KTH Computer Science and Communication

Developing tools for sustainability management in the graphic arts industry

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Abstract

The main aim of this thesis is to develop and test industry-specific, applied work procedures and tools for environmental and emerging sustainability work in the graphic arts industry. This includes methods to quantify, follow-up, evaluate, manage, improve and communicate the environmental performance of activities in the graphic arts supply chain and printed products.

In order to achieve the aims of the thesis, a selection of work areas were chosen as the basis for developing the industry-specific work procedures and tools. The selected work areas are the following: environmental management (being a part of sustainability management), environmental and sustainability strategies, environmental indicators and design for environment (DfE).

The research presented in this thesis was based on survey research methods, case studies and multi-company studies. Within the framework of these methods, quantitative and qualitative techniques for data gathering were used. The companies included in the studies were selected according to their willingness, interest and motivation to participate and develop their environmental or sustainability work.

The most significant results of the research presented in this thesis regarding the selected work areas are the following:

- An evaluation of early certified environmental management systems (EMSs) in Sweden identified four areas as priorities in making the EMSs more efficient. Two of them, viz. improvement in the follow-up of environmental work, and the linking of EMSs to product design, were developed for the graphic arts industry. The remaining two areas were clarifying the identification process and assessment of environmental aspects, and streamlining and co-ordinating different management systems.
- An established and successfully tested working method for formulating and realising corporate sustainability strategies in the graphic arts industry.
- Industry-specific environmental indicator models for the graphic arts industry with defined methods for standardised inventorying and calculations. These models have been tested, used and approved of by the industry itself.
- Collected and compiled data for the developed environmental indicator models. Data have been collected from quite a large number of companies (10-20 companies for each of the printing techniques covered, i.e. coldset offset, heatset offset and gravure) over a period of several years.
- The use of the industry-specific environmental indicator models was developed and illustrated.
- A described and recommended work procedure for DfE in graphic arts companies including industry-specific tools for applying DfE to printed products, in the form of a manual and a checklist. The checklist was designed so that it can serve as a simple tool for the environmental assessment of printed products. The tools were tested by graphic arts companies.

Keywords: graphic arts industry, printing industry, environmental management, sustainability strategy, environmental indicators, design for environment, eco-design.

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List of included papers

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Paper I
Environmental Management Systems – Paper tiger or powerful tool, by Maria Enroth and Mats Zackrisson. Published in Conference Proceedings of the 2000 Eco-Management and Auditing Conference, University of Manchester, ERP Environment, UK, pp. 81-92, 2000.

Paper II
Environmental indicators in the graphic arts industry, by Maria Enroth and Angelica Widing. Published in Advances in Printing Science and Technology. Ed. A. Bristow, Pira International, UK, Vol. 26, pp. 337-356, 2000.

Paper III
Promoting sustainability using business specific indicators, by Maria Enroth. Published in Conference Proceedings of the 2001 Eco-Management and Auditing Conference, Nijmegen School of Management, The Netherlands, ERP Environment, UK, pp. 60-67, 2001.

Paper IV
Tools for Design for Environment (DfE) - Applications in the Printing Industry, by Maria Enroth and Angelica Widing. Published in TAGA Journal, Technical Association of the Graphic Arts, Vol. 2, pp. 205-223, 2006.

Paper V
Environmental indicators in the newspaper industry, by Maria Enroth, Martin Johansson and Åsa Moberg. Published in Acta Graphica, Vol. 15, No. 3-4, pp. 105-115, 2003.

Paper VI
Environmental data on gravure and offset printing, by Maria Enroth and Martin Johansson. Accepted for publication in Acta Graphica.

Paper VII
How to formulate and realise a corporate sustainability strategy, by Maria Enroth. Submitted to International Journal of Environmental Technology and Management. Accepted with revisions.

Errata

Paper III

- Results, Study of newspaper industry with case studies, Table ‘Measures of environmental load’, Hazardous materials, Column 2:

  ‘The definition of hazardous is here related to the Swedish observation list and labelling of chemicals. Calculated without water. ’

  should be

  ‘The definition of hazardous is here related to the Swedish observation list and labelling of chemicals.’

- Results, Study of newspaper industry with case studies, Table ‘Measures of environmental load’, Hazardous materials, Column 3:

  ‘Kg ("dry")’

  should be

  ‘Kg’

Abbreviations

BAT	Best Available Technique
CBA	Cost-Benefit Analysis
CEB	Corporate Environmental Behaviour
CEPI	Confederation of European Paper Industries
CERES	Coalition for Environmentally Responsible Economies
CSA	Canadian Standards Association
CSR	Corporate Social Responsibility
DfE	Design for Environment
DPSIR	Driving force Pressure State Impact Response
EAO	Environmental Assessment of Organising
EDIP	Environmental Design of Industrial Products
EEA	European Environment Agency
EF	Ecological Footprint
EIA	Environmental Impact Assessment
EMA	Environmental Management Accounting
EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management System
EPA	United States Environmental Protection Agency
EPE	Environmental Performance Evaluation
EPI	Environmental Performance Indicator
EPM	Environmental Performance Measurement
ESAP	Environmental Self-assessment Program
ESCM	Environmental Supply Chain Management
FMEA	Failure Mode and Effects Analysis
FSC	Forest Stewardship Council
GEMI	Global Environmental Management Initiative
GMAT	Green Management Assessment Tool
GRI	Global Reporting Initiative
ICC	International Chamber of Commerce
ICM	Integrated Chain Management
ICT	Information and Communication Technology
IE	Industrial Ecology
ILO	International Labour Organization
IOA	Input-Output Analysis
ISO	International Organization for Standardization
IPP	Integrated Product Policy
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
LCI	Life Cycle Inventory
LCM	Life-Cycle Management
MEPI	Measuring Environmental Performance in Industry

