueiden yksittäistä arviointia varten. Kehitelty malli sisältää määriteltyjen strategisten osa-alueiden mukaisesti kolme ulottuvuutta, jotka osoittavat yrityksen sitoutuneisuuden kuhunkin osa-alueeseen. Yrityksen materiaalihallintastrategian kestävän kehityksen periaatteen mukaisuutta voidaan arvioida sillä periaatteella, miten yritys sijoittuu kolmiulotteisen mallin akseleille.

Tutkimuksen empiirisen sovelluksen tulokset osoittavat, että matkapuhelinvalmistajat ovat sitoutuneet kestävän kehityksen periaatteeseen materiaalihallinnassaan suhteellisen hyvin. Sitoutuneisuus oli korkeinta ekologisen tuotesuunnittelun osalta, kun taas tuotteiden takaisinotto ja käsittely niiden käyttöiän jälkeen on vielä rajoittunut pelkkään tuotteiden keräämiseen ilman kerättyjen materiaalien hyödyntämistä uudelleen yritysten omassa tuotannossa.

Avainsanat: materiaalihallinta, kestävä kehitys, matkapuhelinvalmistajat
Sivujen lukumäärä (liitteineen): 90

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This thesis is the result of more than two years of not doing all that much and of less than two months of doing a lot just to get it done.

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Also, big thanks go to my infinite backbone, supporter and niggler, T for staying up with me to correct formatting and draw graphs throughout the night when I was typing forward with the issue on another laptop next to him, and for the sometimes invigorating conversations we have had around the subject of this thesis. And of course for waiting for me to go away together onto our next year and more of adventure in Africa – even if it meant buying new plane tickets because I didn't make it to the original departure date due to bad time management from my part..

During the course of doing this thesis I have found sustainable business practices an area of great personal interest and one which I aim to keep on my focus in the future as well.

Maarika Kulmala
Helsinki, 25.9.2009

“We should recycle, but it is not the first thing we should do, it is the last. Redesign first, then reduce, reuse and finally recycle, if there is no other alternative.”

Bill McDonough,
Co-Author of Cradle to Cradle

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EVALUATING SUSTAINABILITY IN MATERIALS MANAGEMENT – CASE MOBILE HANDSET MANUFACTURERS

1. Introduction

This thesis examines the sustainability of materials management activities in mobile device manufacturing companies operating in the European market. It is focused with identifying the strategic elements of materials management and developing a model that incorporates those elements in order to evaluate the sustainability of materials related activities in companies. The model introduced in this thesis will be tested by applying data from five leading global mobile device manufacturing companies to produce conclusions about both the use and applicability of the model and also about the state of material management strategy in place in this industry.

1.1. Background

Some recent developments can be detected to support the need for research on environmental management and the sustainable use of materials both in multinational corporations in general as well as specifically in the mobile communications industry.

The strategic importance of supply chains and networks and related coordination is ever increasing as inter-company relations on a global scale have become commonplace. In the meantime, also research on supply chain management has increased significantly in the past two decades. Recently, Green Supply Chain Management (GSCM) and Economic Sustainability have emerged as the new operational and managerial practices focusing on reducing the environmental impact from operations, either of individual companies or the whole supply chain. Since companies are not known to operate solely for the point of being ecological, the aspect of productivity has to somehow fit into the equation. Sustainability aims at combining these two aspects, thus companies being ecological and economical at the same time.

On the operational side, cost-pressures initiated by frequent changes in commodity prices, limited supply of critical materials and long transportation distances have forced companies to question and develop their sourcing strategies. At the same time product life cycles have shortened especially in the consumer electronics and telecommunications devices market, which increases the pace of production cycles and increases the need for components and materials in general. These and other variables have contributed to the rise of a trend for closed loop supply

chains, revealing the need to develop best practices in companies for recovering assets through recycling and reusing materials and components.

Also, regulatory changes force companies to pay continuous attention to their manufacturing processes, resource use and waste creation. In Europe, the Restriction of Hazardous Substances (RoHS) and Waste Electrical and Electronic Equipment (WEEE) Directives imposed in 2003 made it mandatory for producers to re-think their use of materials in manufacturing and to bear the responsibility for taking back and destroying end-of-life products they have manufactured. As a result, companies have to redefine their operations, build the required infrastructure for product take-back or source these activities from third-party providers to attend to their responsibility, which brings additional and unexpected costs. The challenge for companies lies in whether – and if so, how – they can turn this into beneficial activity for the company instead of just "putting out fires" where they occur.

Research has been conducted on a general level regarding all of the issues listed above and to generate environmental management systems and assessment tools. Sustainable business practices and corporate sustainable responsibility have been introduced as the new ways of thinking in terms of business. From a more detailed point of view, efficiency calculations have been published about the use of resources as part of business processes. The flow of materials through a company's supply chain has also gained attention in terms of similar efficiency calculations. However, there seems to be a lack of more focused conceptual models that would fall in between these two points of view and incorporate important strategic elements of limited scope into the bigger scheme of sustainability as a comprehensive management practice. This thesis aims to position itself as one of these more focused reviews in dealing with an issue that is a critical core competence to any manufacturing company, its materials management strategy.

More vaguely, attitudes on consumer level as well as in global business and governmental environments are changing towards more ethical business practices. The demand and ordering behaviour are somewhat affected by this development, and increased awareness is raised with investors and shareholders. This promotes the idea of sustainability in operations and a more environmentally friendly company strategy without sacrificing company performance or profit levels.

In the light of all of that has been discussed above, studying the sustainability of supply chains is not only feasible but very topical, as it is something that can drive many companies forward or at least prevent them from staying behind in today's economical environment where governmental interference, consumer awareness and environmental values combined determine the markets to an ever larger extent.

1.2. Objectives

This research focuses on examining the sustainability of the materials management strategy in the mobile telecommunications industry. This is done by studying the concept of sustainable development its linkages to materials-related supply chain operations, both through reviewing previous research on the subject and studying the practices of companies operating in the chosen industry. The product group in research focus is mobile phones and other mobile devices such as handheld computers.

The main objective of this research is to produce a model that can be used to evaluate a company's materials management strategy in terms of environmental and economical sustainability on the strategic level by determining metrics that depict manufacturer involvement in strategic activities related to materials management. Manufacturing companies can then be placed in the model according to their efforts and performance in pursuing a sustainable materials management strategy. Application of data from case studies in this way will provide an insight into the current state of company involvement and performance in sustainability in the mobile devices manufacturing industry – specifically in relation to materials management.

The main objectives of this thesis can be phrased as follows:

1) **To create a model for evaluating the sustainability of a company's materials management strategy.**

2) **To test this model by applying case company data from the mobile device manufacturing industry, and**

3) **To evaluate the sustainability of the materials management strategies in place in these companies.**

The first objective is met through studying literature related to supply chain management (SCM) and environmental management and identifying the different strategic elements connected with the concept of economic and environmental sustainability in terms of materials use. Qualitative metrics will be determined under each of the strategic elements to be used in applying the model to empirical data.

The second objective is met through investigating the environmental management practices that are to do with materials and related considerations of operating in the chosen industry through multiple small case studies. Studying the companies is done in order to achieve an insight into the environmental strategies in place in the companies and to identify the processes and activities these strategies extend over. The aim is to try and form a comprehensive picture of the strategic importance and current status of materials strategy in the mobile devices manufacturing industry. An important limitation to the subject is that only issues related to material resources will be included in this research. Even if important questions about energy consumption and pollution are just as relevant from the standpoint of evaluating the sustainability across the supply chain, they have been ruled out of this thesis in order to keep the research topic manageable and to narrow the focus.

1.3. Methods and scope

The approach used in this research is qualitative. This approach was chosen because of the nature of the research questions, which seek to gain explanatory knowledge on the subject and focus on conceptual relationships between variables in their natural environment (Metsämuuronen, 2006, 88). Strategic questions have also traditionally been studied using a qualitative approach. The case study method will be used to gather empirical information from companies operating in the chosen field in focus. Examples of qualitative research that has been conducted using the case study method exist in the fields of both supply chain management (Jayaraman & Luo, 2007; Handfield et al., 2005; Thierry et al., 1995) and environmental management (Tinsley, 2002).

The empirical part introduces the data conducted from five case companies through using the companies' own published data and external articles and reports on the industry. The case companies are manufacturers of mobile phones and other handheld devices that operate in the telecommunications industry. For this thesis, the scope has been limited geographically to include only these companies' operations in Europe in order to standardize the results in the face of regional factors that affect all manufacturers in the industry.

1.4. Structure of the report

The research is presented in five main sections. After the introduction given in section one, the second section of the report will feature the theoretical background of the subject and related fields of research. It will begin with definitions of the concepts of materials management, sustainable development and Green Supply Chain Management and will further expand the examination to include the concept of eco-efficiency and its elements. At the end of this section the theoretical framework of this research is presented. In section three the different components of both environmental and materials management are investigated more closely: the theoretical models of reverse supply chains and their linkage to re-integration of used materials, and study both product eco-design and environmental sourcing. As a result, a model for evaluating the sustainability of materials management will be introduced. Section four of the report will go through the phases of the empirical research and present the findings which will be applied into the model introduced in the previous section. Finally section five is reserved for conclusions and further analysis and application of these results, as well as assigning further research questions and topics for future reference.

1.5. Concepts used

Below are the definitions to some of the most frequently used concepts in this thesis. This list is not comprehensive, as most of the concepts used are defined and explained while they are being introduced in the text for the first time.

Corporate Social Responsibility – the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of the workforce and their families as well as of the local community and society at large. (WBCSD definition)

End-of-Life (EOL) management – the management of the operations related to the product once it has reached the end of its useful life, such as the collection, recycling and disposal of discarded products

***Environmental Management System (EMS*)** – the overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy. (ISO definition)

Extended Producer Responsibility (EPR) – an environmental policy approach where the producers' responsibility, physical and/or financial, for a product is extended to the post-consumer stage of a product's life cycle. Producers accept their responsibility when they design their products to minimize life cycle impacts and when they accept legal, physical and/or economic responsibility for the environmental impacts that cannot be eliminated by design. A primary function of EPR is the transfer of the costs and/or physical responsibility (full or partial) of waste management away from local government authorities and the general taxpayer to that of the producer. (OECD definition)

Individual Producer Responsibility (IPR) – A producer bears an individual financial responsibility when he/she pays for the end-of-life management of his/her products. A producer bears an individual physical responsibility when 1) the distinction of the products is made at minimum by brand and 2) the producer has control over the fate of their discarded products with some degree of involvement in the organisation of the downstream operation. (Greenpeace definition)

2. Theoretical background

This section gives an overview of the relevant areas of interest among literature and introduces some of the most essential trends related to materials management in terms of sustainability and life-cycle thinking. It will also position this thesis in terms of past research.

2.1. Aspects of materials management

When one thinks about the management of materials in a manufacturing context, the standard viewpoint is of blocks of material being shipped into the factory, ran through the production line and shipped out to customers. This viewpoint is one way of seeing it, but some discrepancies exist as to how the concept of 'materials management' is actually defined (see e.g. Cooper & Argyris, 1998, 407; Datta, 2006, 22). An integrated approach to materials management defines it as:

"the coordination of planning, sourcing, purchasing, moving, storing and controlling materials in an optimum manner so as to provide a pre-decided service to the customer at a minimum cost" (Gopalakrishnan & Sundaresan, 1977, 5).

When observed from this point of view, the broadness of the aspects related to the concept becomes obvious. Studies related to the choice, use and handling of materials have been conducted throughout the history of operations management research, as materials can be a significant core input for a company and the whole supply chain, both in manufacturing and service industries. On a general level, most of this research has been done from the point of view of creating efficiencies in procurement systems in order to cut the costs of materials used in the production of goods or services. Also strategic considerations related to sourcing have been studied widely, especially increasingly in the global context and for the needs of multinational corporations which have production units around the world. Another strain of materials related literature is focused on product design, and manufacturing or even service process design as they have a big impact on the make-up of a company's material purchases. Also, materials must still be managed as waste at the end of the product life cycle, as has been studied under the fields of environmental and waste management.

2.2. Sustainable development

Possibly the most general definition given for the concept of sustainable development originates from what is known as the Brundtland Report (WCED, 1990, 43) and reads as follows:

> ***"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their needs."***

Put simply, the concept is about changing the way of life so that resources are used more sustainability in the long run, in order to guarantee equal distribution of wealth between generations.

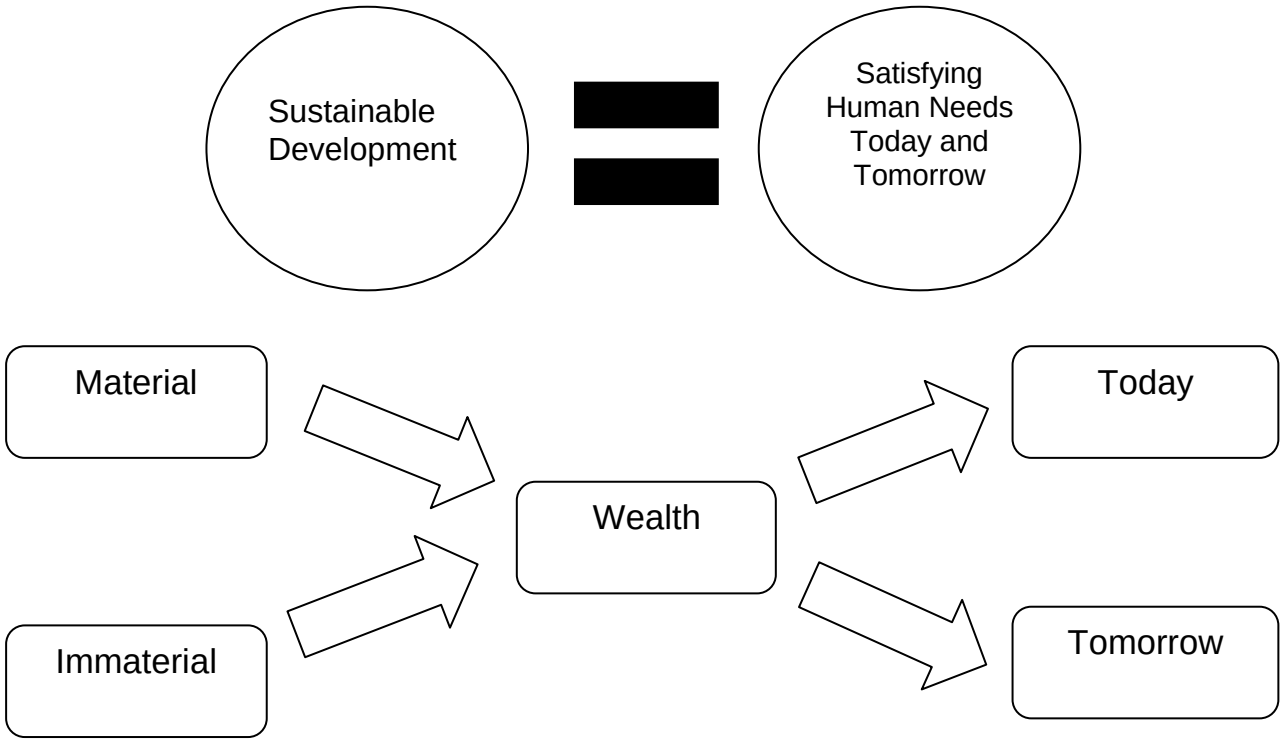

Figure 2-1. Sustainable development.

Source: Adapted from J.H. Spangenberg, 2001.

On the macro level, this change includes all the processes involved in institutional, economic, social and environmental activities in society. The use of resources, whether they are immaterial

or material, should be done more sparingly and more efficiently so that more wealth can be created from them, and therefore distributed over more people.

Out of these four activities mentioned, the focus of examination in this paper will be on the relationship between the economic and environmental imperatives, shown below in figure 2-2. The question of sustainability here is mainly material; to what extent do companies improve their ecological efficiency by making better and longer use of raw materials and other physical resources?

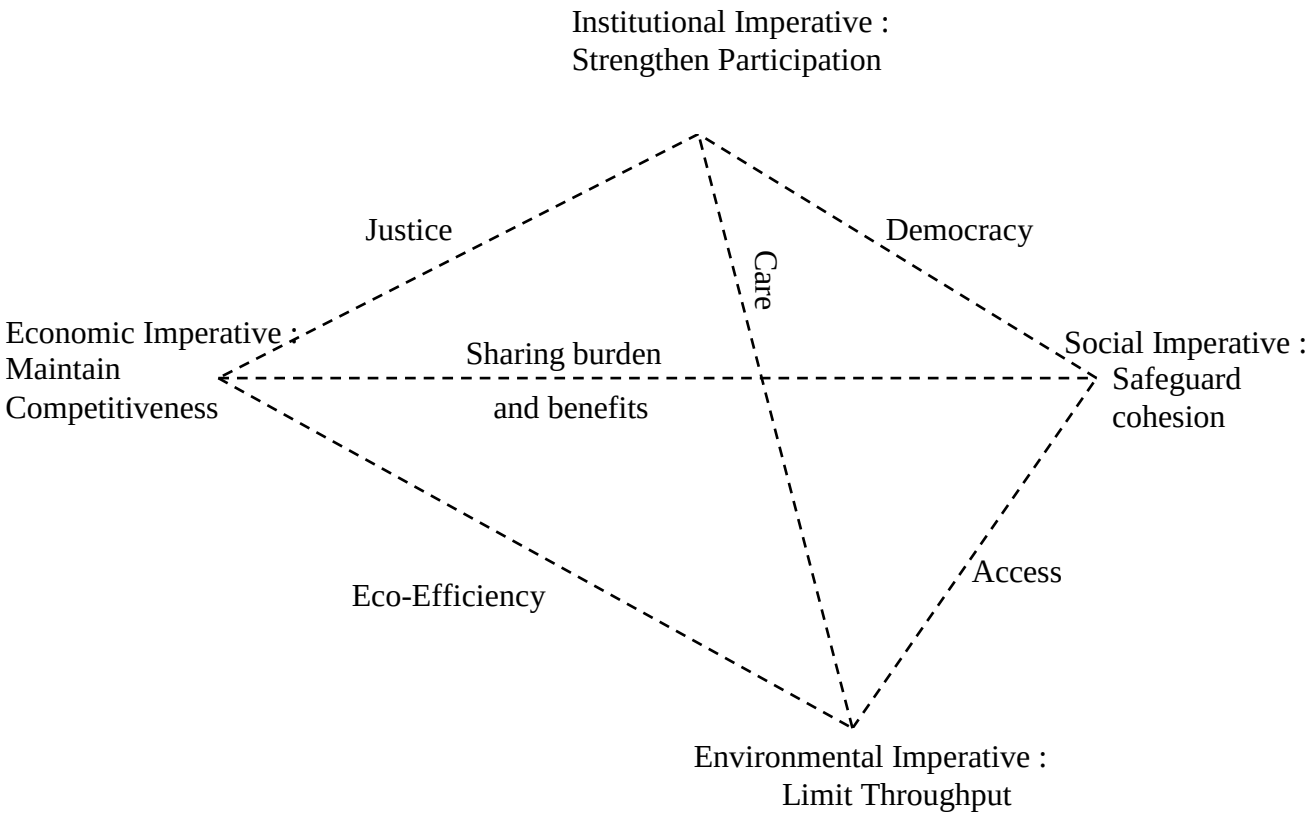

Figure 2-2. 'The prism of sustainability"

Source: Spangenberg, J.H. in Charter & Tischner (eds.), 2001.

2.2.1. Sustainability and economic competitiveness

Stahel (2001) states that the drivers of sustainable development on a company level will be found increasingly in the use of technology to create returns, rather than in the pursuit of environmental thinking. This way the interest of the economic community will be sufficient to cross what has been determined as the first borderline to a sustainable economy: shifting from protecting the environment to increasing economic competitiveness. The goal is to break the link between corporate success and resource consumption in order to create more wealth with fewer resources. Stahel emphasizes the role of the service economy in this transfer, since the de-materialization of production processes is a step in the right direction towards a sustainable economy, but not enough to guarantee sustainability in the long run. He also points to life-cycle assessment (LCA) and innovation in product development as the key tools, and encourages the move away from regulatory control and command in order to encourage a more proactive approach to product development.

However, it can be argued that laws and regulations are first needed to set the base and direction for any business activity even in an environment supporting free innovation. Without them, the standard problem of opportunistic behaviour among the actors in the market remains. Consequently, the transfer across Stahel's first borderline itself could be endangered, or at least severely postponed, in the long run when facing the lack of truly forceful incentives.

Crossing the second borderline to a sustainable society depends on actions on the demand side. Changing the 'wants' and 'wishes' of consumers and the values of society as a whole is the prerequisite for sustainable consumption, or sufficiency. According to Stahel, the service economy is where the concepts of sufficiency and efficiency meet.

The category of efficiency solutions exist as means of increasing resource productivity through more intensive or longer utilisation of goods(see table 4-1), for example through multi-functional products and dematerialized or recyclable goods and by systems solutions that reduce both the volume and speed of resource flows, like providing accessibility to information and visibility in the supply chain, which aims at reducing the unnecessary material flows, also referred to by Stahel as 'moving bytes instead of tonnes'.

Table 2-1. “The five pillars of sustainability”

Source: Product Life Institute (PLI), 1995, from Sustainability and services [W.R. Stahel in Charter & Tischner (eds.), 2001, 152]

THE FIVE PILLARS OF SUSTAINABILITY
1. Nature conservation (precautionary principle) 2. Health and safety, non-toxicity (qualitative) ***The first borderline: from protecting the environment (doing things right) to increased economic competitiveness (doing the right thing)*** 3. Increased resource productivity (reduced throughput, quantitative) ***The second borderline: from a sustainable economy to a sustainable society*** 4. Social ecology (jobs and wants, sharing and caring) 5. Cultural ecology (the choice between sufficiency and efficiency)

Another aspect of increased resource productivity is the creation of sufficiency solutions, i.e. solutions that focus on diminishing the need for material resource flows. Companies can provide the consumer with near-zero options, such as the opportunity to contribute to environmental issues by less packaging or fewer materials involved in the service process, or loss prevention. These both result in fewer resources used by the company in its manufacturing or service process.

Stahel claims that sufficiency solutions are of interest only to economic actors in a service economy where they enable an income without resource consumption, hence by using eco-efficient means. Here, the legal framework should in Stahel’s opinion provide conditions that promote performance and results instead of means.

Table 2-2. Strategies for higher resource productivity.

Source: Adapted from Stahel (in Charter & Tischner (eds.), 2001, 159.

Increased resource productivity through:	***Closing the material loops*** **Technical strategies**	***Closing the liability loops*** **Commercial/marketing strategies**
SUFFICIENCY SOLUTIONS	Near-zero options Loss prevention	Zero options Non-insurance
EFFICIENCY SOLUTIONS ***System solutions*** Reducing volume and speed of the resource flow	***System solutions*** Skin solutions Accessibility	***Systemic solutions*** Selling results instead of goods Selling services instead of goods
More intensive utilisation Reducing the volume of the resource flow	Eco-products Dematerialized goods Multi-functional goods	Eco-marketing Shared utilisation of goods Sale of utilisation instead of goods
Longer utilisation of goods Reducing the speed of the resource flow	Remanufacturing Long-life goods Service-life extension of goods and of components New products from waste	Remarketing Discurement services* Away-grading of goods Marketing of fashion upgrades for goods in the market

*'Discurement': the reverse process to procurement; 'away-grading': export for re-use

This can be stated as an overly simplistic way presenting the problem, overlooking the large potential for use of loopholes in the law, and therefore can be considered ambiguous. This is further demonstrated when Stahel adds that the key tools of the consumer side are the sustainability values that are appealing to people who will apply them only to increase their own quality of life. Cynically seen, this might lead to a way of thinking that follows the norms of ethical egoism instead of utilitarianism; consumers not caring about knowing how goods or services are produced beyond their own actions, i.e. how much and what they buy, and how they use and recycle these goods from the purchase onwards. Even if social innovation is plentiful, the needed emphasis on economic innovation might be neglected. This standpoint is not directly relevant for this thesis, but it is worth a mention where general developments towards improved sustainability are concerned.

2.2.2. Eco-efficiency

What is from here onwards referred to as *eco-efficiency* is among the newest and most comprehensive concepts in the field of environmental management and sustainable development. The concept comprises the mutual goal of corporations, governments and social communities to enhance their activities in the kind of way that reduces inputs and negative environmental effects, such as waste production and pollution, and at the same time increases the economic value of goods, services and entire supply chains. In other words, it points to improved efficiency from both ecological and economical point of view. The concept has been shaped to its current form mostly by the World Business Council for Sustainable Development (WBCSD) which promotes it through its Eco-efficiency Metrics & Reporting and the European Eco-efficiency Initiative (EEEI) programs. As defined in the first eco-efficiency workshop held by WBCSD in 1993:

> ***"Eco-efficiency is achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of 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."*** (WBCSD, 2000)

Other ways of defining eco-efficiency have been presented by business practitioners as '**creating more value with less impact'** or '**doing more with less',** or even **'more welfare from less nature'** by the European Environment Agency (EEA), when applied on the macro-level of economic and sustainable development.

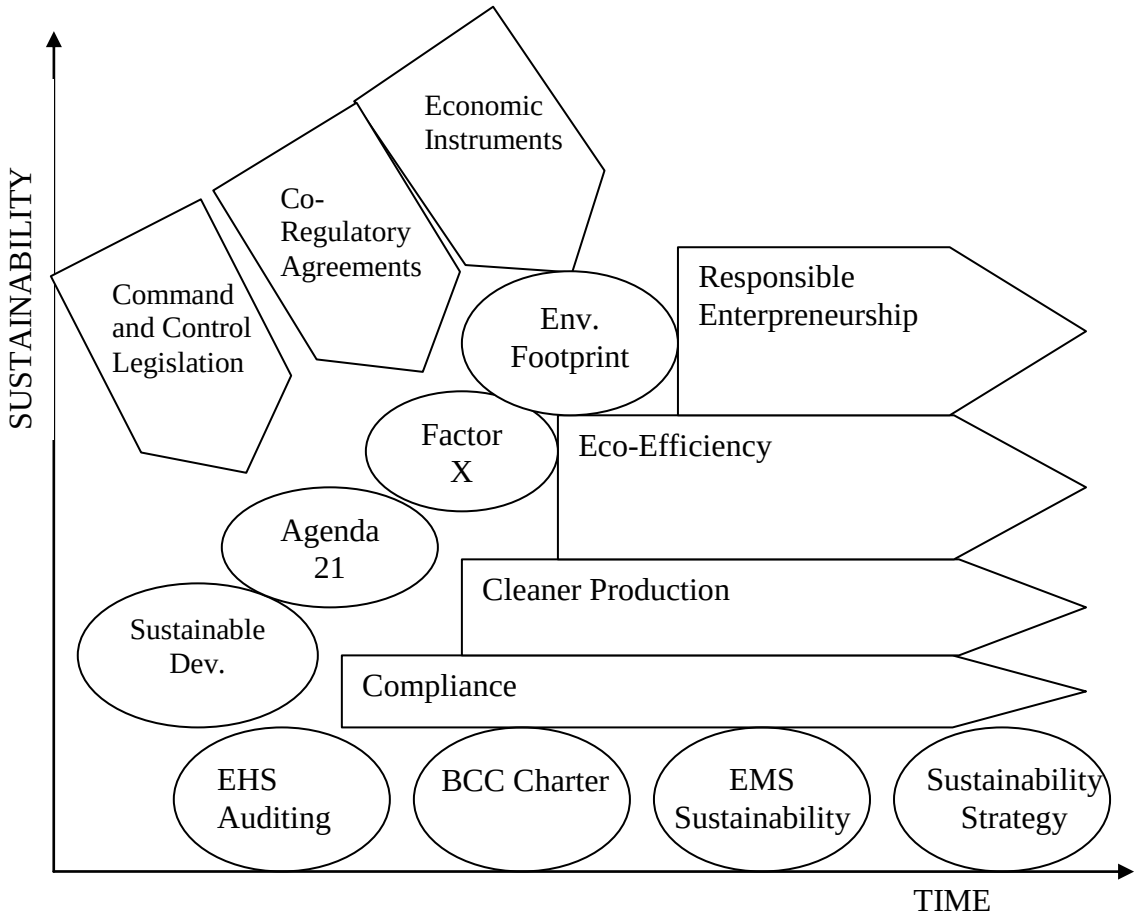

Figure 2-3. Signposts to sustainability.

Source: Eco-Efficiency – Creating more value with less impact, WBCSD, 2000.

On the business side, eco-efficiency is concerned with three broad objectives:

1. **Reducing the consumption of resources:** This includes minimizing the use of energy, materials, water and land, enhancing recyclability and product durability, and closing material loops.
2. **Reducing the impact on nature:** This includes minimizing air emissions, water discharges, waste disposal and the dispersion of toxic substances, as well as fostering the sustainable use of renewable resources.
3. **Increasing product or service value:** This means providing more benefits to customers through product functionality, flexibility and modularity, providing additional services and focusing on selling the functional needs that customers actually want. This raises the possibility of the customer receiving the same functional need with fewer materials and less resources.

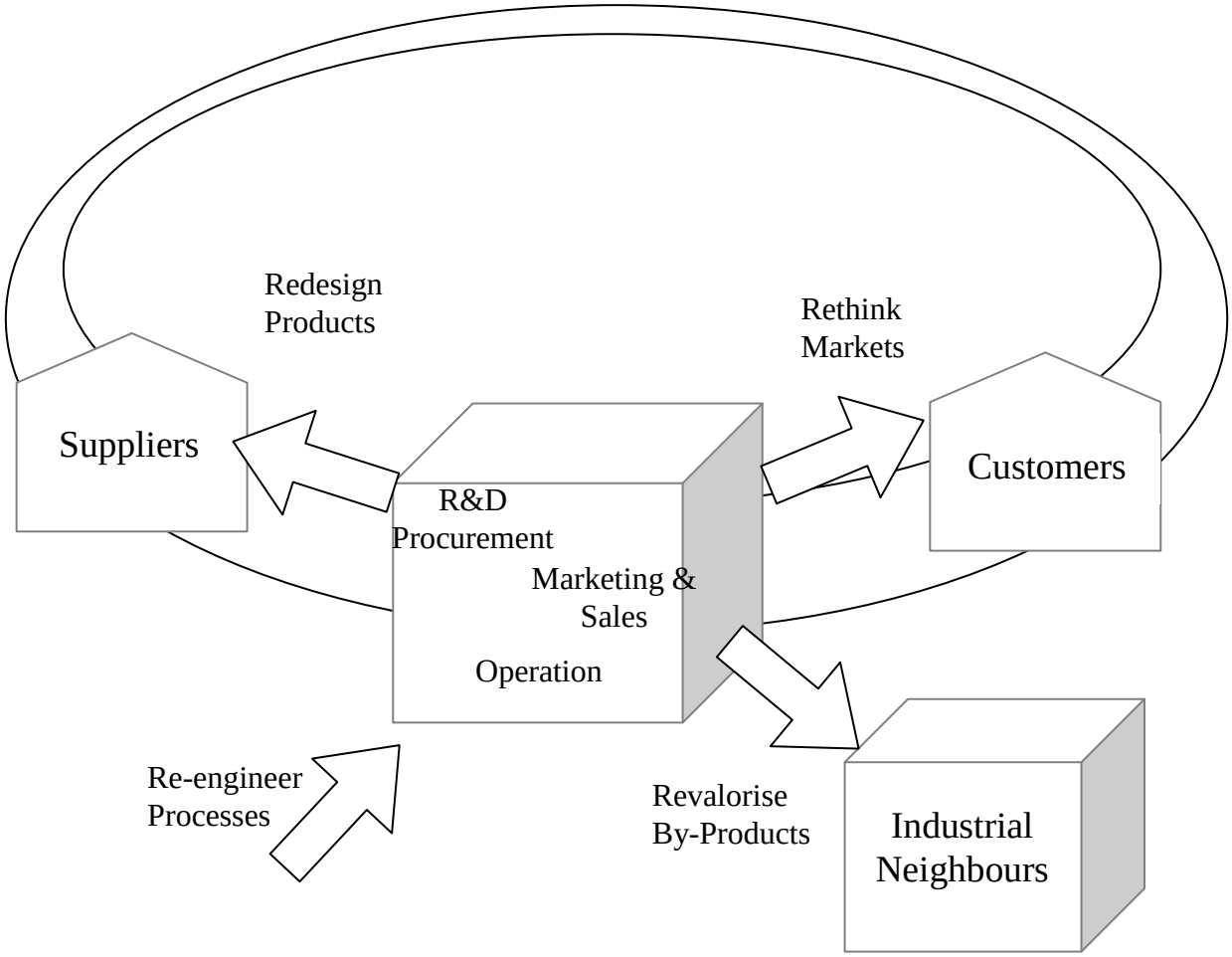

Figure 2-4. Navigating eco-efficient opportunities.

Source: Eco-Efficiency – Creating more value with less impact, WBCSD, 2000.

Within companies, eco-efficiency can be put into practice through various operational and commercial strategies. The main shift behind all the operational strategies involves the transition from traditional supply chain structure, which is focused on efficient forward-oriented flows and high throughput, to one that includes channels for reverse flows of goods and for re-integrating products, parts and materials back into the forward channel, and increased resource productivity. This transition has been depicted by Stahel (2001, 156) as moving from the linear structure of the 'river' economy to one that closes the material loops and forms a self-replenishing 'lake' economy. Incorporating the same basic idea as the closed-loop supply chain models, which have been presented in relation to various other concepts (see e.g. Blumberg, 2005; Srivastava, 2008; Visich et al., 2007), also this one tackles the issue of reducing overall resource consumption through re-use, repair, refurbishing and remanufacturing of goods.

2.2.3. Sustainability performance measurement (SPM) and the role of environmental accounting

For companies to apply the concept of sustainability, efforts should be made to implement also medium- and long-term sustainability targets, instead of the dominant profit-maximizing and cost-minimizing ones. Setting targets obviously calls for performance indicators to report the progress. Sustainability performance measurement is a fairly new approach that incorporates the 'triple bottom line' of sustainability into corporate reporting (Fiksel, 2001, 166), as well as into internal analysis practices that support future developments. SPM focuses on evaluating the three dimensions of economic, environmental and societal performance. In this thesis, the environmental and societal performances are sided, because they are not explicitly related to asset value recovery or possible cost benefits.

Economic sustainability is often defined as a firm's capability to maintain market share under competition, and the succeeding performance indicators measure liquidity and solvency, profitability and growth. However, these indicators are exclusively monetary, and not only misguiding but unable to reflect a firm's level of sustainability as defined earlier. (Spangenberg, 2001) This derives from the fact that traditionally, companies tend to focus on two main strategies: cost or quality competition. Costs, materials, product flaws and other quality levels are carefully monitored in order to provide information of the operations and profits of the company. Important relationships and aspects that could give a more comprehensive picture of the company's operational status can still be hidden behind the numbers. Environmental, life-cycle and full-cost accounting practices, and corporate ecological indicators fill at least a part of this gap. They address the need to develop economic performance evaluation to include hidden costs associated with resource use, to estimate future costs of industrial production and consumption and to determine the costs and benefits across the life-cycle of a product or a process (Fiksel, 2001, 162).

Sustainability measurement principles shown in Table 2-3 introduce the challenges associated with measuring and reporting sustainability on the product level. Various innovative performance indicators have been invented to complement the conventional ones (see Fiksel, 2001, 175; WBCSD b., 2000, 8). By measuring for example material and energy inputs, emissions and waste creation, and combining these with the more traditional indicators, such as production volume, a company can derive information about its material intensity, like MIPS

(material input per tonne of product or per service generated) and 'ecological rucksack' (the total amount of materials activated by a certain production process) (Busch, 2005, 30-31). Measuring resource efficiency in correlation with financial performance in turn produces metrics like 'returns per material input' and 'material input savings per investment' (Spangenberg, 2001). On top of these examples, the WBCSD and its member companies have developed eco-efficiency indicators which measure product or service value in relation to the environmental influence of product or service use (WCSBD b., 2000, 8).