MFA	Material Flow Accounting
MIPS	Material Intensity Per Unit Service
NGO	Non Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
PEFC	Programme for the Endorsement of Forest Certification schemes
P-EMS	Product-oriented Environmental Management Systems
POEMS	Product Oriented Environmental Management Systems
PSR	Pressure State Response
PSS	Product Service System
QFD	Quality Function Deployment
SEA	Strategic Environmental Assessment
SFA	Substance Flow Analysis
SFI	Sustainable Forest Initiative
SBM	Sustainable Business Management
SCM	Supply Chain Management
SEPA	The Swedish Environmental Protection Agency
SME	Small and Medium sized Enterprise
SPD	Sustainable Product Development
SPSD	Sustainable Product and Service Development
SR	Social Responsibility
SWOT	Strengths, Weaknesses, Opportunities and Threats
TBL	Triple Bottom Line
TMR	Total Material Requirement
UNCSD	United Nations Commission for Sustainable Development
UNEP	United Nations Environment Programme
WBCSD	World Business Council for Sustainable Development

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1 Introduction

1.1 Background

1.1.1 The graphic arts industry

The graphic arts and media industries are described as the printing and publishing industries, film and broadcasting and allied activities, where five sub-sectors are identified (EMCC 2003b):

- Equipment and materials suppliers
- Advertising agencies
- Printers
- Publishers
- Audiovisual industries (i.e. radio and TV)

If the audiovisual industries are excluded, the remaining sub-sectors can be described as the graphic arts industry. In turn, the Printers, delivering different types of printed products, can be divided into the following sectors:

- Commercial printing industry
- Newspaper printing industry
- Packaging print industry

The graphic arts and media industry is a producer of products which are both tangible and intangible. Three main components (or products) of the media sector have been described by Lindqvist et al. (2003) as print media (e.g. newspapers, magazines, books), electronic media (e.g. on-line information services, radio, television) and recorded media (e.g. CD-roms, DVDs, cinemas). The graphic arts and media industry products could be seen as a means (or function) of satisfying customers' needs for different kinds of information.

During the last few decades, the graphic arts industry has been and still is in a wide-ranging process of change. Today, printing is just one way of reproducing and distributing information. As new media technologies are being established, the graphic arts industry is being broadened to include new types of companies with operations in electronic publication and the Internet.

The number of players in the graphic arts industry is numerous and the structure therein can be complex. The different types of roles that exist can be categorised as follows (EMCC 2003b):

- Content creators (e.g. authors, journalists, photographers, graphic designers)
- Content traders (e.g. picture libraries, press agencies)
- Content processors (e.g. reproduction houses, in-house publishing staff)
- Content packagers (e.g. printers)

- Distributors (e.g. newspaper and magazine distributors)

In addition to these generalised categories of roles, there are suppliers of associated services and products. Associated services include, for example, specialist services such as the indexing of reference books and subscription agencies. Examples of associated products include equipment for prepress and printing, i.e presses, and consumables such as paper or other printing substrates, chemicals, including printing ink, and printing forms.

Packaging print can be seen as a special case, since the information content is being created here as an adjunct to the physical product to be packaged and not for consumption of the information content itself.

Prepress includes the processes and associated equipment and software which manipulate the raw content, e.g. text, images, and graphics, into the required layout and format for the printing process. This includes processes such as text editing, page layout, image processing and colour management.

In the printing industry sub-sector, there are different printing techniques, which, according to their distinct characteristics and capacity, are used for different kinds of printed products. The printing techniques can be divided into the following: Offset/Lithography printing (with the sub-types Sheet-fed offset, Web fed Coldset offset and Heatset offset), Flexographic/Letterpress printing, Rotogravure printing, Screen printing and Digital printing (with the most important methods electrophotography and ink jet) (EUEB 2005, Johansson et al. 1998, Kipphan 2001, Lindqvist et al. 2003). Ink jet printing is so far the only non-contact printing method and, because of this, it has many promising advantages. Important characteristics, such as print speed, resolution, overall print quality, costs, etc., decide the areas of use for the different printing techniques. In Table 1, preliminary information on economic run lengths (number of copies) is listed, together with products typical of the different printing techniques.

In the research presented in this thesis, we have focused on sub-sectors of the commercial printing industry and of the newspaper industry. The research described here has concentrated on the tangible, physical publication product range of these sub-sectors. The printing techniques involved in the research have mainly been Sheet-fed offset; Web fed Cold-set offset and Heatset offset (a Heatset dryer facilitates a forced drying process) and Rotogravure printing. To a certain extent, Flexographic printing and Digital printing have been involved.

Table 1 Different printing techniques and preliminary information on economic run length and typical products, status 1999 (Glassman 1985, Kipphan 2001).

PRINTING METHODS	ECONOMIC RUN LENGTH	TYPICAL PRODUCTS
Sheet-fed offset	1,000 – 50,000	Brochures, Books, Posters
Web fed Coldset offset	25,000 – 1,000,000	Newspapers, Journals
Web fed Heatset offset	25,000 – 1,000,000	Magazines, Journals
Flexographic printing	25,000 – 1,000,000	Packaging, Books, Wallpaper
Rotogravure printing	500,000 – 10,000,000	Catalogues, Magazines, Packaging, Wallpaper
Screen printing	10 – 1,000	Posters, Signs, Textiles
Digital printing, electrophotography	1 – 5,000	Brochures, Books, Posters
Digital printing, ink jet	1 – 5,000	Brochures, Posters

Many of the graphic arts and media industries are directly or indirectly funded by advertising expenditure, the volume of which in turn is closely related to the prevailing economic environment. The total European advertising expenditure in 2003 was approximately EUR 80 billion, with a growth rate of 5% - 6% (EMCC 2003b). This can be related to the reported turnover in 2003 of the graphic arts industry in Europe, viz. EUR 72 billion (Intergraf 2004). In Europe, TV and radio advertising has increased in market share between 1990 and 2001 at the expense of the print media, although the continuation of the increase in the overall advertising spending has resulted in the print media growing too, albeit at a lower rate (EMCC 2003b, Kipphan 2001). The print media market share of advertising spending was 66% in 1990 and 54% in 2001. As a comparison, in 2000, the share of advertising expenditure on the Internet was just over 1%. In general, there is an expectation of a decline in advertising expenditure related to print and a growth in the electronic media, in the context of a continually growing business (EMCC 2003b). However, there are no clear signs of a declining trend for the consumption of printed products in Europe or in Sweden. The consumption of graphic paper in Europe (the CEPI Countries) was 41 million tonnes in 2003 and 1.2 million tonnes in Sweden in the same year (Intergraf 2004).

In most European countries, there has been a decline in the number of printing companies since the beginning of the 1990s. In all European countries, it

appears that there are relatively few companies that produce 60% - 80% of the industry turnover and a very large proportion of small companies. The overwhelming majority of print companies are small, employing less than 10 people (EMCC 2003b). When it comes to turnover, data from 2003 states that, Germany and the UK dominate the European market share at around 25% each, followed by Italy (18%), France and the Netherlands (10% each) and Spain (8%) (Intergraf 2004).

The commercial printing industry in Sweden comprises approximately 2,000 companies, with a work force of 20,000 workers. The total turnover of the commercial printing industry, including the newspaper industry, in Sweden amounted to approximately EUR 4.1 billion in 2003. The share of the newspaper industry amounted to 41% of the total turnover. (Intergraf 2004)

Traditionally, printing was seen as a polluting industry, with harsh emissions to the air and water and that it used a large number of chemicals (e.g. inks and solvents) and produced a lot of wastage (GFF 1999, EMCC 2003b). New technologies, such as digitalisation of the prepress, including, among others, computer-to-plate (CTP), automatic cleaning systems, production control systems, the substitution of hazardous chemicals and economical short run lengths have reduced the emissions, the amount of chemicals used in the processes (and the need for cleaning presses) and also the amount of end product wastage. In Sweden, at the end of the 1990s, these changes contributed to a start in the changing of attitudes to the graphic arts industry (GFF 1999).

Due to the development of new technologies, on one hand, the graphic arts industry is now an integrated part of the information and communication technology (ICT) sector while, on the other hand, close to the forest sector. The value chain of electronic media is completely digital, right up to the end user, and that of printed media goes up to the multiplying (printing) phase. From that point on, it is still strongly linked to the forest industry (Lindqvist el al. 2003). This close relationship influences the environmental pressure on the printing industry since the forest industry (including pulp and paper industry), has had a long period of customers making environmental demands. Further environmental considerations in the graphic arts industry are described in Section 1.1.5. Considerations regarding drivers of change for the graphic arts and media industry, e.g. the ICT development, and the relationship between ICT and the environment are discussed in Chapter 4.

1.1.2 Environmental management and strategies

Environmental and sustainability management factors are rapidly emerging as important issues for the business world to consider. Klassen and McLaughlin (1996) define environmental management as ‘encompassing all efforts to

minimise the negative environmental impact of a firm's products throughout their life cycle'. The definition of environmental management has been discussed in Burström and Frostell (2000) as consisting of two parts, viz. society's handling and protection of the environment and natural resources, and different organisations' handling of environmental matters. The second part is described as 'corporate environmental management'. When the terms environmental and sustainability management are used in this thesis, this latter part, dealing with the environmental work of companies is intended.