Table 2-3. Sustainability measurement principles.

Source: Fiksel, 2001, 169.

Sustainability measurement principles
• Address the dual perspectives of resource consumption and value creation • Include economic, environmental and societal aspects of the product • Systematically consider each stage in the product life-cycle • Develop leading and lagging indicators of product performance

Sustainability should not be thought of as a profound strategy in itself. Moreover, companies should develop their internal analysis so that aspects of it can be used to support integrating sustainability into one of the more traditional cost- and quality-based viewpoints. The use of the abovementioned indicators to help this development is essential. After all, and as Spangenberg (2001) states as well, it is only attractive for a company that follows a cost competition strategy to operate sustainably, if it is cheaper than operating with a non-sustainable production mode. For those following a quality competition strategy, the positive image gained from environmentally and socially friendly production further contributes to the possible cost benefits. To improve its operational efficiency and level of sustainability at the same time, a company must first see which crucial links in operations affect both of these for its part.

2.3. Sustainability and the supply chain

In recent operations management literature, a fair amount of attention has been given to environmental considerations and the importance of sustainable development, and this has resulted in that life-cycle thinking has gained support over the more traditional view of seeking efficiencies in individual activities along the supply chain.

The concept of life-cycle management is involved with managing the impact a product or service, and the resources used to produce it, have on the environment at each stage of the product life-cycle. Life-cycle assessment is formally defined by ISO (1997) as "a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life-cycle". It has been widely accepted within the environmental research community as a good basis on which to compare alternative materials, components, and services. (see CMFANR, 2004, 57-58)

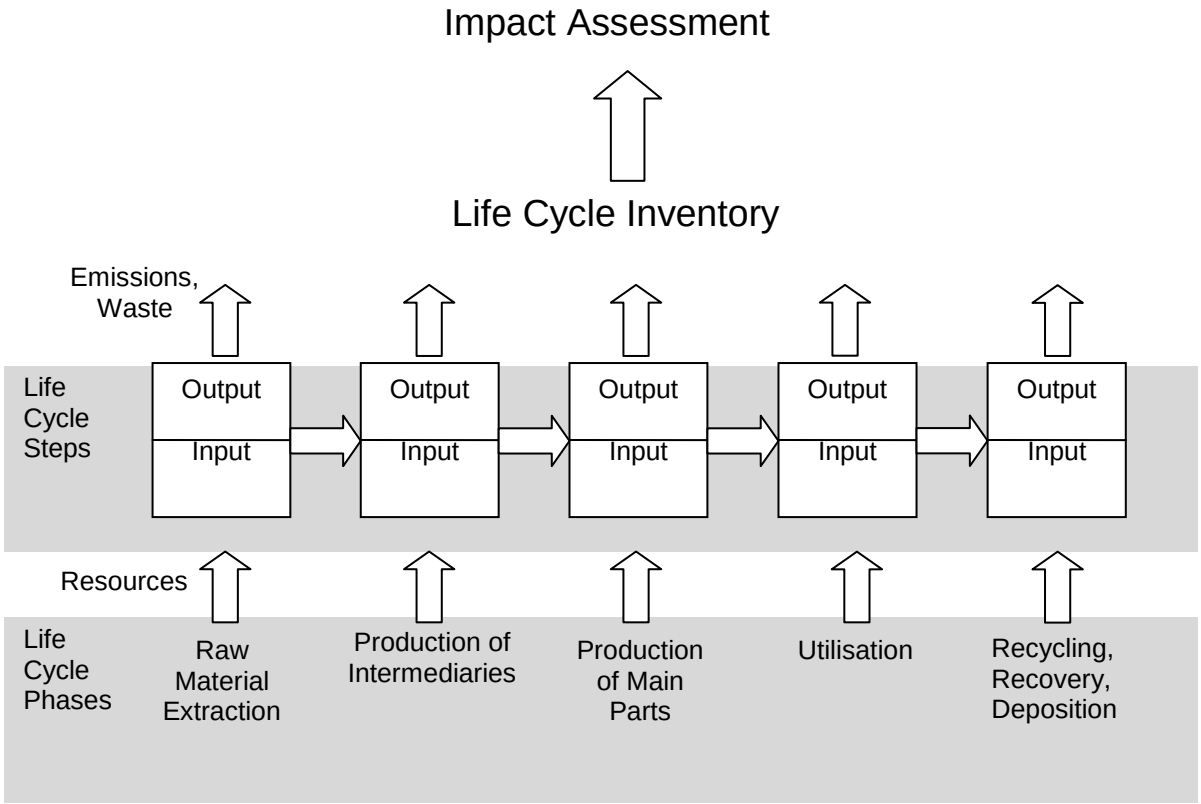

Figure 2-5. Life-cycle assessment.

Source: IKP University of Stuttgart.

The increased interest in impact assessment and other environmental aspects has sprouted a new field under the supply chain management literature called Green Supply Chain Management (GSCM) and concerned with:

> ***"Integrating environmental thinking into supply chain management including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life."*** (Srivastava, 2008)

Supply chain management plays more of a strategic than an operational role in this development. Environmentally oriented strategy is put into action by introducing elements of sustainable development in the supply chain, such as a thorough end-of-life management policy incorporating recycling, re-use and remanufacturing of products and materials as well as efficient processes for handling returns and product take-backs. Together with eco-friendly product design and sourcing and environmental manufacturing processes, reverse logistics operations and coordination of the echelons close the loop to create a green closed loop supply chain.
As a result of this development of converging environmental aspects to supply chain management, the concepts of sustainable development and eco-efficiency are increasingly linked with product design, sourcing and materials management, and reduction of resources and waste in the supply chain (see Fiksel, 2001: Linton et al. 2007; Stahel, 2001; WBCSD, 2000). The strategic importance of the use of resources focusing on the importance of product and process design and sourcing has been discussed by for example Handfield et al. (2005), Scott (2008) and Tischner (2001).

In general, a broader view on operations management in the environmental context is demanded and predicted in the future. For example, Corbett & Klassen (2006) argue that this trend will be one of the most prevailing in the field for the next decade or so, and that both theory and practice show improvement in operations achieved by adopting an all-inclusive environmental perspective to company strategy. They use the development of Total Quality Management (TQM) and Supply Chain Management (SCM) in demonstrating the shift and suggest that also other fields are increasingly raising their awareness in the operations management community. Their main conjecture involves the "law of the expected unexpected side benefits" which means that the benefits of adopting an environmental perspective are unexpected and often greater than can be predicted with accuracy. This in turn makes it difficult to measure the benefits, especially

when more stakeholders, such as governments, communities, public interest groups and future generations, need to be considered in addition to the more traditional combination of manufacturers, suppliers and customers.

Additionally, as regulatory changes, such as the WEEE Directive in the EU, are already forcing companies to engage in product take-back and disposal, there is a pressure for companies to get more deeply involved in end-of-life management. In the SCM context, the treatment of end-of-life products, such as recycling and disposal, are comprised in the closed loop supply chain model (Blumberg, 2005; Guide & van Wassenhove, 2002). This applies especially to processes related to waste generation and disposal. Waste management is a significant logistical effort for many operations, whether the waste is hazardous or not. Failing to incorporate the costs associated with this process into the full supply chain results not only in higher costs but a loss of potential revenue-generating opportunities (LMI, 2003). Research on product disposal and recovery and remanufacturing has been produced by Aras et al. (2004), Linton et al. (2007), Rogers & Tibben-Lembke (1998), Savaskan et al. (2004), Thierry et al. (1995) and Tibben-Lembke (2002) among others.

2.4. Theoretical framework

Even if the different aspects related to environmental performance and materials have been studied individually or, on the other hand, broadly concerning the whole supply chain, there is a lack of practical assessment tools for focused areas of interest such as materials management. An increasing amount of companies are certifying their environmental management system (EMS), and literature shows that companies that adopt an EMS more frequently also adopt GSCM principles (Darnall, 2006, p.42). However, certified environmental systems (EMS) provide a standardized approach to analysing the general environmental performance of companies, but are usually more involved with achieving compliance at a certain level through a documented protocol and audits than actually with identifying areas for strategic development. Also, different organisations promoting sustainable business practices have created indicators for companies to use in assessing their performance on sustainability criteria (WBCSD, 2000b), but these tend to be limited to measuring general resource efficiency and waste levels, and do not incorporate sourcing or supply chain coordination aspects under the same assessment system.

This research aims to incorporate all the different aspects discussed here to create a model which can be used to evaluate the sustainability of materials management throughout the supply chain. The theoretical framework of this study (see Figure 2-6) is therefore formed from three aspects that contribute to sustainability in terms of materials management and that are in this research titled as follows: environmental or ecological product design i.e. 'Product eco-design', 'Sustainable sourcing and supply chain coordination' and 'Product recovery and end-of-life management'.

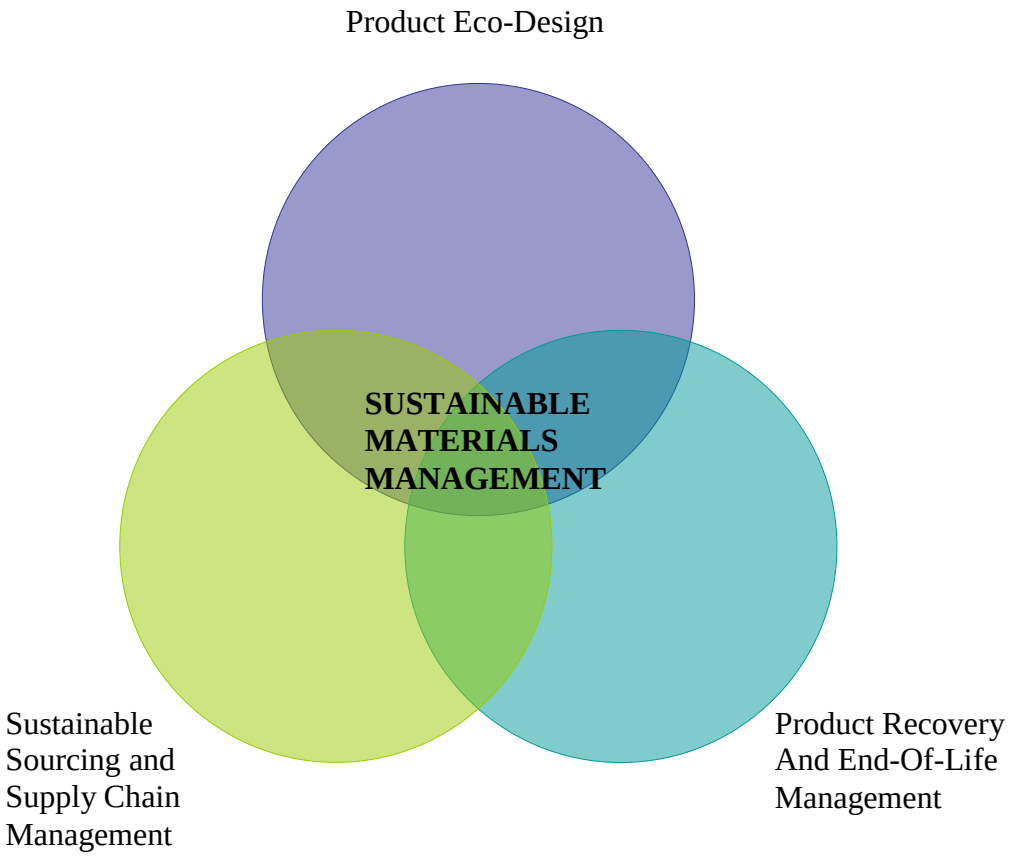

Figure 2-6. Theoretical framework of sustainable materials management.

3. Sustainable materials management evaluation

This section introduces the model constructed to evaluate the sustainability in materials management. The model incorporates product design, sourcing and product recovery and end-of-life management activities as the strategic aspects of sustainable materials management (SMM). First, the methodology used in building the model is presented. Second, the aspects and their implications on different levels of the supply chain are discussed. It is shown that the elements can bring benefits to the company when integrated to company strategy thoroughly.

3.1. Defining metrics

The evaluation metrics determined for the model are provided in the form of simple checklists identifying the central issues under each of the strategic aspects of sustainable materials management, as introduced in the previous section. The choice of checklists as metrics for the model is based on the need for a basic approach in a situation where no existing model can be identified to depict a similar combination of aspects as chosen for this research. According to Tischner (2001, 272), taking a practical approach to integrating environmental aspects into the product design process helps to define appropriate strategies and ideas, offers criteria in a more or less situation specific manner, present these briefly and to the point and dispense with in-depth examination of the background, this way giving a good overview and enabling stakeholders to quickly absorb the important aspects of eco-product design and development.

It can be argued that the same principle applies more generally to the development of assessment tools in that a simplistic approach provides a good general base for the future development of models that are concerned with the same aspects as this study. Also, the availability of data in this case affected the research design in such a way that the model was simplified in order to provide standardized results for all empirical cases.

The indicators on the checklists are mostly based on what has been identified as relevant for this study from previous literature and industry practices related to CSR. For other parts, they have been created by the researcher to complete the checklists. The guiding principle in the selection has been to consider the importance of the indicator to a company's stakeholders. The checklists

are presented below as part of the discussion on each aspect of the model and summarized at the end of this section.

The evaluation of sustainability in materials management is done on a simple sum-principle, i.e. the checklists are ticked off depending whether the subject depicted in the metric is in active use in the company (not in preparation) and then the total of metrics that have been ticked will be counted to represent the level of involvement in that aspect. The total sum of ticks earned from all the aspects will then point the overall result for each individual company.

3.1.1. Product eco-design

The activity at the core of continuous sustainable use of materials is product design. The delivery of 'the product' to the customer can take many material forms and requires not only technical and material knowledge but, with increasing importance, innovation and thinking in terms of solutions. The product eco-design process entails the integration of environmental aspects into all product and production planning processes. Adoption of eco-design leads to:

"products, systems, infrastructures and services, which require a minimum of resources, energy and land area to provide the desired benefit in the best possible way while at the same time minimising pollution and waste arisings over the entire life-cycle of the product" (Schmidt-Bleek and Tischner, 1995; see Tischner, 2001, 266).

Environmental product design can be considered to have three main aims: 1) to reduce the amount of resources used to manufacture the product, 2) to reduce the environmental impact caused from the use of the product (energy-efficiency) or 3) to reduce the amount of (non-recyclable) waste at end-of-life stage. Each of these aims is relevant to companies either from a financial point of view or for company image reasons, not to mention tightening regulation on substance use and waste handling. Principles such as Extended Producer Responsibility (EPR) and Individual Producer Responsibility (IPR) target the issue of end-of-life product waste by placing the negative incentive of disposal costs of products on producers.

Life-cycle analysis (LCA) is a useful tool to be used in the product design process to evaluate the cradle-to-grave implications of different product options. Each LCA has three parts (Schmidheiny, 1992, 111):

1. An inventory of energy, resource use and emissions during each step of product life
2. An assessment of the impact of the these components
3. An action plan for improving the product's environmental performance

While interest in environmental management has increased across different industries, also other new tools have been developed for priority-setting (e.g. ABC analysis), for design and draft specification (e.g. recycling checklist) and for assessing profitability (e.g. Life-Cycle Costing) (see Tischner, 2001, 269).

Using checklists as a starting point in the product development process helps to determine the properties that support the three aims of environmental product design. They can also provide information on the quality of the design process itself and should be questioned and updated to meet higher demands and targets. Examples of eco-design checklists are given in Tables 3-1 and 3-2.

Table 3-1. Corporate options for product improvement.

Source: Schmidheiny, 1992, 110.

CORPORATE OPTIONS FOR PRODUCT IMPROVEMENT
• Eliminate or replace product • Eliminate or reduce harmful ingredients • Substitute environmentally preferred materials or processes • Decrease weight or reduce volume • Produce concentrated product • Produce in bulk • Combine the functions or more than one product • Produce fewer models or styles • Redesign for more efficient use • Increase product life span • Reduce wasteful packaging • Improve repairability • Redesign for consumer re-use • Remanufacture the product

Table 3-2. Eco-design checklist.

Source: Tischner, 2001, 278-279.

EXTRACTION OF RAW MATERIALS, CHOICE OF RAW MATERIALS
• Minimising material input • Minimising energy input • Minimising land use (raw materials extraction, production) • Avoiding input or emission of hazardous substances • Avoiding emissions (e.g. by transport) • Minimising waste production, recycling materials • Preferring local raw materials • Using renewable raw materials produced using sustainable methods • Using socially acceptable substances that will pose no health hazards • Using recycled materials
PRODUCTION
• Minimising material input • Minimising energy input • Minimising land use • Avoiding input or emission of hazardous substances • Avoiding emissions (e.g. by refinement procedures) • Minimising pre-consumer waste production, recycling materials • Preferring local suppliers along the whole supply chain • Minimising packaging • Using renewable ancillary materials produced by sustainable methods • Using socially acceptable processes that will pose no health hazards
USE/SERVICE
• Creating excellent customer benefits • Appropriate design for target group • Minimising complaints and returns • Keeping service available • Understanding design for the user • Design for self-controllable and optimisable functions • Dirt-resistant, easy-to-clean design • Minimising material and energy input during use • Avoiding input or emission of hazardous substances
RE-USE/RECYCLING (CLOSING TECHNICAL MATERIAL AND ENERGY CYCLES
• Recycling strategy in place? • Guarantee for take-back in place? • Re-use of the complete product (e.g. second-hand, recycling cascade) • Recycling of components (e.g. upgrading, re-use of components) • Recycling of materials • Dismantling of products • Separability of different materials • Low diversity of materials • Low material and energy input for re-use/recycling
FINAL DISPOSAL
• Compostable, fermentable products (closing biological cycles) • Combustion characteristics • Environmental aspects at deposition

Based on what has been discussed before, the relevant metrics chosen under the product eco-design aspect are listed in Table 3-3. The metrics have been chosen on the basis of how well their focus corresponds to the three main aims of environmental product design (see p. 31), with the addition of stakeholder interest as one focus factor. Metrics that are concerned with stakeholder interest have been included because they provide information about whether the product design process is structured and/or controlled by outside actors, which is important for long-term development of sustainable materials management.