Few trends in society have been growing more steadily over the last few decades than the concern of society for current non-sustainable development and the increasing willingness of society to deal with this situation (Robèrt 2000). As part of this, a growing number of principles, concepts, programmes and tools for the management and monitoring of sustainable development in society and industry have gained worldwide acceptance in the last decade. This section gives a brief introduction to a selection of these principles, concepts, etc., which have been influencing the research presented in this thesis. Since environmental management in companies is becoming integrated into sustainability management, it is important, first of all, to clarify the concept of sustainability:

The concept of sustainability

'The World Conservation Strategy' report of 1980 (IUCN et al. 1980), subtitled 'Living Resource Conservation for Sustainable Development', introduced the concept of sustainability in the international discussion forum. The Brundtland Commission described sustainable development in 1987 as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED 1987). Since the Brundtland Commission, many alternative definitions of sustainability have been proposed and diverse interpretations of the concept have been made. Many of these are based on the 'three-pillar' or 'triple bottom line' concept including three dimensions; economic, social and environmental (Pope 2004).

Since 1995, the institutional dimension has been introduced by the United Nations as the fourth dimension of sustainable development in 'the Prism of Sustainability'. Sustainability was then described by referring to the four dimensions (economic, social, environmental and institutional) and their six inter-linkages. Since the fourth dimension of sustainability has been mostly applicable to societies, it has not been discussed or used very much in industry. (Spangenberg 2002)

In the context of companies, the three dimensions of sustainability have sometimes been included in the 'profit, people and planet' approach (Hueting and Reijnders 2004).

Management stance, principles and frameworks

It is widely acknowledged that environmental issues must be considered as strategic in a growing number of industries, due to environmental legislation, other regulations and market pressure (Humphreys et al. 2003). With a growing awareness of environmental issues, i.e. from global climate change to local waste disposal problems, businesses and governments have come under increasing pressure to reduce the environmental impact involved in the production and consumption of goods and services (Roy 2000). When it comes to environmental change in industry, the main impetus so far has come from large companies located in Western Europe and North America. In these cases, the focus of environmental efforts has shifted from industrial emissions and waste, including their treatment and disposal, to remedying environmental problems at the source and taking preventive action. The most efficient way of using resources is to consider, from the very design stage, the resources, emissions and waste that will arise during production, the utilisation and the disposal when the products concerned reach the end of their useful life.

However, several organisations still favour off-the-shelf, less disruptive solutions, which keep their production processes and products unchanged. For instance, a recent survey from Statistics Canada, referred to by Vachon and Klassen (2005), shows that the environment-related *capital* expenditures of Canadian plants were divided fairly equally between end-of-pipe technologies and integrated process technologies, defined as process modification and material substitution leading to the reuse of waste and water in order to reduce both the emission of pollutants and the amounts of waste. Furthermore, the same survey reported that, out of environment-related *operating* expenditures (in contrast to capital expenditures), end-of-pipe technologies are favoured 3:1 over integrated process technologies.

The choice of management stance and management's interpretation of its boundaries for environmental responsibility and influence will define the degree of environmental improvement action in the individual case. The proper selection of a management stance regarding environmental and sustainability matters is necessary for an individual company before its strategies can be decided on for its entire sustainability efforts. di Norcia et al. quoted in Thoresen (1999) suggested four possible levels of stance, representing widely different improvement ambitions for management in an obvious way, namely unresponsive, reactive, responsive and proactive. In compliance with these levels of stance, Humphreys et al. (2003) concludes from the literature that there are two main strategies as to how a company can deal with environmental issues, namely reactive and proactive. Companies with a reactive environmental strategy (a cost mode strategy) act in order to comply with environmental regulations. Companies with a proactive environmental strategy (a sustainable

business strategy) consider environmental concerns to be a part of their overall management.

Other researchers have looked at the different types of actions in a company when categorising environmental strategies, e.g. improving market communication, improving manufacturing processes and carrying out research and development (Welford 1998). In line with this, Vachon and Klassen (2005) have characterised the environmental management of a company according to its selection of environmental technologies, i.e. pollution control technologies, pollution prevention technologies and management techniques and procedures (e.g. ISO 14001 certified system). In a recent study on the state of corporate sustainability in German companies, Hahn and Scheermesser (2006) identified three significantly distinct types of approaches to corporate sustainability, viz. those from sustainability leaders, environmentalists and traditionalists.

The International Chamber of Commerce (ICC) principles (www.iccwbo.org) are one of a series of frameworks developed for an environmental improvement of businesses. The ICC principles consist of 16 principles for sustainability. The Global Environmental Management Initiative (GEMI) is an organisation comprising of industries that support the Principles for Environmental Management, as contained in the ICC Business Charter for Sustainable Development (Eagan and Joeres 1997). Other frameworks for environmental improvements include, among others the Natural Step (www.naturalstep.org, Robèrt 2000) and the Coalition of Environmentally Responsible Economies (CERES) (www.ceres.org).