Metrics that focus on the reduction of resources in making of the product and the reduction of waste at the end of product life have been taken from Tischner's (2001, 278-279) eco-design checklist and include 'use of renewable resources', 'use of recycled materials' and 'design for disassembly/recycling'. Use of renewable resources can be considered as reducing resource use because less virgin materials are used in production.

Two of the metrics address the issue of avoiding the use of hazardous substances, namely the ones titled 'RoHS compliance on all newly designed products' and 'third-party certified substance analysis methods in place'. The first one is a general criterion used in corporate social responsibility (CSR) evaluation in manufacturing industries, in accordance with the International Standard on Assurance Engagements (ISAE 3000), and the second one is adopted from Tischner's (ibid.) checklist (where it can be found as 'avoiding input or emission of hazardous substances') and modified by the researcher to also match general CSR criteria, with the third-party control aspect embedded into the metric. This way the metric contributes to depicting the degree of organizational structure of hazardous substance control in the product design process.

The remaining metrics, 'structured environmental impact assessment tool in place' and 'eco-design targets in place' are similarly concerned with stakeholder interest as they are also part of CSR criteria, the latter being stipulated under ISO's LCA standardization requirements as well.

Table 3-3. List of metrics used to evaluate the sustainability of product design.

Metric	Focus	Source
Use of renewable resources (e.g.bio-plastics, waterborne paints)	Reduction of resources used to make the product Reduction of waste at the end of product life	Tischner (2001)
Use of recycled materials	Reduction of resources used to make the product Material consideration	Tischner (2001)
Structured environmental impact assessment tool in place (e.g. LCA)	Stakeholder interest Structured process	CSR criteria
Design for disassembly/recycling	Reduction of waste at the end of product life Closing material loops	Tischner (2001)
RoHS compliance on all newly designed products	Stakeholder interest	CSR criteria
Third-party certified substance analysis methods in place	Reduction of (hazardous) waste Stakeholder interest Structured process	CSR criteria Tischner (2001)
Eco-design targets in place	Stakeholder interest Structured process	CSR criteria

3.1.2. Sustainable sourcing and supply chain coordination

Suppliers are an important stakeholder group for companies involved in environmental management, because companies rely increasingly on their suppliers for competitive advantage and also because environmental risks can be passed onto a company through its suppliers (Handfield et al., 2005, 1). As a result, it has become viable for companies to integrate their own environmental management systems and policies to their suppliers' activities as well and hence to also monitor related supplier performance. Recently, companies have started to introduce supplier certification programs based on ISO 14001 or an equivalent standard to their suppliers in a display of environmental stewardship.

According to Handfield et al. (2005, 3) implementation of any supply chain strategy will not be truly effective unless done on the commodity or product family level, and he therefore suggests the commodity strategy as the primary tool for integrating environmental aspects into the supply

chain strategy. The commodity strategy process includes the identification of commodities – materials and their sources of supply – that are critical and the application of the company's EMS to concern these critical commodities (Handfield et al., 2005, 4).

Problems related to commodity strategy stem from e.g. the conflicting requirements for product quality and environmental standards. In situations like these it might be difficult for the company to determine what the actual effect of sustainable choices on product performance is. Lack of analytical tools and procedures has been identified as one of the barriers to adopting a commodity strategy (ibid).

One key aspect of sustainable sourcing comes in the form of hazardous substances management, already briefly discussed in the previous chapter, and legal restrictions on the use and import of certain materials, referring especially to the RoHS and REACH directives in the EU. The control of such substances poses challenges to companies sourcing materials and components from areas other than their operational market area where differences in regional regulations and their enforcement occur. It is therefore important for a company to keep its suppliers up-to-date about the requirements on all the different target market areas. Just as important, companies should work towards creating an environment of mutual openness as working together across the supply chain can with suppliers is essential in trying to reduce the use of materials and resources and waste levels (Scott, 2008, 309). Transparency of the supply chain has also been emphasized as a source of competitive advantage in addition to reducing environmental impact (Handfield et al., 2005, 15).

As sourcing and supply chain coordination are activities that are done in cooperation with suppliers and agents, and that are looked over by other stakeholders, such as outside auditors, public interest groups and government officials, it is natural that this area raises high stakeholder interest in general and has established monitoring and measurement tools in use by the different stakeholder groups. The metrics chosen under this aspect are therefore also in line with already established procedures, mostly with CSR criteria. The metrics are shown below in Table 3-4.

Under the list of metrics for sustainable sourcing and supply chain coordination, the ones indicating if the company has a supplier certification program in place and whether suppliers are monitored and audited regularly (on the 1st tier) are all of general interest to stakeholders. They are used in CSR evaluations to show whether the company has a structured procedure in place

for supplier evaluation and thus form the ground stone of sustainability evaluation in terms of sourcing of materials. Monitoring and 1st tier audits are also part of ISO standard life-cycle assessment tool.

To take the evaluation one step further and to reveal if there is transparency in the supply chain other metrics have been included from this aspect. From this point of view it is firstly feasible to investigate if the company performs 2nd tier audits by default, a metric added by the researcher. Other metrics stating whether the company requires its suppliers to follow similar EMS standards as it does itself in terms of placing resource use and waste level targets and if suppliers are being trained by the company in issues of sustainability show the degree of commitment to supply chain coordination and increasing transparency in the supply chain. Training suppliers especially gives a good image of the company as being open about its operations and taking initiative towards the development of its partners, and can be a valuable publicity asset. These two metrics have been pointed out by Scott (2008, 311) in the form of advice to managers, but could not be found to be part of any existing sustainability evaluation tool. Also, Handfield et al. (2005, 15) give recommendations towards the same direction and present some case examples of companies that are already engaged in working together with their suppliers to reduce environmental impacts.

Further, whether the company is sharing information with its suppliers about (hazardous) substances that are not to be used in components is a clear metric for the transparency of the supply chain. This metric is more of a prerequisite for procuring due to the risk involved for the company. It is introduced against a similar background as the two last ones mentioned in that it has also been discussed earlier by Scott (ibid.) and Handfield et al. (ibid.) but does not seem to have been used in any previous tool or model.

Table 3-4. List of metrics used to evaluate the sustainability of sourcing and supply chain coordination.

Metric	Focus	Source
Supplier certification program	Structured process Stakeholder interest	CSR criteria
Supplier monitoring	Structured process Stakeholder interest	CSR criteria
Audits conducted regularly (1st tier)	Structured process Stakeholder interest Transparency of supply chain	CSR criteria
Audits conducted regularly (2nd tier)	Structured process Transparency of supply chain	Researcher
Supplier training in environmental issues	Initiative Stakeholder interest	Handfield et al. (2005) Scott (2008) Researcher
Information sharing on controlled (hazardous) substances	Risk management Stakeholder interest	Handfield et al. (2005) Scott (2008) Researcher
Resource use and/or waste level targets for suppliers in place	Transparency of supply chain Stakeholder interest	Scott (2008) Researcher

3.1.3. Product recovery and end-of-life management

Even if both material use and product-specific life-cycle impact would be accounted for, there is also an important notion regarding manufacturer's resource efficiency in how the product is treated when it is returned to the producer as either unused, used but no longer needed, faulty or at its end-of-life. Product recovery and end-of-life management form a part of a company's reverse logistics operations, the operations concerned with these cases. Reverse logistics has emerged as a new business opportunity with growing importance in two areas in particular: 1) environmental concerns focusing on consumer and industrial waste (normal and hazardous) reduction; and 2) economic value in terms of extending the product life and usability and uptime of products manufactured (Blumberg, 2005, 203).

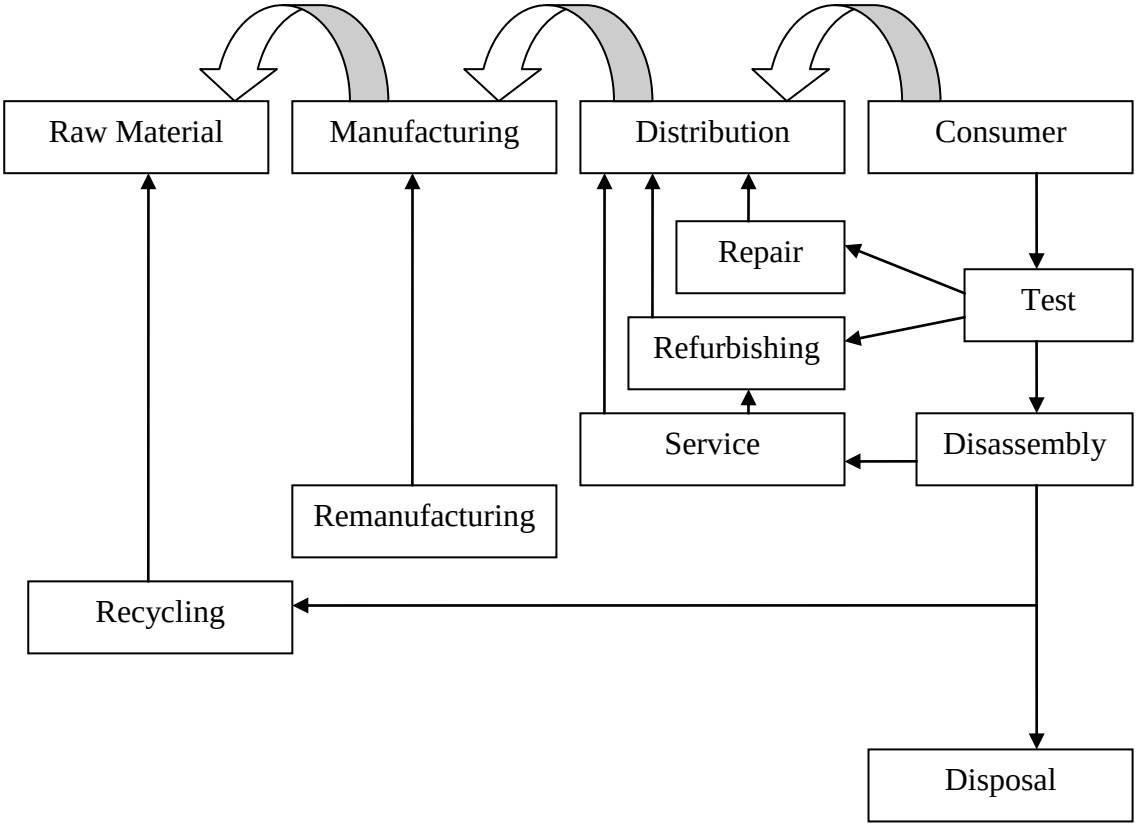

Figure 3-1. Basic flow diagram of reverse logistics activities.

Source: Srivastava, 2008.

The growing volumes of reverse flows in certain industries suggest that more attention should be given to improve asset recovery from end-of-life and returned products. For example, in the electronics industry product life-cycles are becoming shorter and shorter as technology evolves and new models are introduced to the market at frequent intervals, as most of the profits from these products are made in the early stages of the product life (Rogers & Tibben-Lembke, 1998, 172). At the same time warranties given to these products often do not match the average life-cycle of the product, which leads to a spiral of products being returned to retailers in exchange for a newer model before the warranty closes. This way the retailers end up with increased inventories of returned products which they will send further back in the chain to the manufacturer – provided that both the consumer-to-retailer return policies and contracts between the supply chain partners allow this.

This pattern combined with flows of non-sold products and actual end-of-life products under extended producer responsibility regulations amount to big quantities of products that end back

up in manufacturer's hands. Concerning mobile phones, the estimates vary: according to Oertel et al. (2005) 130 million mobile phones were retired in the world in 2005 (see Babu et al., 2007, 309) whereas Scott (2008, 9) has stated more recently that over 175 million mobile phones are thrown away every year in the United States alone. Whichever one of these estimates is closer to the truth, with recent sales figures of mobile phones reaching more than one billion units annually (Gartner, 2009), one can at least predict the growth direction in the number of end-of-life mobile phones to be upwards.

Increasing asset recovery through reselling, re-using, remanufacturing products and recycling components and materials can prove to be cost-efficient to the manufacturer, especially in a situation such as described above. These issues are often underestimated even though the potential for cost reductions and improved competitiveness through material efficiency has been quantified to be significant. According to the German Federal Ministry for the Environment/Federal Environmental Agency, approximately 60 % of costs are attributed to materials, while only 25 % to personnel, in a typical cost distribution of a manufacturing company (see Busch et al., 2005, 22). Additionally, the management consulting company Arthur D. Little has found that increasing material efficiency can cut production costs by 20 % in almost every case (see Busch et al., 2005, 23). Practical examples also exist, as shown by companies like 3M, AT&T, BMW, Canon, Hewlett-Packard, IBM, Kodak, Motorola, ReCellular and Xerox which have successfully implemented re-use, repair and remanufacturing activities into their operations and realized cost savings as a result (see Carter & Ellram, 1998; Guide et al., 2003; Jayaraman & Luo, 2007; Thierry et al., 1995).

Metrics under this aspect are mainly focused on recovery and recycling as ways to close the material loops, as Table 3-5 shows. Most of the metrics are derived from Tischner's (2001, 278-279) eco-design checklist which was introduced earlier in chapter 3.1.1. From this list come the points of reuse and refurbishment of products and reintegration of recycled materials which are direct metrics to do with closing the material loops by recovering as much as possible and feeding it back to the forward channel – either that of the company's own or one in secondary markets. Supporting these is the researcher's own additions, the metrics of 'voluntary take-back program in operation' and 'participation in global development initiatives' (such as MPPI, GeSI etc.) which are concerned with closing the material loops, but also answers to stakeholder interest and in this way can be very important for company image as well as to developing processes for recovery, recycling and reintegration materials. The base level metric for this

aspect is 'WEEE compliance' which is part of any CSR evaluation. Whether a company has a collection rate in place (aside from the general WEEE collection target set by the EU) for the amount of recovered products as a metric has been added by the researcher because it contributes to evaluating the level of structure of product recovery and end-of-life management activities.

Table 3-5. List of metrics used to evaluate the sustainability of product recovery and end of life management operations.

Metric	Focus	Source
WEEE compliance (participating in a collective scheme)	Stakeholder interest	CSR criteria
Voluntary take-back program in operation	Closing material loops Stakeholder interest	Researcher
Reuse of products (sales to secondary markets)	Closing material loops	Tischner (2001)
Refurbishment of products (sales to secondary markets)	Closing material loops	Tischner (2001)
Reintegration of recycled materials	Closing material loops	Tischner (2001)
Company-specific collection rate target in place	Structured process Stakeholder interest	Researcher
Participation in global development initiatives	Stakeholder interest	Researcher

3.2. Model for evaluating sustainability in materials management

As was discussed in the previous section, operations focusing on production, product design and handling of end-of-life and returned products are of significant importance in reducing the use of resources, and thus in promoting sustainability in the supply chain as a whole (Linton et al., 2007). The link between materials management and environmental sustainability is formed through managing product and process design, sourcing, by-products, product life-extension and product end-of-life related considerations.

In order to evaluate the level of sustainability of a company's materials management strategy in the scope of this framework, each of the activities will be assigned with a simplistic system of metrics (see Table 3-6) which have been introduced in this section. A three-dimensional conceptual model will be used to present the results of this analysis, with the combined score of

all the metrics under each activity pointing out the level of sustainability performance in the said activity. The model is shown in Figure 3-2.

The different levels on which this development towards increased sustainability in the supply chain might take place are shown in the model. A limitation to this model is that it does not comment on the make-or-buy decision of the manufacturer, i.e. whether these operations are being done in-house or outsourced, but instead looks only at which operations are being incorporated to the supply chain all in all.

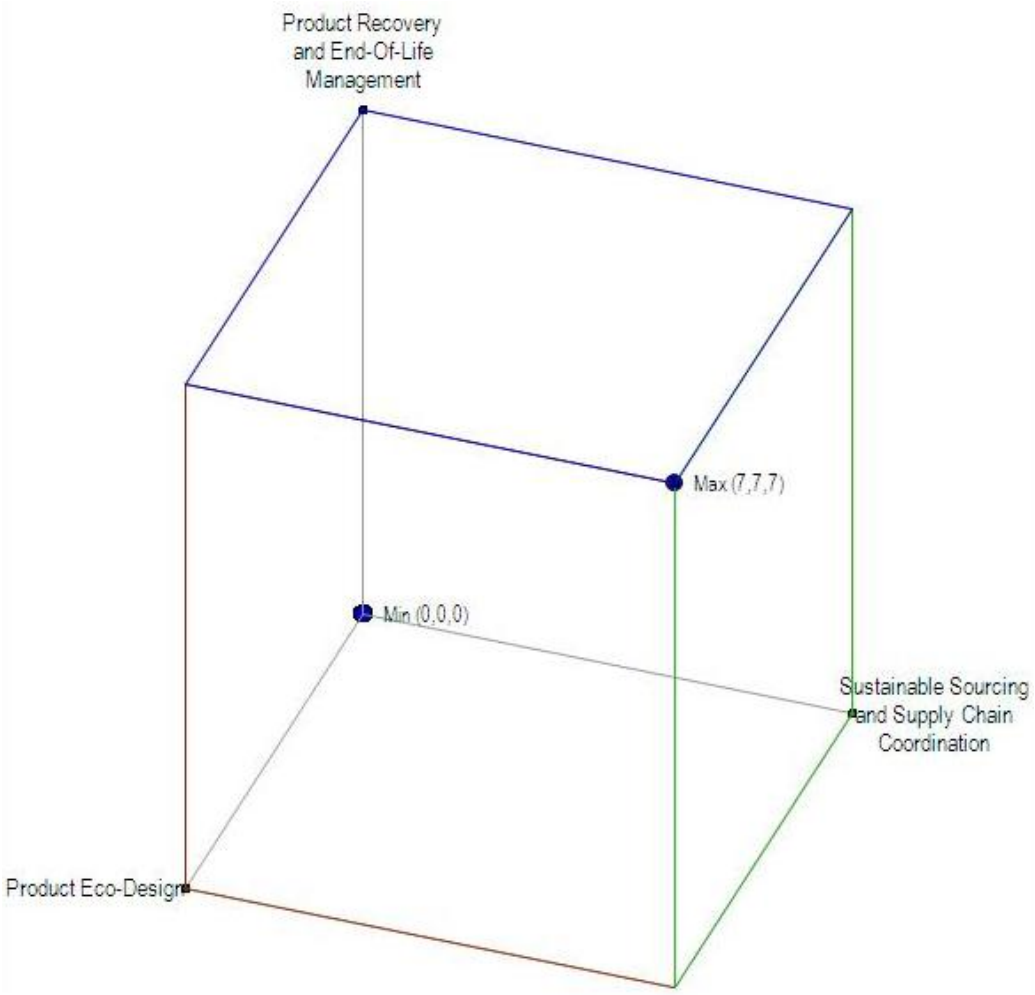

Figure 3-2. Model for evaluating the sustainability of materials management.