Corporate Social Responsibility (CSR) is a phenomenon that has become firmly established in society. It is the response of the private sector to structural changes in society and the international community. A universally applicable and accepted definition of CSR is difficult to give, due to the enormous diversity of enterprises, stakeholders, environments and social objectives. Essentially, there are two elements that define CSR. They are a sufficient focus by the enterprise on its contribution to public prosperity in the longer term and the relationship with its stakeholders and society at large (SER 2001). CSR is supported by the European Commission, which is in the process of raising its profile and promoting the adoption of CSR by organisations throughout Europe (SER 2001; EMCC 2003b). The European Monitoring Centre on Change (EMCC 2003b) has described the main principles of CSR as the following;

- Life-long learning
- Work organisation
- Equal opportunities
- Social inclusion
- Sustainable development

The international community has enshrined public expectations and values in various systems of standards in a number of areas. Besides the Universal Declaration of Human Rights (1948) and the international treaties concerning civil and political rights as well as economic, social and cultural rights (both 1966), these include the International Labour Organization (ILO) Conventions (www.ilo.org) and the Organisation for Economic Co-operation and Development (OECD) Guidelines for Multinational Enterprises (www.oecd.org). The OECD Guidelines reflect the joint expectations of the governments of the OECD countries, with respect to international enterprises. For CSR to be carried out appropriately, it is very useful for companies to follow these standards (SER 2001).

In 2000 the United Nations initiated a Global Compact for the New Century. The aim of this compact, which sets out ten principles, is to involve companies, trade unions, and Non Governmental Organisations (NGOs) in the promotion of human rights, fundamental labour standards and ecological sustainability (www.unglobalcompact.org).

Corporate strategies

Many have discussed the definition of a strategy. Porter (1996) defines a strategy as 'the creation of a unique and valuable position, involving a different set of activities'. Porter further claims that the essence of strategic positioning is to choose activities that are different from rivals. Strategies and the business mission for packaging are discussed in Olsmats (2002). When it comes to making a strategy, Hart (1992) proposed an integrative framework for strategy-making processes. Some methods for making a strategy that can be related to this study are discussed by Hutchinson (1992), suggesting a strategic framework for environmental management based on SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis, by Eden and Ackermann (1998), using the so called oval mapping technique and by Handfield et al. (2005), integrating environmental management and supply chain strategies.

The attempt to improve the corporative strategy development process has fostered a range of approaches, which have enjoyed different levels of support and popularity over time. One of the most popular is the SWOT analysis. It could be claimed that strategic planning, in general, and the SWOT analysis, in particular, have their mutual origins in the work of business policy academics at the Harvard Business School and other American business schools from the 1960s onwards (Hill and Westbrook 1997). Despite criticism over the years, a SWOT type analysis, involving an external and internal factors assessment and seeking a match between the two perspectives, has still remained popular. The SWOT method has been described and used in different recent strategy studies, e.g. Bernroider (2002), Leskinen et al. (2006) and Dyson (2004).

Concepts and programmes for environmental management

Over the last few decades, organisations have responded to increased demands for environmental management by implementing a number of programmes. The mid 1980s is generally regarded as a turning point, when industry ceased resisting the environmental pressures and began embracing them or, at least, considering them. This was a reaction to satisfy their more environmentally aware customers and governments (Argument et al. 1998). In the Swedish forest industry, this turning point was seen at least ten years earlier (SSVL 1974). Humphrey et al. (2003) have made a description of different phases of environmental management. Firstly, managers introduced end-of-pipe initiatives, aimed at reducing emissions, waste and energy use. At the end of the 1980s, clean technologies were introduced, along with programmes for reducing the environmental impact of key steps in the production processes. At the beginning of the 1990s, enterprises changed their operating procedures and introduced eco-auditing frameworks for modifying products and services. Currently, organisations are facing a fourth phase, in which environmentally conscious firms, mainly large companies, are developing environmental programmes aimed at organising their supply chains. As competition has intensified and globalised over the last decade, many companies increasingly rely on their supply network to handle more complex technologies and higher customer expectations (Vachon and Klassen 2005).

Cleaner production

Cleaner production has been defined by UNEP as the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment (www.uneptie.org).

Cleaner production is not only about changing raw materials, processes and products. It is also about changing corporate culture and the attitudes of people, viz. human dimensions of organisational change. As discussed by Stone (2000), organisational theory covers many of the aspects involved in organisational change. During the 1990s, demonstration projects from all over the world indicated that an introduction of environmental management systems, such as ISO 14001 or the European Union's Eco-Management and Audit Scheme (EMAS), which address many of these factors, may contribute significantly to the uptake of cleaner production (Stone 2000).

Baumann (2004) discusses a new perspective on the environmental performance of the industry and presents the concept of an environmental assessment of organising (EAO). EAO has been defined by Baumann as the combined study of the organising features and the environmental aspects of a technical system. The concept of EAO aims at a theoretical framework that bridges environmental management, organisational theory and environmental systems analysis. One

objective of EAO is to develop an understanding of the role of organisational processes and management for environmental performance.

Environmental Management Systems (EMSs)
An environmental management system is defined as the part of an organization's management system used to develop and implement its environmental policy and manage its environmental aspects. It is a set of inter-related elements, used to establish policy and objectives and to achieve those objectives. It includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources (ISO 2004, Henricson et al. 2000).

ISO 14001 (International Organization for Standardization) (ISO 2004) and EMAS (Eco-Management and Audit Scheme) (EMAS 2001) can be seen as two systems with a common basis. Even so, there are certain differences. According to EMAS, the greatest difference is that companies have to produce an official, assessed environmental statement or report. EMAS also makes more explicit demands with regard to the preliminary environmental review.

ISO 14001 has newly been revised, with the intention of being more comprehensible, more compatible with ISO 9001 (the ISO standard for quality management systems) and of meeting the needs of small and medium sized enterprises (SME). The revised standard puts more emphasis on continual improvement of environmental performance and management commitment.

The environmental performance of an organisation has been defined as the measurable results of an organisation's management of its environmental aspects. In turn, an environmental aspect has been defined as an element of an organisation's activities or products or services that can interact with the environment. (ISO 2004)

In an environmental management system (EMS), the process of identification and assessment of environmental aspects is crucial. An approach to a new reproducible method, based on LCA methodology with examples from 14 business units in Stora Enso, an integrated forest company, has been developed by Zobel et al. (2002). Zobel and Burman (2004) have contributed to knowledge in this area of research, by further identifying general factors of importance for the process of identification and assessment of environmental aspects in an EMS context.

Supply chain interactions
In order to develop their products from an environmental point of view, companies need to work on their approach to supply chain management or supply chain collaboration. This approach is very important, when the main environmental aspects of a product can be identified as parts of the product life-

cycle that the company has limited direct impact on itself. This is valid for many of the parties in the graphic arts production chain.

What Humphrey et al. (2003) have described as the fourth phase of environmental management in organisations, viz. organising supply chains, has been discussed by Seuring (2004) from a somewhat wider perspective. Seuring discusses various concepts that have arisen in recent years in environmental management that may facilitate the organising of supply chains. These include industrial ecology (IE), life-cycle management (LCM), integrated chain management (ICM) and environmental or sustainable supply chain management (ESCM). They directly address the flow of material (and information) along life cycles or supply chains and, thereby, are related to inter-organisational management aspects. Seuring (2004) analyses and compares these four concepts: A distinctive feature for IE is its *geographical approach* or regional application. LCM gives priority to *product design* as the most important decision phase. ICM emphasises *stakeholder integration* in societal and legal systems, while ESCM focuses on the *managerial activities* needed in an actor network in order to *satisfy customer needs*.

Integrating environmental management techniques along the supply chain is an appropriate method of enhancing the environmental performance of an industry (Humphreys et al. 2003). Handfield et al. (2005) have developed a framework and guidelines for environmental supply chain strategy decision-making for companies. According to Handfield et al., environmental supply chain management (ESCM) should identify, quantify, assess and manage the flow of environmentally critical materials through the value chain, with the aim of reducing waste and maximising resource efficiency. The close relationship between an environmental management system (EMS) in a company and ESCM is described in suggested guidelines.

Supply chain management (or collaboration) is closely related to both suppliers and customers. Humphreys et al. (2003) present a framework of environmental criteria that can be considered by a company during their supplier selection process. In a study described by Vachon and Klassen (2005), the impact of environment-related interactions in the supply chain on operational performance was examined. Using data from a survey of the Canadian and United States package printing industry, the link between green project partnership and five performance indicators was tested. Green project partnership was defined by the extent of interaction between a plant and its primary suppliers and major customers. A partnership with major customers could likely generate benefits in more dimensions of operational performance than a similar partnership with primary suppliers. The study by Vachon and Klassen (2005) supports the argument that interaction among organisations in the supply chain can lead to a cross fertilization of knowledge and know-how, resulting in an improved organisational performance. However, the managerial processes needed for such

cooperation and the instruments applied have rarely been presented (Seuring 2004).

van Kleef and Roome (2005) have tried to define the requirements needed for businesses to innovate in ways that are sustainable. This has resulted in an applied research agenda for sustainable business management (SBM). Requirements for innovation as part of SBM have been identified as collaboration in networks and multi-actor forums. This raises concerns about the challenge of establishing trust and commitment for innovation, especially given the tension between sharing and the appropriation of knowledge. In a similar way, Clarke (2005) suggested there should be research on corporate environmental behaviour (CEB) to help in designing more effective policy approaches.

1.1.3 Environmental and sustainability indicators

Need for environmental and sustainability data

To be able to work effectively with environmental tasks in industry and organisations, there is a growing need for environmental information in the form of relevant, easily understood and comparable data.

Information is essential to make it possible to quantify, follow-up, evaluate, manage, improve and communicate environmental work not only internally but also externally among stakeholders, such as customers, investors, financing institutions, authorities and competitors, where the desire for reliable and objective environmental data has rapidly increased during recent years. Environmental performance indicators (EPIs) are a vital step towards effective, verifiable reporting and strategy formation.

For the graphic arts industry in Sweden, there has been a need to break down governmental commitments, e.g. the Swedish National Environmental Quality Objectives, into goals for individual companies on a more practical level. For example, graphic arts companies want to be able to show and communicate the connection between the environmental impact of the industry and the major environmental threats and to illustrate the environmental impact of using information products in relation to other activities in people's daily lives. Another problem for specific industries or individual companies is to cover all areas of the concept of sustainable development in their practical work with continual improvements. So far, most of the work concerning sustainability in small and medium-sized enterprises (SME) has been carried out in the environmental and financial areas, while omitting the social aspects. With the use of structured indicators, these challenges may be overcome.

Purpose and general requirements of indicators
One basic purpose of an indicator is to focus complex information, thereby facilitating the solution, understanding and communication of a problem.