Table 3-6. Sustainability metrics for materials management.

Product eco-design	**Sustainable sourcing and supply chain coordination**	**Product recovery and end-of-life management**
Use of renewable resources (e.g. bio-plastics, waterborne paints)	Supplier certification program	WEEE compliance (participating in a collective scheme)
Use of recycled materials	Supplier monitoring	Voluntary take-back programs
Structured environmental impact assessment tool in place (e.g. LCA)	Audits conducted regularly (1st tier)	Reuse of products (sales to secondary markets)
Design for disassembly/recycling	Audits conducted regularly (2nd tier)	Refurbishment of products (sales to secondary markets)
RoHS compliance on all newly designed products	Supplier training in environmental issues	Reintegration of recycled materials
Third-party certified substance analysis methods in place	Controlled substance list	Collection rate target in place
Eco-design targets in place	Resource use and/or waste level targets for suppliers in place	Participation in global development initiatives

The elements introduced in the model (product eco-design, sourcing and supply chain coordination and product recovery and end-of-life management) can be identified to increase both economic and environmental sustainability of a company's materials management strategy. Ecological product design reduces the material content's environmental impact and increases the recyclability and reintegrability of products and their components back into the chain. Sustainable sourcing provides analysis of the choice of materials under the criteria of how critical, durable and recyclable they are and how they thus match the requirements set by production and product design, and sets procedures in place to monitor hazardous substance use and suppliers' compliance to regulations. Product recovery and end-of-life management reduce the environmental impact of product waste through collection and recycling, and helps to reduce the use of materials in production through refurbishment and reintegration of materials.

Whether these elements are independent (e.g. outsourced) or an integrated part of the manufacturer's operations, they are in interaction with each other to close the material loops inside the supply chain. However, in developing the supply chain towards being truly sustainable, integration of operations is practically unavoidable as sourcing is a core function for any manufacturer. Through developing a commodity strategy, the manufacturer can construct its complete closed-loop supply chain to support eco-efficient and sustainable business practices,

and also try influence the supplier base of the industry by exerting power over the supply chain members through choosing and rejecting suppliers based on CSR criteria.

If a manufacturer decides to be actively involved in the collection of end-of-life products, the strategic choice of collection channel depends on the wanted outcome for the reverse supply chain operations. As discussed by Lebreton (2007, 5) the outcome can be either cost minimizing or lead-time minimizing, with a functional or reactive supply chain structure, respectively. This outcome depends on the marginal value of time (MVT) of the components and materials used in production, thus their estimated residual value at the end-of-life stage compared to their initial value. When the MVT of said components is high, the supply chain should be constructed to cater for an environment of fast throughput, whereas when facing a market or production environment with less cannibalization effect the emphasis can be on constructing a clearly cost-efficient reverse flow.

4. Sustainable materials management in mobile device manufacturing companies

This section introduces the empirical part of this thesis which is conducted in the form of case studies of mobile device manufacturers operating in the European market. The choice of companies for the case studies has been made on the basis of the size and presence of these companies in the market, and the sample includes the five global leaders Nokia, Samsung, LG, Motorola and Sony Ericsson.

The data chosen for the case studies is limited to the elements introduced in the model for evaluating sustainable materials management. Therefore, the cases focus on presenting information about the companies' product design, sourcing and product recovery activities, which is used to evaluate the sustainability of these activities through using the sustainable materials management metrics. All of the data is derived from the companies own publications or press releases unless otherwise stated. Ultimately, the findings will be applied to the assessment model in order to draw conclusions on the level of sustainability of the companies' materials management strategy in the focus industry. A summary of findings concerning the whole industry is presented in the last chapter of this section.

First, a short overview of the mobile device market is given below.

4.1. Overview of the mobile device market

As mentioned earlier in this thesis, the global sales of mobile handsets totalled to 1,2 billion units in 2008 out of which 229 million units were sold in the biggest market area, the EMEA region (Gartner, 2009a)..The handset market has been enjoying steady growth until the end of 2008 when the economic crisis hit the global economy. As a result, the market fell five per cent in Q4 of 2008 and continued to decline through the first two quarters of 2009 as well (see Gartner, 2009b and Gartner, 2009c). Many of the leading manufacturers estimated at the end of 2008 that the global market would decline by 10 % overall year-on-year in 2009 (see e.g. Nokia, Motorola, Samsung). The product group of so-called smartphones has kept itself afloat even through the economic downturn and grew by 27 % in 2008. The global handset market is predicted to pick up again latest in 2010.

Nokia is the leading global manufacturer of mobile handsets and was also the current market leader in Europe at the time of writing. Samsung and LG Electronics followed behind Nokia after both having gradually won over market share from Motorola and Sony Ericsson (Gartner, 2009c). Handset manufacturers sell their products through both direct and indirect sales channels, thus using operator owned or independent distributors, offering subsidies on handsets when subscribing to an operator contract, specialist stores and national chain retailers (ARC Group, 2004, 1-14).

The mobile handset manufacturing industry is particularly interesting from a materials management point of view due to forces affecting the supply chain operations on several levels (see Table 4-1.).

Table 4-1. Forces supporting sustainable materials management across the supply chain in the telecommunications industry.

Industry level	**Company level**	**Consumer level**
- Regulations increasing producer responsibility (RoHS, WEEE)	- Costs from operations related to product take-backs (in-house/outsourced)	
- Limited supply of critical materials - Changing commodity prices - Shortened product life cycles	- Difficulties in sourcing - Importance of resource efficiency	
- General attitudes changing towards environmental sustainability and ethical business practices		- Increased ethical awareness - Pro-environment attitudes

4.2. Nokia

Nokia is an EU-based (headquartered in Espoo, Finland) provider of wireless communications solutions. Nokia's service offering includes the sale of mobility solutions in the form of mobile devices and services and software, consumer internet services and enterprise solutions and software. It also provides network equipment, services and software through its joint venture Nokia Siemens Networks, which it owns with Siemens AG in equal shares of 50% each. Its latest acquisition, NAVTEQ, is a leading producer of digital mapping and navigation applications and devices and solutions. Nokia's structure is organized into four main business units: Devices, Services & Software, Markets and The Corporate Development Office. Nokia runs its business activities of R&D, production, sales and marketing around the world. During 2008 Nokia manufactured over 1,25 million devices per day in its nine main manufacturing facilities worldwide.

Nokia has been an active agent in integrating environmental management aspects into its operations. Nokia also cooperates with many international partners in reducing its environmental impact, such as EICTA, WBCSD, WWF, GeSI and SteP (Nokia, 2009).

Product design

As the global leading manufacturer of mobile devices, Nokia shows a strong R&D focus also on the environmental side of materials management. In 2008, Nokia brought to the market the latest advance in environmental product design in its industry: a mobile device whose covers are made of 50 % renewable materials, thus saving the same amount in fossil fuels. The same year saw the introduction of another, revolutionary sustainable solution in terms of material usage as Nokia introduced the Remade concept phone where no virgin materials have been used to manufacture the entire phone. Instead the phone was made using materials extracted from old rubber tires, aluminium cans, and plastic bottles and with printed circuit boards providing the technology.

Reduction of hazardous substances has also been a continuous improvement target for Nokia, and was the first mobile manufacturer to have a full material declaration of its mobile devices, first made available on its website in 2003. PVC has been phased out of all newly manufactured Nokia mobile devices and all the mobile devices have been RoHS compliant starting from 2006.

In 2008, Nokia introduced its first two devices which are fully free of brominated compounds, antimony trioxide and chlorinated flame retardants.

In packaging, Nokia made significant monetary savings of 474 million Euros by reducing the size of packages by 60 % for some of its models, this way saving 100 000 tons of paper. These days, more than 95 % of packaging materials are renewable paper-based materials.

Table 4-2. Product eco-design results for Nokia.

Product eco-design	**Nokia**
Use of renewable resources (e.g. bio-plastics, waterborne paints)	X
Use of recycled materials	X
Structured environmental impact assessment tool in place (e.g. LCA)	X
Design for disassembly/recycling	
RoHS compliance on all newly designed products	X
Third-party certified substance analysis methods in place	
Eco-design targets in place	X
Total	**5**

Sourcing and supply chain coordination

Nokia has a set of global supplier requirements under their Nokia Supplier Requirements (NSR) policy which include environmental and social aspects and are based on the international standards of ISO14001, SA 8000, OHSAS18001, PCMM and ILO, and UN conventions. Nokia requires that all its suppliers have an environmental management system (EMS) in place and also monitors its main contract manufacturers' site certification to ISO 14001, but does not inform the frequency of the audits. However, general supplier assessment is done on a regular basis as either using the self-assessment online tool (E-TASC) or as on-site assessment. In 2008 Nokia conducted 62 NSR assessments and eight in-depth labour, health, safety and environmental assessments, with the in-depth assessments conducted by both internal and external assessors as part of the GeSI and Electronic Industry Citizenship Coalition (EICC) joint industry audit pilot.

Starting from 2007, Nokia has also collaborated with its component and contract manufacturer suppliers in increasing the visibility of their environmental performance and target setting – and ultimately reducing the environmental impact of its supply chain. The focus is on the key areas of energy and water consumption, CO^2 emissions and waste generation at suppliers' sites. In 2008 of Nokia's suppliers that together account for 69% of their overall hardware expenditure, 82% had reduction targets for energy, carbon dioxide, water and waste in place and monitored. Nokia has also announced that this monitoring is continuing in 2009.

As for materials, Nokia has environmental requirements in place for products, components and parts that they source. It also works to raise awareness about and ensure compliance to the European REACH regulation among its suppliers.

Table 4-3. Sustainable sourcing and supply chain coordination results for Nokia.

Sustainable sourcing and supply chain coordination	
Supplier certification program	X
Supplier monitoring	X
Audits conducted regularly (1st tier)	X
Audits conducted regularly (2nd tier)	
Supplier training in environmental issues	
Controlled substance list	X
Resource use and/or waste level targets for suppliers in place	X
Total	**5**

Product recovery and reintegration of materials

Nokia mobile devices are 65-80 % recyclable. The company encourages end-users to return their old phones to collection points – operated either collectively with other manufacturers or as a national collection scheme, or through its own service network – in more than 85 countries worldwide by campaigning to raise awareness among consumers. It started voluntary take-back activities on a global scale already in 1999 (Herold, 2007, 90), four years before the WEEE directive of the EU came into force. In 2008, the collection volumes following the Green Box campaign in China exceeded 42 tons of waste, which equals to approximately 470 000 devices. Similar campaigns in Europe have brought back volumes of 14 000 (in Finland in 2008)

discarded devices. Nokia reports that it has continued to finance the collection and treatment of electronic and electrical waste in the EU in 2008, in accordance with the WEEE directive.

Nokia is not involved in the reuse of complete phones or recovery of materials of recycled phones (Nokia, 2009; Herold, 2007, 93), so there is no reintegration of materials into the forward channel. Similarly, Nokia does not sell recovered handsets to second-hand markets under its own brand as it has stated that selling second-hand phones of inferior quality might hurt its brand image (Herold, 2007, 94) and because Nokia wants to provide sustainable solutions designed especially to be sold in developing countries instead of contributing to the existing problem of e-waste accumulation (Nokia, 2009).

Table 4-4. Product recovery and end-of-life results for Nokia.

Product recovery and end-of-life management	
WEEE compliance (participating in a collective scheme)	X
Voluntary take-back programs	X
Reuse of phones (sales to secondary markets)	
Refurbishment of phones (sales to secondary markets)	
Reintegration of recycled materials	
Collection rate target in place	X
Participation in global development initiatives	X
Total	**4**

4.3. Samsung

Samsung, the Korean electronics giant, is currently the second biggest manufacturer of mobile devices globally and is involved in the core business areas of digital media, telecommunication networks, semiconductor and LCD products and services. The distribution of consolidated sales between the company's business units in 2008 was the following:

Digital media	35 %
Telecommunication networks	28 %
Semiconductor	17 %
LCD	12 %
Other	8 %

Samsung merged its business units and introduced a new organization structure in 2009 where it has two main businesses: Digital Media & Communications and Device Solutions. The split between B2B and B2C sales is roughly 30 % - 70 % (Herold, 2007, 176). Samsung's mobile devices sales strategy emphasizes design and cutting-edge technology as value creators, and Samsung has gained market share with its premium quality touch screen models and smartphones.

At Samsung, sustainability is managed through Corporate Social Responsibility (CSR) initiatives, namely Integrity Management, Green Management, Social Contribution, Products & Services and Partner Collaboration. Since January 2009, these initiatives have been organized under a CSR Liaison Office which is supervised by the CEO. Official CSR meetings are held twice a year to discuss CSR policies and to follow up on the performance of the initiatives and new action points to be taken up in the future. Samsung has conducted materiality tests since 2008 to identify key issues of social concern and impact on the company within the areas of its CSR initiatives. In addition, there is also a company-wide ESH committee which sets mid- and long-term targets within the scope of the Green Management initiative, and senior level ESH Managers are assigned to each site of each division with ESH personnel in all corporate departments. Samsung announced its Environmental Policy for the first time in 1992, the Green Management Charter was declared in 1996, and the first environmental report was published in 1999.

In the mobile device business area the implementation of the Green Management initiative is concerned with two areas related to materials management: Greening of Products and Greening of Processes. The Supply Chain Environmental Management (SCEM) program in use at Samsung includes the elements of eco-friendly product design, environmental certification of suppliers, eco-labelling of products and the recovery and recycling of waste products.

Product design

Samsung has followed LCA and DfX (Design for Assembly/Disassembly/Recycle/Service) practices supporting product development of whole product categories since 1995 as part of improving the eco-friendliness of its products. Mobile phones as a product group were introduced into the LCA scheme of eco-friendly product development in 2003. The following year, Samsung adopted the Eco Design Assessment Process which, using an eco-design manual (see Table 4-6), evaluates products in categories such as resource efficiency, energy conservation and eco-friendly materials in compliance with regulations (including RoHS and WEEE). Evaluation and upgrading of target value for each item is done on a continuous basis. Under the assessment process products are categorized based on their eco-friendliness as either eco-products (compliant with regulations), good eco-products (environmental certification level) or premium eco-products (innovative, eco-friendly products). Samsung also operates a data system that measures and stores data on many environmental criteria (e.g. weight of unit, weight of all accessories, weight of packaging material, type of hazardous materials etc.) for each product under development (Herold, 2007, 179). The data needs to be inserted in the system before the product can be sold or even allocated a model number (ibid.).

Samsung has developed different mobile phone models that either use bio-plastics (made out of corn starch) as component material or are free of hazardous substances such as halogen, BFR and PVC. In 2008, Samsung launched three eco-friendly mobile phone models (SCH-W510, SGH-E200E and GT-S3030).

Table 4-5. Product eco-design results for Samsung.

Product eco-design	**Samsung**
Use of renewable resources (e.g. bio-plastics, waterborne paints)	X
Use of recycled materials	X
Structured environmental impact assessment tool in place (e.g. LCA)	X
Design for disassembly/recycling	X
RoHS compliance on all newly designed products	X
Third-party certified substance analysis methods in place	X
Eco-design targets in place	X
Total	**7**

Table 4-6. Samsung's eco-design guidelines.

Source: Samsung, 2009.

SAMSUNG'S ECO-DESIGN GUIDELINES
Resources efficiency • Reduce the resources to produce the products and consumables • Design to maximize the recyclability of products after usage by implementing marking the plastics labelling according to ISO 11469, reduce the type of materials and so on. Toxicity to environment • Minimize to use and emit the materials potentials to give negative influences to human and environment. • Do NOT use the hazardous substances corresponding to 2002/95/EC for products • Do NOT use four heavy metals according to 94/62/EC for packaging. Energy efficiency • Reduce the energy consumption in on-mode and standby-mode. The eco-design activities are linked the existing product quality activities in R&D process and are unclosed with Product Eco Declaration to stakeholders.

Sourcing and supply chain coordination

Samsung has a Green Procurement Policy in place as a general guideline for sourcing of all materials and components. As part of this policy, Samsung established in 2004 its Eco-Partner Certification process for its global business partners, in which suppliers are assessed based on their environmental management systems, processes, facilities and components supplied to Samsung. The Eco-Partner program covers all suppliers of core products, parts, components and raw materials, including packaging materials. The program does not cover service providers or suppliers outside the direct product supply chain (e.g. transport, office supplies). To become an Eco-Partner certified company, suppliers must fulfil two main elements: (i) compliance with the Samsung Electronics standard on hazardous substances in products and (ii) demonstration of an adequate environmental management system.

Since 2005, Eco-Partner certification has been a mandatory prerequisite for doing business with Samsung. The certification program is currently operated by nearly 600 auditors who have received internal training, and required elements are monitored by supplier documentation, audits and in-house testing. The number of certified suppliers currently amounts to over 3 000 globally, with 100 in Europe.

Components and materials supplied to Samsung are tested in internationally certified (by UL in 2005, KOLAS in 2006 and BAM in 2007) laboratories to secure an independent analysis of hazardous substance use. Samsung operates a system for managing the use of hazardous substances (called e-HMS) which is integrated with their product design and purchasing systems, and does not allow the use of parts that are not approved by the system on development and purchasing levels.

In cooperation with its suppliers, Samsung has completed the pre-registration of all chemicals and compounds used in its products in accordance with the impending REACH regulation.

Table 4-7. Sustainable sourcing and supply chain coordination results for Samsung.

Sustainable sourcing and supply chain coordination	
Supplier certification program	X
Supplier monitoring	X
Audits conducted regularly (1st tier)	X
Audits conducted regularly (2nd tier)	
Supplier training in environmental issues	
Controlled substance list	X
Resource use and/or waste level targets for suppliers in place	
Total	**4**

Product recovery and reintegration of materials

The company pronounces raw materials and water resource management and scrapped electronic products and waste management as priority issues under its Green Management initiative. Inside Korea, Samsung runs its own recycling plant where product waste from all of its different business divisions is treated. The company has recovered substantial amounts of end-of-life mobile phones, for example 250 000 handsets were recovered and recycled in 2008 in a mutual

campaign by Samsung and Korean governmental authorities, and Samsung has also participated in numerous recycling programs in the U.S., latest being in April of 2009 together with the local Environmental Protection Agency (EPA). In Europe, Samsung has so far resided to organizing the take-back of phones through its retailers or national collection schemes, i.e. to the level required by the WEEE directive. A pre-paid postage collection system is planned for establishment in 2010 (Samsung Mobile, 2008).

According to data gathered from sales and recycled amounts in Korea & Japan, Europe and North America, the recycling rate for mobile phones in 2007 was 9 % based on an average life-span of two years (e.g. taking the average life-span of a mobile phone as two years, the recycling rate for 2007 is the weight of mobile phones recycled in 2007 as a percentage of the weight of mobile phones sold in 2005). Separate data from Europe was not available to be used for this thesis, but the recycling volume of 'small appliances' in Europe gives a rough estimate on mobile phone recycling (see Table 4-8).

Table 4-8. Samsung's annual recycling volumes in Europe (tonnes).

Source: Samsung, 2009.

Product	2005	2006	2007
Large Household Appliances	1,652	5,120	8,121
Cold	6,364	11,452	33,704
CRT & Display screens	11,495	18,309	80,749
Small Appliances	1,761	3,935	14,086

As for the reintegration of materials, Samsung is not currently involved in product recovery or refurbishment in the EU and it does not collaborate with third party refurbishers (Herold, 2007, 178). However, in the UK Samsung is currently investigating the possibility of collaboration with a take-back scheme and the major mobile phone networks on promoting recycling, reuse and extended lifespan of used mobile phones. In Samsung's view, ensuring correct high-quality parts are used for refurbishment may increase costs, but greatly reduces risks of harm to users from poorly repaired phones with imitation parts, as has been witnessed in the Middle East and SE Asia. Together with other leading mobile phone manufacturers, Samsung also takes part in the Mobile Phone Partnership Initiative (MPPI), coordinated by UNEP, which aims at improving the take-back and recycling operations for end-of-life products in developing countries.

Samsung also supports the concept of Individual Producer Responsibility (IPR), one by which the producer of e-waste should be properly identified (through tagging of devices, for instance) and then be held responsible for the disposal of its own products. Samsung is actively involved with academics, governments and scientists in an attempt to find out if IPR is feasible and, if it is, how it could be implemented. This would include not only tagging of devices but also pan-European standardisation of databases, collection points and so forth.

Table 4-9. Product recovery and end-of-life management results for Samsung.

Product recovery and end-of-life management	
WEEE compliance (participating in a collective scheme)	X
Voluntary take-back programs	
Reuse of phones (sales to secondary markets)	
Refurbishment of phones (sales to secondary markets)	
Reintegration of recycled materials	
Collection rate target in place	
Participation in global development initiatives	X
Total	**2**

4.4. LG Electronics

Regardless of its strong background in consumer electronics, LGE is the relative newcomer of the mobile handset market. In addition to mobile telecommunications, LGE's main businesses are home entertainment and appliances, air conditioning and business solutions in the product categories of LCD monitors and consumer displays.

In a materiality test conducted by LGE in 2008 as part of its corporate sustainable reporting, a couple of environmental issues related to materials management were raised up as 'very important' in the stakeholders' interest. Development of greener products was seen as the most pressing of the environmental issues, as it was considered to have a very important influence on the company itself, as well as being on the priority list of stakeholders. Another environmental concern that was seen as very important from stakeholders' point of view was managing WEEE products. In the end of 2008, LGE named the development of green flagship products and

strengthening voluntary take-back operations as its future direction for addressing the issues highlighted by the materiality analysis.

LGE's environmental management practice includes its Green Product Strategy which is divided into the sub-categories of Resource, Human and Energy. As part of the resource aspect of this strategy, LGE emphasizes the same focus areas as the other leading mobile handset manufacturers, namely reduction of resource use and increasing recycling. The human aspect is concerned about minimizing the amount of hazardous substances in products.

Product design

LGE established its eco-design system in 2003 and launched a company-wide Eco Design Committee to discuss relevant issues with the lead of the Chief Technological Officer of the company. Environmental product design activity is concerned with four key strategies: replacing hazardous substances, enhancing energy efficiency, improving recyclability and reducing the use of resources. LGE performs LCA to determine the product's environmental impact, and experts from relevant departments review the product at every development stage to address problems before moving onto the next stage. The success of LGE's eco-design process execution is measured numerically by using an eco-index, developed by the Eco Design Committee in 2006, which covers all the four main strategic focus areas (see Table 4-12). In total, 30 items are used for the evaluation.

LGE is currently investing in R&D in the field of incorporating bio-plastics and recycled materials into its products, and in simplifying the fastening of parts. In addition, it pursues the optimization of parts design and the development of multifunctional integrated circuit components.

Hazardous substance management is done under the company's "Green Program" where substances are classified into categories A1 (in RoHS), A2 (banned by national or international legislation other than RoHS or pose risk to human health or environment) and B (substances to be monitored or reduced). LGE is compliant with the RoHS directive, and is seeking ways to eliminate PVC, BFRs and phthalates from its mobile phones, 2010 set as timeline target. LGE uses X-ray fluorescence technology to check parts and materials sourced outside the company

for hazardous substances, and has a certified (by UL in 2005 and by TÜV in 2006) hazardous substance analysis laboratory in operation.

Table 4-10. Product eco-design results for LG Electronics.

Product eco-design	**LG**
Use of renewable resources (e.g. bio-plastics, waterborne paints)	
Use of recycled materials	
Structured environmental impact assessment tool in place (e.g. LCA)	X
Design for disassembly/recycling	
RoHS compliance on all newly designed products	X
Third-party certified substance analysis methods in place	X
Eco-design targets in place	X
Total	**4**

Table 4-11. Elements of LGE's eco-index evaluation system.

Source: LGE, 2009. Compiled from LGE's Sustainability Report

Resource consumption	**Improvement of recyclability**	**Energy efficiency**	**Use of hazardous substances**	**Others**
▪ reduction of the weight or volume of a product ▪ lowering of water consumption ▪ longitude of life-cycle (term of guarantee) ▪ use of recycled substances ▪ recyclability of parts ▪ use of natural substances	▪ quantity of materials used ▪ weight of recyclable parts ▪ number of tools necessary for disassembling the product ▪ requirements for special tools ▪ number of standard parts ▪ number of parts overall	▪ standby electricity ▪ consumable electricity ▪ emission of GHG	▪ use of each of the listed hazardous substances	▪ additional weight added during processes ▪ use of recyclable materials in packaging ▪ noise

Sourcing and supply chain coordination

LGE uses the Green Program also to promote environmental awareness and reduction of hazardous substances among its partners. The program is a type of certification system which was designed to comply with national and international regulations on hazardous substances and serve as a guideline in decreasing the negative impact that materials and manufacturing have on the environment and in offering more eco-friendly products to customers. The program is targeted to all LGE's partner firms that supply parts and/or materials and includes the evaluation of LGE and its partners on their EMS, hazardous substance management and product management system. Companies that pass the evaluation will be awarded a Green Program Certificate, but on the other hand, not passing the evaluation does not bring any effective sanctions.

LGE requires all relevant suppliers to pre-register substances and preparations used in industrial processes according to the REACH regulation, and supports and monitors its suppliers in the pre-registration process. LGE follows a win-win partnership principle with its suppliers which aims at transparent trade conditions and the notion of free competitive environment. Part of this principle is for LGE to side with its suppliers and strengthen their competitiveness, because LGE's total purchases make up more than 80 % of total revenue. Support is therefore given widely in all areas of business and in improving suppliers' CSR activities, for example environmental facility benchmarking, eco-product development, chemicals management and creating an ESH plan.

Table 4-12. Sustainable sourcing and supply chain coordination results for LG Electronics.

Sustainable sourcing and supply chain coordination	
Supplier certification program	X
Supplier monitoring	X
Audits conducted regularly (1st tier)	X
Audits conducted regularly (2nd tier)	
Supplier training in environmental issues	X
Controlled substance list	X
Resource use and/or waste level targets for suppliers in place	X
Total	**6**

Product recovery and reintegration of materials

LGE conforms to the WEEE directive of the EU through fulfilling its responsibility as the financer of national take-back systems and informing its customers about contracted schemes in different regions, but has not so far introduced any voluntary take-back schemes in Europe. However, LGE supports IPR and the introduction of take-back systems that are economically viable, and is involved in investigating ways to provide incentives for take-back systems by integrating them to eco-design activities.

In 2008, LGE's global recycling rate for mobile phones was 7,1 % based on an average life-span of two years. The amount of collected and recycled IT and telecommunications equipment in Europe was 2 554 tonnes in 2007 and 14 017 tonnes in 2008.

Table 4-13. Product recovery and end-of-life management results for LG Electronics.

Product recovery and end-of-life management	
WEEE compliance (participating in a collective scheme) Voluntary take-back programs Reuse of phones (sales to secondary markets) Refurbishment of phones (sales to secondary markets) Reintegration of recycled materials Collection rate target in place Participation in global development initiatives	X
Total	**1**

4.5. Motorola

The developer of the world's first handheld mobile phone in 1983, Motorola (headquartered in Illinois, USA) is today engaged in the sale of enterprise mobile solutions, home and networks mobility products and mobile devices. Motorola has been one of the losers on the mobile phone market in recent years, but continues to be a strong player in the North American market, with nearly half of its sales coming from the U.S.

Motorola is an active participator in the fight against climate change, and environmental proactiveness and end-of-life management are considered as sources of competitive differentiation at Motorola (Herold, 2007, 210-211). Motorola was the first company in the telecommunications industry to start a volunteer take-back program for its products in the U.S. Motorola is a member of the GeSI and has an ISO 14001 certified EHS program in place in all but two of its sites, for which it aims to complete certification by the end of 2009.

Product design

Motorola started using LCA in 2008 to measure and control carbon dioxide emissions of selected products in all of its business units. In mobile handset design, Motorola is striving to reduce product mass and to increase recycled material content.

Motorola introduced its first environmentally friendly mobile phone model MOTO W233 Renew in January 2009. It includes 19 % of recycled material content in total, and the housing contains 25 % of bio-plastics made out of recycled plastic water cooler bottles. The Renew model can be disassembled in less than 10 seconds, and it contains no PVC or nickel. Motorola started phasing out phthalates, BFRs and PVC from new mobile phone parts in 2008 and aims to have eliminated them from all newly designed mobile phones introduced after 2010. So far, two of its models are completely PVC-free and nearly 60 models have BFR-free printed circuit boards. All of Motorola's mobile phones also meet the 65 % recyclability target set by the EU under its WEEE directive. Furthermore, it has consistently reduced the amount of materials used in packaging of mobile phones.

Table 4-14. Product eco-design results for Motorola.

Product eco-design	**Motorola**
Use of renewable resources (e.g. bio-plastics, waterborne paints)	X
Use of recycled materials	X
Structured environmental impact assessment tool in place (e.g. LCA)	X
Design for disassembly/recycling	X
RoHS compliance on all newly designed products	X
Third-party certified substance analysis methods in place	
Eco-design targets in place	X
Total	**6**

Sourcing and supply chain coordination

The Motorola supply chain at 2008 year end consisted of more than 4 400 suppliers of direct materials. All Motorola's suppliers are required to conform to the suppliers code of conduct. As part of this code of conduct, suppliers must have an ISO 14001 certified or equivalent EMS implemented and functioning, third-party registration is recommended but not required. In addition, compliance with Motorola's materials disclosure specification is required to qualify parts supplied to Motorola. A list of more than 65 substances targeted for exclusion, reduction or reporting during the design or manufacturing of Motorola products has been compiled as part of this disclosure requirement. Motorola offers training and support to its suppliers in order for them to meet the specification. In 2008, key performance indicators were created to assess corporate responsibility programs of suppliers and the E-TASC tool was adopted for managing supplier CR information.

In monitoring its suppliers, Motorola focuses on first-tier "preferred" suppliers, i.e. those who it wants to have a deep partnership with (90 % of direct-material suppliers), and on those who pose a high risk to the company. The monitoring program follows the EICC/GeSI supplier engagement model, and findings are categorized on four levels with consequent actions taken depending on the level. Each month, senior procurement managers have reviews where they assess progress against a scorecard, including corporate responsibility metrics such as number of open and closed issues. Second-tier suppliers are monitored only against specific issues that have been reported.

Motorola is fully compliant with the RoHS directive for those products that are subject to it. Verifying the continuous compliance with the RoHS directive is done through random testing. Motorola is also filling its current obligations under the REACH regulation.

Recently, Motorola has also participated in the creation of a forum to increase transparency, accountability and assurance mechanisms in the supply chains of industries that use extracted metals. This issue has increased its importance as some of the critical metals are extracted from areas of conflict where their trade can contribute to fuelling the instability of these areas.

Table 4-15. Sustainable sourcing and supply chain coordination results for Motorola.

Sustainable sourcing and supply chain coordination	
Supplier certification program	X
Supplier monitoring	X
Audits conducted regularly (1st tier)	X
Audits conducted regularly (2nd tier)	
Supplier training in environmental issues	X
Controlled substance list	X
Resource use and/or waste level targets for suppliers in place	X
Total	**6**

Table 4-16. Product recovery and end-of-life management results for Motorola.

Product recovery and end-of-life management	
WEEE compliance (participating in a collective scheme)	X
Voluntary take-back programs	X
Reuse of phones (sales to secondary markets)	X
Refurbishment of phones (sales to secondary markets)	X
Reintegration of recycled materials	
Collection rate target in place	X
Participation in global development initiatives	X
Total	**6**

Product recovery and reintegration of materials

In 2008, more than 2 560 tonnes of e-waste was collected for recycling worldwide through Motorola's take-back programs, internal recycling efforts and community recycling. Motorola has participated in e.g. MobileMuster (Australia), Green Box (China) and Plug-In to eCycling (the U.S.), and 1,288,901 Motorola phones were handed back to the recycling organization ReCellular in 2008 as well. In the EU Motorola operates a scheme where phones can be returned to retailers and operator-owned stores, to municipal collection points (where applicable) or, in

selected countries, by post by using envelopes or labels that can be printed from the Motorola website.

In 2008, the global collection rate for all mobile phones was an estimated 2,5 % of the total phones sold in 2006. The company goal is to increase the amount of collected e-waste for recycling by 5 % by 2010. The target was not reached in 2008 as the increase from 2007 was only 1 %. Motorola supports the concept of IPR – collected phones are reused as such or refurbished is possible, otherwise they are recycled. In the EU, the products end up at a recycling facility run by a service provider where they are inspected for reuse and remarketing purposes (Herold, 2007, 212). Refurbished phones are sold in developing markets (ibid.). Motorola audits its recyclers to monitor that they comply with its supplier code of conduct, as well as with industry standards.

4.6. Sony Ericsson

Sony Ericsson is a 50/50 joint venture between the Japanese Sony Corporation, electronics and entertainment manufacturer, and Swedish Ericsson, the world's largest supplier of telecommunications network equipment and related services. Sony Ericsson is currently the fifth largest supplier of mobile devices measured by global market share.

Since its inception in 2001, Sony Ericsson has led the development of environmentally friendly products, especially the removal of hazardous substances. Therefore, even with its first sustainability report having been published only in 2008, it already has an honourable record of CSR-related achievements. Sony Ericsson's sustainability activities are driven and coordinated by the Corporate Sustainability Office which provides expertise, strategy and guidance to operational activities conducted by line functions. The Sony Ericsson management system has environmental and social issues integrated into the normal business processes and procedures and this is audited and certified by Det Norske Veritas (DNV) in accordance with ISO 9001:20005. All manufacturing sites and suppliers are required to have systems with an expanded scope i.e. meeting the ISO 14001:20046 standard.

Product design

Sony Ericsson was the first manufacturer to remove BFRs nearly fully from its mobile phones already in 2001. The company has also been RoHS compliant since 2004, with the exception of one phone model, and from 2007 onwards all new Sony Ericsson products have also been PVC free. The phase-out of the remaining small-scale use of BFR is currently underway together with phasing out beryllium, phthalates and antimony. During the development phase, materials in all Sony Ericsson phones and accessories are analysed by third-party laboratories for detecting banned and restricted substances before the materials are accepted for mass production. Material disclosure of all components is found in the COMET (Compliance On Materials and EnvironmenT) database to ensure compliance to legal requirements. As a result, all Sony Ericsson products have a complete eco-declaration. Environmental Coordinators in each Sony Ericsson development unit are in charge of the collection of material declarations and the screening process. International industry benchmark studies have been conducted by Sony Ericsson since 2005 to analyze the status of its phones compared to those of competitors in terms of substance phase-out.

GreenHeart, Sony Ericsson's eco-product portfolio concept, was launched in 2008 in an attempt to provide consumers with green innovation products that reduce overall environmental impact without compromising in design, features or quality. GreenHeart is in line with the concept of LCA in that the environmental impact reduction starts already from the planning stage of product development. So far, two models have been introduced as part of the GreenHeart portfolio, including recycled plastics as raw material, energy efficient display, waterborne paint and power saving charger.

Sourcing and supply chain coordination

Sony Ericsson has had its supplier social responsibility code in place since its establishment in 2001. This code stipulates the ESH and ethics standards to which all Sony Ericsson suppliers are expected to conform. In addition, environmental and legal requirements are placed on suppliers. Suppliers are also requested to submit full material content of each new component to Sony Ericsson, which will then be updated onto the COMET database.

Table 4-17. Product eco-design results for Sony Ericsson.