Environmental performance measurement (EPM) has been defined as the measurement of the interaction between business and the environment (Olsthoorn et al. 2001). The ultimate aim of EPM and environmental performance evaluation (EPE), through the use of environmental performance indicators (EPIs), is to ensure that industrial activities move in a sustainable direction at a rate which is acceptable to society and the environment (Thoresen 1999).

The general requirements for any kind of indicator are that they should be objective, understandable, significant, consistent with the actual objectives, responsive to stakeholder expectations and allow meaningful comparisons at a reasonable cost. They should also be "workable" in the sense that the data required to implement them are truly available in practice. (Olsthoorn et al. 2001 and Thoresen 1999).

Sustainability indicators translate sustainability issues into quantifiable measurements, with the ultimate aim of helping to address the key sustainability concerns (Azapagic 2004).

Frameworks for environmental and sustainability indicators
There has been a development of many different frameworks and types of environmental and sustainability indicators. One of the most well-known indicator frameworks is the PSR-model, initially proposed by the OECD (Organisation for Economic Co-operation and Development) in 1993 (OECD 1993). This model is based on casual chains. PSR stands for Pressure, State, Response and the model since then has been extended into the DPSIR-model, where suggested indicators for Driving Forces and Impact have been added. In addition, the model has been continuously developed with socio-economic indicators. Today, the DPSIR model forms the basis for the indicator work performed by the OECD, the United Nations, the World Bank, the EEA (the European Environment Agency) and the Swedish Environmental Protection Agency (SEPA), among others. The OECD set of core indicators were mainly developed for national and international use. The principle of formulating indicators, based on casual chains, has been adopted in industrial focused frameworks as well.

Since 1995, the UNCSD (United Nations Commission for Sustainable Development) has been developing indicators for sustainable development, according to Agenda 21. The indicators have been developed for usage on the national or international levels. The aim has been for these indicators to be made available to national decision-makers as of 2001. The UNCSD indicators have

been extensively tested in more than twenty countries from all geographic regions of the world. Since applicability at corporate level has been low, these indicators have not been used by industry to any great extent (Carlsson Reich et al. 2001).

In a general survey of current indicator frameworks and projects, where some 40 projects were surveyed, only a handful of them were identified as covering all three aspects of sustainability, viz. GRI (Global Reporting Initiative), Eurostat, OECD PSR, UK Quality of Life Counts and UNCSD (Carlsson Reich et al. 2001). A more recent study presents a list of existing social sustainability-related principles and guidelines (Waage et al. 2005). Even if these principles and guidelines do not specify the frameworks for indicators in all cases, they are a good complement to the indicator frameworks that focus on environmental tasks.

There are many indicator frameworks that have a strong industrial focus, e.g. AccountAbility 1000 (AccountAbility 2004), the Global Reporting Initiative (GRI) (GRI 2002) and the World Business Council for Sustainable Development (WBCSD) (WBCSD 2000).

AccountAbility 1000 (AA1000) is an accountability standard (not certifiable) that has been developed to improve the accountability and overall performance, social and ethical, environmental and economic, of organisations by increasing quality in social and ethical accounting, auditing and reporting. AA1000 aims at supporting organisational learning and the contribution of organisations towards a path of sustainable development (AccountAbility 2004).

The Global Reporting Initiative (GRI) was founded in 1997. The GRI Sustainability Reporting Guidelines have been developed through a multi-stakeholder dialogue. The first Guidelines appeared as an Exposure Draft in 1999. The main aim of this industrial supported initiative is to develop a generally accepted indicator framework for sustainability reporting in industry and other organisations. The GRI aims at covering a full range of social and ethical issues, as well as environmental and economic concerns. (GRI 2002) The Guidelines have been revised several times and a new version, the G3 Guidelines, was released in October, 2006 (www.globalreporting.org or www.grig3.org).

The World Business Council for Sustainable Development (WBCSD) has developed a framework for measuring eco-efficiency, which was first introduced in 1992. The WBCSD aimed at establishing a framework that can be used by any business to measure progress towards economic and environmental sustainability. The environmental indicators are divided into two groups, viz. a small number of generally applicable indicators and different lines of business specific indicators. (WBCSD 2000).

Categorisation of environmental and sustainability indicators

The categorisation of environmental performance indicators (EPIs) is an important area of research and has been discussed in many studies, e.g. Azzone et al. 1998, Eagan and Joeres 1997, ISO 1999, Stone 2000, Thoresen 1999 and Young and Rikhardsson 1998.

In the framework for EPI by Azzone et al. (1998), the indicators fall into four categories, viz. the state of the environment, the corporate environmental policy, the environmental management system and the products and processes of the company. In another study, the indicators are separated according to the four company functions, viz. processes, products, financial and management (Young and Rikhardsson 1998).

In 1999, the ISO 14031 standard, Environmental management – Environmental performance evaluation – Guidelines (ISO 1999), was published. This ISO guideline includes guiding principles for establishing indicators and gives suggestions for two main categories of indicators, viz. environmental condition indicators (ECI) and environmental performance indicators (EPI). The latter are divided into management performance indicators (MPI) and operational performance indicators (OPI). The content in ISO 14031 was discussed by Jasch (2000), to give an example.