Product eco-design	
Use of renewable resources (e.g. bio-plastics, waterborne paints)	X
Use of recycled materials	X
Structured environmental impact assessment tool in place (e.g. LCA)	X
Design for disassembly/recycling	X
RoHS compliance on all newly designed products	X
Third-party certified substance analysis methods in place	X
Eco-design targets in place	X
Total	**7**

Table 4-18. Sustainable sourcing and supply chain coordination for Sony Ericsson.

Sustainable sourcing and supply chain coordination	
Supplier certification program	X
Supplier monitoring	X
Audits conducted regularly (1st tier)	X
Audits conducted regularly (2nd tier)	
Supplier training in environmental issues	X
Controlled substance list	X
Resource use and/or waste level targets for suppliers in place	X
Total	**6**

Sony Ericsson monitors the compliance to the code as well as to all the other requirements by audits on its first-tier suppliers in order to verify their control over the supply chain and to support suppliers in adhering to the code. Non-compliance will ultimately lead to actions towards terminating the supplier contract if no corrective measures are taken.

Product recovery and reintegration of materials

Fully compliant with national legislation based on the WEEE directive in all countries of operation in Europe, Sony Ericsson is concerned with exceeding compliance to legislation and,

in support for IPR, launched its Global Environmental Warranty in 2008. This meant the establishment of the company's own global take-back system which guarantees that all end-of-life products returned to one of Sony Ericsson's collection points will be recycled or disposed of in an environmentally sound way. Sony Ericsson also set a goal for its own global take-back activity: to collect one million mobile phones for recycling annually by the end 2011. Mobile phones collected through the Sony Ericsson take-back system will end up under inspection for reuse and recycling possibilities.

Sony Ericsson participates in the development of pan-European collection and recycling scheme of e-waste through the European Recycling Platform (ERP) and is a member of the MPPI which has developed guidance documents for design, collection, refurbishment, recycling and trans-border movement of products for re-use. However, Sony Ericsson is not involved in refurbishment of phones or in the reintegration of recycled parts or materials into its own manufacturing operations. According to Sony Ericsson, regulation should not prevent companies setting up alternative systems if it means better efficiency and environmental performance. Therefore it rather develops solutions suitable for emerging markets than provides them with refurbished models which account to the amount of e-waste imported to developing nations.

Table 4-19. Product recovery and end-of-life management results for Sony Ericsson.

Product recovery and end-of-life management	
WEEE compliance (participating in a collective scheme)	X
Voluntary take-back programs	X
Reuse of phones (sales to secondary markets)	
Refurbishment of phones (sales to secondary markets)	
Reintegration of recycled materials	
Collection rate target in place	X
Participation in global development initiatives	X
Total	**4**

4.7. Industry analysis results and managerial implications

Based on the companies' performance as measured by the metrics created for the purpose, sustainability in materials related operations seems to be well inherent in the mobile device manufacturing industry (see Table 4-20). All of the companies show standardized procedures for monitoring corporate sustainable responsibility and environmental performance through the adoption of key performance indicators. Motorola survived as the one to have the most sustainable materials management strategy based on the analysis using the metrics determined in this research, whereas LG Electronics was the least involved in sustainability in terms of materials management.

The results are shown as applied to the evaluation model in Figure 4-1 and discussed by each aspect further below.

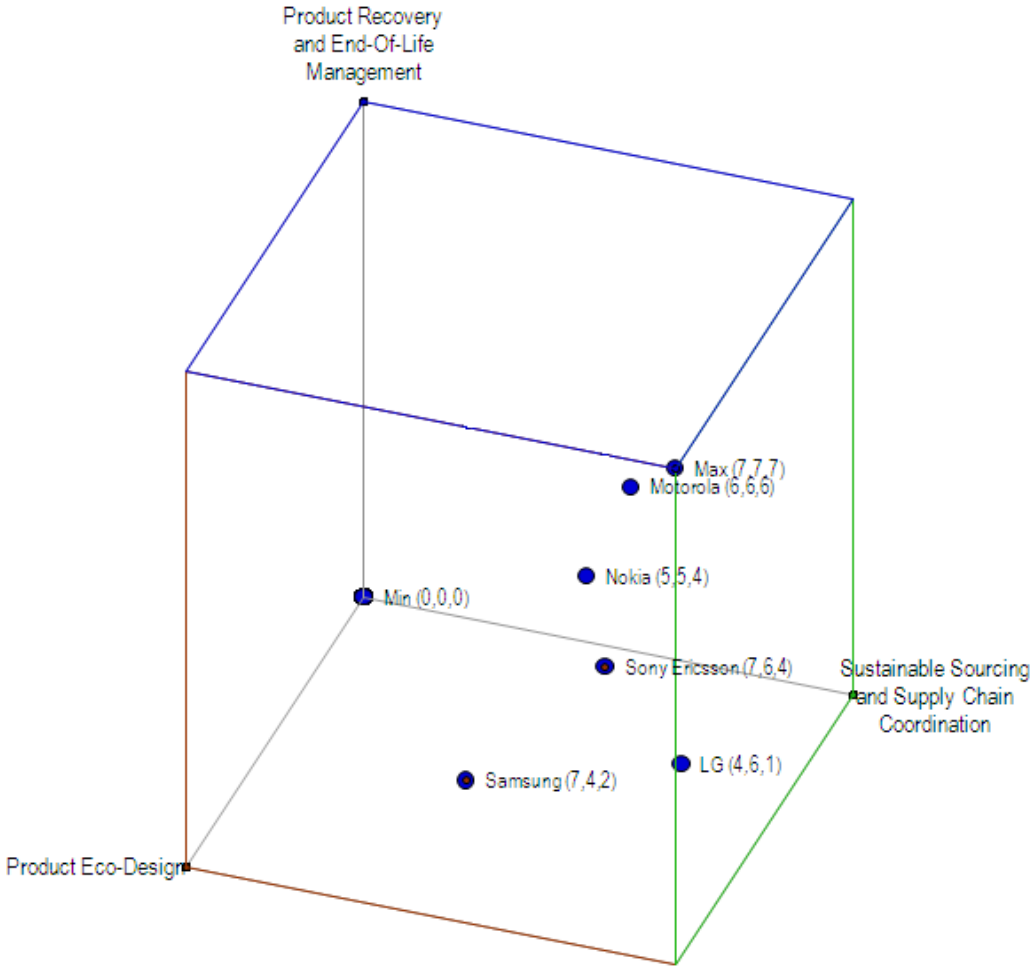

Figure 4-1. Results applied to the model for evaluating sustainability of materials management strategy.

Product eco-design	Nokia	Samsung	LG	Motorola	Sony Ericsson	Total
Use of renewable resources (e.g. bio-plastics, waterborne paints)	X	X		X	x	4
Use of recycled materials	X	X		x	x	4
Structured environmental impact assessment tool in place (e.g. LCA)	X	X	X	x	x	5
Design for disassembly/recycling		X		x	x	3
RoHS compliance on all newly designed products	X	X	X	x	x	5
Third-party certified substance analysis methods in place		X	X		x	3
Eco-design targets in place	X	X	X	x	x	5
Total	**5**	**7**	**4**	**6**	**7**	**29**
Sustainable sourcing and supply chain coordination						
Supplier certification program	X	X	X	x	x	5
Supplier monitoring	X	X	X	x	x	5
Audits conducted regularly (1st tier)	X	X	X	x	x	5
Audits conducted regularly (2nd tier)						0
Supplier training in environmental issues			X	x	x	3
Controlled substance list	X	X	X	x	x	5
Resource use and/or waste level targets for suppliers in place	X		X	x	x	4
Total	**5**	**4**	**6**	**6**	**6**	**27**
Product recovery and end-of-life management						
WEEE compliance (participating in a collective scheme)	X	X	X	x	x	5
Voluntary take-back programs	X			x	x	2
Reuse of phones (sales to secondary markets)				x		1
Refurbishment of phones (sales to secondary markets)				x		1
Reintegration of recycled materials						0
Collection rate target in place	X			x	x	3
Participation in global development initiatives	X	X		x	x	4
Total	**4**	**2**	**1**	**6**	**4**	**17**
COMPANY TOTAL	**14**	**13**	**11**	**18**	**17**	

4.7.1. Product eco-design

The results from the analysis show that product eco-design is the most comprehensively adopted activity in promoting sustainability in materials management in the mobile device manufacturing industry. All of the companies have an assessment tool, LCA or equivalent, as an integrated part of their product development process and have eco-design related targets in place for the future. Most have also recently launched new environmentally friendly, low-impact phone models. The strongest performers in the area of product design are Samsung and Sony Ericsson who complied with all the metrics. LGE is the only one without any 'green models' on the market yet, even if research and development towards more efficient use of renewable materials was under way there as well.

The prevalent issues in product eco-design throughout the industry seem to involve the use of technology to integrate bio-plastics and recycled plastics into the manufacture of new phone models. Nokia's concept of a 100 % virgin material-free phone shows that capabilities do exist even further than what has been made commercially available. This implies that there is great importance of R&D advances also in ecological product design in the industry. For example, Motorola launched its first and second eco-design product on the same year with only eight months between the launches, and Nokia and Sony Ericsson have been marketing their green concept phones months before the first commercial model from these concepts has been launched.

4.7.2. Sustainable sourcing and supply chain coordination

In the areas of sourcing and supply chain coordination, substance management and supplier certification and monitoring are the equalling elements between all the case companies. Hazardous substance management has been taken as an issue of proactive concern in some of the companies which have decided to exceed the legal requirements set in the RoHS directive. For example, Sony Ericsson started the voluntary phase-out of substances of concern years before imposing legislation came into force. Sony Ericsson and Samsung both also use advanced software databases to manage their substance listings, and Samsung has integrated this listing into its procurement and product design functions as well. Even if supplier monitoring procedures are in place in all the companies, auditing is done predominantly solely on first tier

suppliers, with second tier audits organized by some companies when reported issues arise to their knowledge.

Supplier training has also been adopted in more than half of the sample companies as a strategic direction. The analysis suggests that this might be a rising trend in CSR in the future, as for example LGE is making substantial efforts towards its suppliers in terms of organizing training and constructing EHS plans for its suppliers. In addition, it has announced its willingness to cooperate in a transparent way in what it calls a win-win partnership with its suppliers, something that has not been very traditional in R&D intensive industries. Another similar move towards the visibility of supply chains is seen in Motorola's latest project which involves promoting stakeholder engagement in metals extraction from developing countries together with other companies mainly from the IT industry.

4.7.3. Product recovery and end-of-life management

WEEE compliance is achieved, as it should, by all the companies for their operations inside the EU. Voluntary take-back schemes are organized in Europe by only Nokia and Sony Ericsson, with Motorola having a pre-postage system in place in parts of the continent. Not surprisingly, these three are also the only ones to announce any targets for their collection and take-back schemes. Of those who have their own collection programs, Motorola is the only one to engage in any kind of reuse or refurbishment activities in that it treats its old phones to be sold as refurbished on secondary markets. Nokia and Sony Ericsson are involved in the MPPI initiative which develops recycling and refurbishment solutions for emerging markets but do not want to be directly involved with reusing or refurbishing in their own operations as they do not see it as their core activity and because they are concerned about increasing the waste load in countries without proper treatment facilities. Samsung and LGE on the other hand do not even run their own collection schemes in Europe even if both have recycling activities in place in Korea. Samsung has named the lack of local market knowledge as one of the reasons for this (Herold, 2007, 177) and has also referred to the fact that the current take-back legislation and systems do not allow for economically sensible operations in this area. However, they have announced that a pre-postage collection scheme will be launched in Europe in 2010.

4.8. Secondary analysis using weighted scores

The results derived using the metrics introduced and simply applying the scores to the model are representative of the companies' status with respect to how sustainability considerations are included in their materials management operations at present. This kind of analysis alone, however, can seem rather superficial in a situation where data is collected only from external sources and not from within the companies, i.e. when there is a lack of a more transparent view on the strategic development targets or emphasized areas of involvement in the future. The analysis provided so far is also solely focused on attributes that are directly comparable between the target case companies. The information about these attributes has either been given out by companies as part of required reporting to shareholders or released to the press for the purpose of public relations management to keep up with the same level of news provided than what the competitors are publishing. What is always interesting in this type of context is what exactly is published and what has been left with less or no attention by the companies, and also what material the media has been able to get. This aspect has been visible already in this report as well, as pieces of information about the companies have been presented in the case studies beyond just the metrics included in the model.

To address the demand for a wider observation on materials management related sustainability issues in the target companies of this research, a supplementary analysis is provided in this chapter. This secondary analysis is done under the subjective choice by the researcher of factors that either contribute to, or diminish the effect of each strategic aspect (product eco-design, sourcing and supply chain coordination, and product recovery and EOL management) towards the overall score by the company in the sustainability evaluation model used in the primary analysis. In other words, the companies will be given weights on their original scores depending on how they are seen to perform all in all under each aspect based on additional information that can be extracted about them outside the simplistic metrics used in the primary analysis. The factors used in conducting this analysis come partially from data that has already been presented earlier in the case studies with some additions being introduced for the first time in this chapter.

The weights for the effect of each aspect are given on a scale of 'high effect' = 1,5 x score, 'neutral effect' = 1 x score and 'low effect' = 0,5 x score. After the weights have been placed on each aspect for all the companies, the subsequent scores are applied to the sustainability

evaluation model in the same way as during the first round of analysis and presented to provide a comparative result between the two analyses.

4.8.1. Assigned weights by aspects of sustainable materials management

The weights given in the second analysis are listed below by each aspect. To keep the analysis concise, grounds are given only for those cases that are assigned with other than neutral weight (= 1 x score).

Product eco-design

Three case companies were given weights to their existing scores that deviate from 'neutral effect' under the aspect of product design.

Nokia and Sony Ericsson both earned a high effect score as their advances in environmental product design can be considered to show consisted development efforts that have already materialized as achievements. Nokia's Remade concept phone is an example of focused research work towards finding truly innovative solutions that can also be carried out by looking into sustainable use of materials from various angles, in addition to the development made in renewable materials use for other models. Nokia also has a good record in hazardous substance removal with two completely BFR-free phone models, something that no other mobile manufacturer has introduced.

Sony Ericsson on the other hand has showed consisted long term progress in the area of sustainability in materials management by being the first company to effectively start removing hazardous substances from its phones well before any restricting regulations came into force, and it is still currently leading the race of cleaning out the material base of products in terms of volume; all its models are PVC-free and nearly all also BFR-free. The structured development efforts of Sony Ericsson are also shown in the continuous benchmarking studies conducted by the comany and in the creation of a full material control database. Furthermore, Nokia and Sony Ericsson are the only two of the case companies to give full material declarations on all of their phones.

LG Electronics' score has been modified in the secondary analysis to have a low effect, i.e. reduced weight of 0,5 x score, as their product design activities are so far more in an establishment stage than in actual operation. For example, LGE has a eco-product design strategy in place and has announced targets for phasing out hazardous substances, but so far has not reached the same level as the other manufacturers in terms of actually having phone models in distribution that are PVC or BFR free. Also, LGE does not currently use any renewable resources in its production operations.

Sourcing and supply chain coordination

Concerning sustainable sourcing and supply chain coordination, the performance of the companies is very levelled. All of the companies seem to have a structured system in place in terms of supplier monitoring and substance control. The only differences on the second level of analysis are made by judging the nuances in how these are executed.

As a result, LGE is granted a low effect weight on its score because of the fact that its supplier certification program is based on supplier evaluation that accredits suppliers for good performance rather than actually requiring any level of conformance to established standards of internal or external source.

Motorola stretches its score onto high effect level through its efforts towards supply chain transparency. Unlike the other case companies, it announces to conduct second tier supplier audits when issues emerge, even if this is not done by default. Motorola's recent actions towards stakeholder engagement, shown in the form of participation in cross-industry forum to increase supply chain transparency for metal extraction, contribute to the weight given for their part.

Product recovery and integration of materials

Product recovery activities also receive a couple of changes in scores in the secondary analysis. Even if this area remains as the one to which the least emphasis is given on the industry level in total, weight is added on the scores of two of the case companies.

Motorola earns its high level of effect again by seeing through to its operations being performed as targeted, which is shown in the extensive coverage of its take-back activities, in the active monitoring of its ambitious collection target and in recycler audits.

Samsung gets into the high level effect category as a result of its efforts in investigating the future practical solutions to implement IPR in an economically sustainable way. Promoting IPR will ultimately provide the best possible incentive for companies to fully engage in researching for ways to design products so that reintegration of materials back into their own forward channels or to appropriate secondary markets for optimal sustainable use.

4.8.2. Results of the secondary analysis

The compiled results of the secondary analysis suggest the same overall results as what was derived from the initial analysis, as shown in Table 4-21 and as applied into the evaluation model in Figure 4-2.

The involvement in the different aspects of SMM rank in the same order, with product eco-design and sustainable sourcing and supply chain coordination remaining as the areas of relatively higher emphasis as opposed to product recovery and end-of-life management. Also, the order of the case companies stays the same in terms of overall performance measured as total of the scores of all aspects. The companies mostly improved their scores through the secondary analysis, with the exception of LGE whose score worsened by nearly 50 %. Motorola remains as the best performer also under the secondary analysis and improved its lead compared to the next best performer, Sony Ericsson.

Inside the product eco-design aspect the ranks changed so that Nokia's score surpassed those of Samsung and Motorola and is the second best after Sony Ericsson, the other improver, in the secondary analysis. For the other two aspects, the ranks remain the same, with Motorola increasing its score in both.

Table 4-21. Results for case company secondary analysis using weighted sustainability evaluation metrics for materials management.

Product eco-design	**Nokia**	**Samsung**	**LG**	**Motorola**	**Sony Ericsson**	**Total**
Use of renewable resources (e.g. bio-plastics, waterborne paints)	X	X		X	X	4
Use of recycled materials	X	X		X	X	4
Structured environmental impact assessment tool in place (e.g. LCA)	X	X	x	X	X	5
Design for disassembly/recycling		X		X	X	3
RoHS compliance on all newly designed products	X	X	x	X	X	5
Third-party certified substance analysis methods in place		X	x		X	3
Eco-design targets in place	X	X	x	X	X	5
Total	**5**	**7**	**4**	**6**	**7**	**29**
Weight given	**1,5**	**1**	**0,5**	**1**	**1,5**	
Weighted score	**7,5**	**7**	**2**	**6**	**10,5**	**33**
Sustainable sourcing and supply chain coordination	**Nokia**	**Samsung**	**LG**	**Motorola**	**Sony Ericsson**	**Total**
Supplier certification program	X	X	x	X	X	5
Supplier monitoring	X	X	x	X	X	5
Audits conducted regularly (1st tier)	X	X	x	X	X	5
Audits conducted regularly (2nd tier)						0
Supplier training in environmental issues			x	X	X	3
Controlled substance list	X	X	x	X	X	5
Resource use and/or waste level targets for suppliers in place	X		x	X	X	4
Total	**5**	**4**	**6**	**6**	**6**	**27**
Weight given	**1**	**1**	**0,5**	**1,5**	**1**	
Weighted score	**5**	**4**	**3**	**9**	**6**	**27**
Product recovery and end-of-life management	**Nokia**	**Samsung**	**LG**	**Motorola**	**Sony Ericsson**	**Total**
WEEE compliance (participating in a collective scheme)	X	X	x	X	X	5
Voluntary take-back programs	X			X	X	2
Reuse of phones (sales to secondary markets)				X		1
Refurbishment of phones (sales to secondary markets)				X		1
Reintegration of recycled materials						0
Collection rate target in place	X			X	X	3
Participation in global development initiatives	X	X		X	X	4
Total	**4**	**2**	**1**	**6**	**4**	**17**
Weight given	**1**	**1,5**	**1**	**1,5**	**1**	
Weighted score	**4**	**3**	**1**	**9**	**4**	**21**
COMPANY TOTAL	**14**	**13**	**11**	**18**	**17**	
COMPANY TOTAL WEIGHTED SCORE	**16,5**	**14**	**6**	**24**	**20,5**	

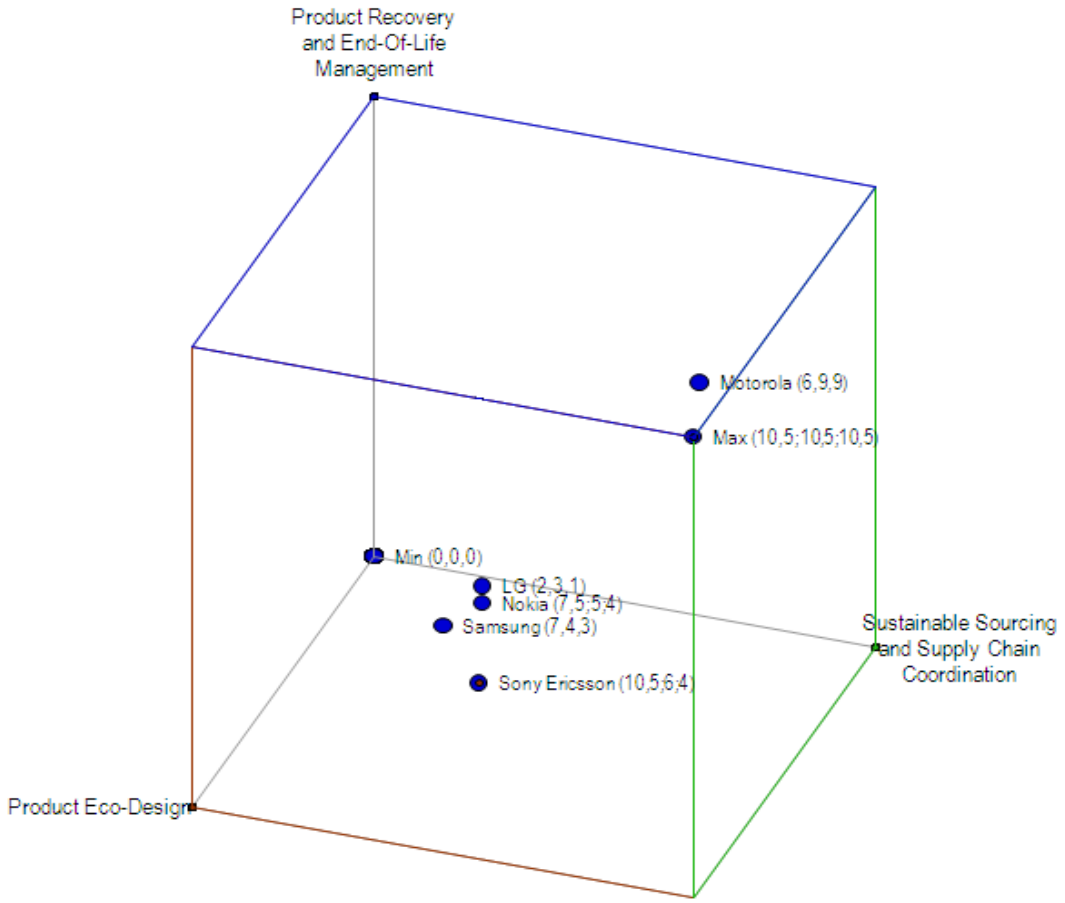

Figure 4-2. Secondary analysis results applied to the model for evaluating sustainability of materials management strategy.

The fact that the overall results of the secondary analysis, conducted under suggestive criteria chosen by the researcher, are similar to the initial analysis reinforces the feasibility of the metrics chosen for evaluating the sustainability of materials management. In addition, the secondary analysis provides an important additional interpretation of the data available from the case companies, as some of the non-comparable information between companies contributes to a more comprehensive evaluation of sustainability in each case and for the whole research sample. This was expressed in this research as well as ranks under the different aspects included in the evaluation model changed or were reinforced by better scaling.

5. Conclusions

This research has covered the examination of a company's material management related activities from the point of view of environmental sustainability.

The paper set out to identify the critical strategic elements of materials management through studying relevant literature and to incorporate the elements into a model that can be used to measure the sustainability of operations. The objective of the thesis was the creation and testing of this model by using data from case companies in the mobile device manufacturing industry. The approach of the study was qualitative and the method used in acquiring empirical data was the gathering of company information from published company data and external sources and reports on the mobile communications industry. Data from five leading global mobile device manufacturers, namely Nokia, Samsung, LG Electronics, Motorola and Sony Ericsson, was used in the research.

The objectives of the thesis were met in as much that a model using the identified strategic elements of materials management was developed and empirical data was applied to the model for the purpose of evaluating the sustainability of materials management operations of case companies in target of this research.

The strategic elements for sustainable management of materials identified in the research were product eco-design, sustainable sourcing and supply chain coordination and product recovery and end-of-life management, including the take-back operations and reintegration of materials back into the forward supply chain. The theoretical contribution of the thesis was the development of a three dimensional impact factor model, where the impact factors for increased sustainability were the strategic elements identified earlier. Metrics were developed in the form of simplistic checklists under each of these strategic elements to be used as part of the evaluation model.

Further, a secondary analysis was provided using suggestive factors chosen by the researcher and extracted from the data available in order to gain a more comprehensive interpretation and better scaling of the results. This analysis was done by giving weights to the scores of the case

companies under each aspect to indicate high, neutral or low effect of the said aspect on the overall score of the company.

The most important findings from the empirical research included the demonstration of product design as being the activity with the most environmental aspects integrated to it in terms of material management. The findings also showed the status of the companies' eco-product design procedures and their outcomes in terms of the features and material base of environmentally friendly products launched onto the market. In the areas of sourcing and supply chain coordination, it was shown that all the companies have structured supplier certification programs in place with hazardous substance control systems (all are RoHS compliant) and phase-out targets for substances that are categorized to be eliminated from production processes. As for supplier monitoring, regular first-tier audits are conducted but second-tier suppliers are not audited by the companies without a targeted and reported issue having come to the attention of the buying company. Compliance to WEEE regulations is achieved by all companies and involves mostly participating in collective schemes or take-back programs without any reintegration processes in operation for utilizing the recycled content of old end-of-life phones.

The results of the secondary analysis were consisted with those of the initial analysis both in terms of the total rank of the companies and the overall involvement in each of the strategic aspects of sustainable materials management. They did, however, improve the scaling of the scores and indicated some changes in company ranks and scores inside aspects. The conformance of the results also contributed to validating the metrics used in the evaluation.

5.1. Applications of the findings, limitations and future research topics

The model developed in this study can be used in similar conceptual evaluation as has been carried out in the course of this report in virtually any manufacturing company where data is available. The metrics assigned to the different elements included in the model (product design, sourcing and supply chain coordination and product recovery and end-of-life management) are general by nature and not restricted to be measured by using any specified units, so their applicability can be considered good.

The empirical results derived from the data in this study are specific to the mobile device manufacturing industry and therefore cannot be generalized as such. Individual findings concerned with the three strategic elements of sustainable materials management do, however, have parallels to patterns in other R&D-intensive industries such as digital media and information technology.

As far as limitations are concerned, the paper did not take into account some of the other important elements of corporate sustainable responsibility such as energy consumption, emissions, and so forth.

Future research topics could include the relationship between profit margins and the extent to which the strategic aspects of sustainable materials management are implemented. Given that the subject is very much still in its infancy, it is difficult at this point in time to conduct a study on the long term effects of sustainable materials management on a company's financial performance. A study carried out in ten years would have the benefit of more constant data streams and would therefore be able to draw much more accurate conclusions as to the depths to which a company will engage in these activities and its reasons for doing so.

In another interesting potential research topic for the future, it would be feasible to give a detailed analysis on the drivers and obstacles of reintegrating recycled materials (in this case, mostly metals and plastics). The development of economically viable recycling programmes under the concept of IPR is also a topic which already raising discussions between legislators and manufacturers.

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Appendix 1

The Directive on Waste Electrical and Electronic Equipment (WEEE or 2002/96/EC)

In the EU, electro-scrap is the fastest growing waste stream, growing at 3-5% per year, which is three times faster than average waste source. Each EU citizen currently produces around 17-20 kg of e-waste per year. Some 90% of this waste is still landfilled, incinerated, or recovered without any pre-treatment. (IPTS, 2006, 1) In the first phase of implementing the WEEE directive, the EU set a target stating that this waste equipment must be separately collected from private households at an average rate of at least 4 kg per person per year. This target was to be reached by December 31, 2006. A new target will be set by December 31, 2008.

The Directive applies the 'Extended Producer Responsibility' (EPR) according to which the producers are financially liable to take back end-of-life products and managing them subject to the Directive. Also, waste collection has to be paid by the producers so that consumers can return the waste to collection points free of charge. Pan-European initiatives, such as the European Recycling Platform (ERP), have been created to enforce compliance to the directive and to improve cost-efficiency of take-back operations, but scepticism remains over the success of these in the short term. This is due to difficulties in coordination over a large scale of products and markets and in following the varying national regulations. (IPTS, 2006, 56-57)

As for the directive's impacts on company level, WEEE recycling has the potential to be an attractive business venture, which has been shown as both formal and informal recycling industries have emerged around it in different parts of the world – even if current technologies to date depend on manual operations and are not particularly cost-efficient. Examples of companies investing in WEEE recycling include Boliden in Sweden, WEEE AS in Norway and Citiraya in the UK. (Babu et al., 2007, 311, 317) The WEEE directive also encourages OEMs to improve their product design so as to increase recyclability, recovery and reuse of materials from end-of-life products. In order to capture most of the recoverable value from products, manufacturers and recycling companies will have to provide good enough incentives for consumers to return their unused products as soon as possible after they have reached their end-of-life. According to USEPA (2000), more than 70 % of retired consumer electronic devices (CEDs) are kept in storage for 3-5 years (see Babu et al., 2007, 312). Also, Nokia found in its global consumer

survey that 44 % of used mobile phones lie at consumers' homes after their end-of-life and are never used while at the same time only 3 % of used mobile phones are taken to recycling (Nokia, 2008).

Table A1-1. Key aims of the WEEE directive.

Source: IPTS, 2006, 1.

Key aims of the WEEE directive
• Reduce WEEE disposal to landfill • Provide for a free producer take-back scheme for consumers of end-of-life equipment from 13.08.2005 • Improve product design with a view to both preventing WEEE and to increasing its recoverability, reusability and/or recyclability • Achieve targets for recovery, reuse and recycling of different classes of WEEE • Provide for the establishment of collection facilities and separate collection systems for WEEE from private households • Provide for the establishment and financing by producers of systems for the recovery and treatment of WEEE, including provisions for placing financial guarantees on new products placed on the market.

Table A1-2. Product categories covered in the WEEE and their recovery and re-use/recycling targets.

Source: IPTS, 2006, 4.

December 31, 2006, Targets for Recovery and Reuse/Recycling, by weight

Product Category	Recovery Target	Recycling Target
Large household appliances	80%	75%
Small household appliances	70%	50%
Information and telecoms	75%	65%
Consumer equipment	75%	65%
Lighting	70%	50%
Tools	70%	50%
Toys, Leisure, Sports	70%	50%
Medical equipment	NA*	NA*
Monitoring instruments	70%	50%
Dispensers	80%	75%

* Target to be set by December 31, 2008.

Appendix 2

The Directive on the Restriction of the use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS or 2002/95/EC)

The EU *directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment* (RoHS) has its roots in a Council resolution of 25th January 1988 aimed at combating cadmium pollution and a wider-reaching resolution of 30th July 1996, and was enacted on 27th January 2003. It was prompted by the differences in Member States' regulations on the use of hazardous substances in such products amid fears that certain states' industries could gain an unfair advantage on those of others due to more relaxed legislation in those states, and aimed to harmonise laws across the EU.

The preamble, paragraph 5, points out that the WEEE directive has been a necessary part of efforts to reduce "waste management problems linked to the heavy metals and the flame retardants concerned." It expressed concern, however, that disposal of electric and electronic equipment, even if carried out according to the WEEE directive, could pose risks to the environment and to human and animal health due to previously permitted levels of mercury, cadmium, lead, chromium VI, PBB and PBDE. Hence, it was decided that a new directive, complementary to the WEEE directive, was required to manage the production of such equipment at an EU-wide level. The preamble also points out the likelihood of increasing the economic profitability of recycling e-waste while having a positive impact on the environmental damage caused by it.

The directive stated that, from 1st July 2006, electrical and electronic equipment put onto the market should not contain any of the above mentioned chemicals, a list to be added to by the Parliament and the Council on further scientific advice. It also considered that penalties should be applied to companies found to be in breach of national legislation which would be "effective, proportionate and dissuasive". Article 9 further stated that each piece of national legislation controlling the composition of electric and electronic equipment should contain a reference to the RoHS directive as well as communication to the Commission "the text of all laws, regulations and administrative provisions adopted in the field covered by" the RoHS directive, demonstrating the desire of the Commission to make it wide ranging and effective.

Appendix 3

The Basel Convention on the control of Transboundary Movements of Hazardous Wastes and their Disposal, and the Mobile Phone Partnership Initiative

The report of the sixth meeting of the Basel Convention (UNEP/CHW.6/40), section VI/31 (Basel Convention, 2002, pp.148-151) contains a decision on the environmentally sound management of end-of-life mobile telephones. This initiative was introduced during the 5th Conference of the Parties to the Basel Conference, and subsequently to that, ten OEMs (LG, Panasonic, Mitsubishi, Motorola, NEC, Nokia, Philips, Samsung, Siemens and Sony Ericsson) expressed their willingness to work alongside the Basel Convention.

The environmentally sound management of end-of-life mobiles was identified as an important activity, and a group of experts was assembled featuring representatives of the Parties to the Convention, members of the secretariat and representatives of the above mentioned OEMs. A working group was established at the 6th CoP in order to draft a work programme identifying the main objectives of the newly established Mobile Phone Partnership Initiative (MPPI).

The MPPI established its main duties as detailed in Table A3-1 below. Three projects particularly relevant to this thesis were identified as being underway in the report.

Project 1.1 – Refurbishment of Used Mobile Phones – aims to produce guidelines on four topics: Guidance applicable to refurbishment facilities product handling and refurbishment; Management of components and materials removed from end-of-life wireless devices, including administrative measures; Guidance for mobile phone /mobile devices product handling and refurbishment; and Remarketing of refurbished mobile devices.

The project's main aim is to encourage companies involved in the refurbishing of mobile phones to carry it out in an environmentally sound manner, and to guide these companies in order to help them ensure that refurbished devices re-entering the market comply with applicable standards and regulations.

Table A3-1. Objectives of the MPPI Work Programme (UNEP/CHW/OEWG/4/INF/14)

Source: http://www.basel.int/meetings/oewg/oewg4/documents/i14e.pdf#pg_4_1A Report of the Open Ended Working Group of the Basel Convention)

Objectives of the MPPI Work Programme
Promote the objectives of the Convention in the area of the environmentally sound management of end-of-life mobile telephones through : • The achievement of better product stewardship • The influencing of consumer behaviour towards more environmentally friendly action • The promotion of the best refurbishing/recycling/disposal options • The mobilization of political and institutional support for environmentally sound management • The construction, through these actions, of an initiative that could be replicated to build new public/private partnerships for the environmentally sound management of hazardous and other waste streams. The MPPI Work Programme was, through its own work programme, required to consider: • Initiatives (regulatory, voluntary, economic) for reused phones that re-enter the market to ensure high quality and standards that satisfy the product requirements of manufacturers, network providers and operators alike • Rules that govern transboundary movements of mobile phones to be reused • Advice on any programmes, legislation and /or regulations for an effective collection of end-of-life mobile phones • Rules that apply to transboundary movement of end-of-life mobile phones to be sent for refurbishing, recycling and recovery • Guidance on environmentally sound practices for recycling and recovery • Elaboration of the role of the Basel Convention Regional Centres to assist countries in developing legislation, establishing potential recycling companies, raising awareness, dissemination of information and capacity building.

Project 2.1 - Collection and Transboundary Movement – has two objectives: To provide guidance on best practice for setting up collection schemes for end-of-life mobile phones to be refurbished or recycled; and To provide guidance on implementation of control systems for transboundary movement of used mobile phones destined for refurbishment and reuse and end-of-life mobile phones destined for recovery and recycling.

Project 3.1 - Material Recovery and Recycling of end-of-life Mobile Phones – aims to identify recycling technologies for environmentally sound management of end-of-life devices and to provide recommendations for future research and development of end-of-life product recycling, taking into account the financial implications of such actions.