Categories suggested by Thoresen (1999) for guiding the construction of EPIs are: Product lifecycle performance indicators and Environmental performance of operations indicators, the latter being divided into Management system performance indicators and Manufacturing operations performance indicators. Except for the use of somewhat different terms and there being no explicit suggestion for environmental condition indicators, this categorisation is similar to the categorisation used in ISO 14031 (ISO 1999).

Thoresen (1999) pointed out that for external and internal use, EPIs must be correlated to address the same environmental end effect categories, but that they may be expressed on different levels of aggregation and in different formats, according to the requirements of different stakeholders.

Establishment of environmental and sustainability indicators

For environmental indicator models, this section focuses on industrial applications. When it comes to sustainability indicator models, examples of applications for both society and industry are given.

The Global Environmental Management Initiative (GEMI), developed during the beginning of the 1990s, was one of the first measurement techniques that attempted to address sustainable development issues and goals (Eagan and Joeres 1997). It was called the Environmental Self-assessment Program, or

ESAP. ESAP was developed and tested for monitoring a company's progress in meeting the ICC principles and was designed as a self-use tool. A further developed version, titled the Green Management Assessment Tool (GMAT) was more facility focused, more practical and applicable in its use (Eagan and Joeres 1997).

Olsthoorn et al. (2001) discuss environmental indicators for comparing environmental performances of business, to be used by a business itself plus external information users. Based on a European research project (MEPI – Measuring Environmental Performance in Industry), a process of developing appropriate indicators was suggested. This process has four core elements:

- Data collection, which results in financial, environmental or social variables describing the reviewed system.
- Establishment of a database. The uniformity of measurement, often described in the data collection protocol, is ensured. Data are stored in common units of measurement, which are referred to as a normalisation process, thus ensuring that data are transformed into compatible or comparable forms.
- Aggregation. Appropriate and feasible indicators are aggregated into a single indicator for each environmental impact, respectively.
- Standardisation. Data are combined into performance indicators, using some kind of standardisation scheme as a denominator or normalising factor, e.g. output, turnover, number of employees etc.

A proposal from the Olsthoorn et al. (2001) study is that data from firms, which reflect the major environmental aspects of a firm, should be transformed into indicative information on kinds of environmental impact. This is because it is the kinds of impact rather than the aspects that are of importance. To facilitate this, agreement should be sought in establishing a list of relevant impact categories that can be used as a guiding matrix for corporate environmental indicators. The advantages of expressing environmental objectives and targets for companies with the intention of reducing the contributions to a certain environmental problem (impact category), instead of an intention of reducing the amount of the release of a certain substance, is also discussed by Zobel et al. (2002). One advantage is that interaction with the environment will be more obvious and the risk for sub-optimisations hence decreases. However, it may not yet be possible to include all the significant aspects of a company in a characterisation process, due to the current lack of well-established characterisation models.

Furthermore, Olsthoorn et al. (2001) suggest that data collection should be separated from the indicator generation, viz. the follow-up steps of subsequent stages of data manipulation of the "raw" data into environmental information, including aggregation or standardisation. This would facilitate a cost-effective use of environmental information for a variety of purposes and users. Many

different indicators, tailored to the information needs of the different data users, could then be developed, based on a comparatively small dataset. Fraser et al. (2005) suggest a similar procedure for collecting and handling indicator data.

The construction and the use of sustainability indicators for society have been thoroughly described by Ekins and Simon (2001), Spangenberg (2002) and Hueting and Reijnders (2004), to give some examples.

In order to assess the impact of participatory processes on environmental management projects, Fraser et al. (2005) critically examined three case studies, where community input was used to identify sustainability indicators. One advantage with participatory processes is that they bring experts together with community members, which, in turn, brings in local knowledge in the process and improves the possibilities of generating community support for policy changes. The process of engaging people to select key indicators provides a valuable opportunity for community empowerment and education. Some disadvantages are that participatory processes run the risk of being time and resource intensive and that they may create non-standardised data that prevent regions or other units (such as companies) from being compared.

Use of indicators

A sharp increase in the use of environmental indicators has been apparent since the end of the 1990s. Traditionally, many ecological indicators, such as key species for biological monitoring and pollutants in the environment, have been used. The strategic use of environmental indicator systems is being developed with a view to promoting an enhanced awareness of the environmental situation, an improvement in communication regarding the situation, a formulation of action plans/policies and, last but not least, an improvement in the environmental situation and how people operate with regard to the environment. Examples of this appear in the literature (Malkina-Pykh, 2000; Niemeijer, 2002; Plut, 2000; Walz, 2000).

Examples of the main uses of EPIs are listed by Jasch (2000), Olsthoorn et al. (2001), Thoresen (1999) and Young and Rikhardsson (1998). They can be summarised as follows:

Macro level uses;

- The regulation, control and surveillance of individual companies.
- To influence individual companies to secure a sustainable performance.
- To supply information to external stakeholders, performance reporting.

Micro level uses;

- Basis for strategic decisions.
- Scenario evaluations.
- Internal goal setting, planning, managerial control and surveillance of processes and products, and internal information.

- Benchmarking vs. competitors or vs. the average branch performance for triggering the continuous improvements of processes and products.
- Identify the potential monetary benefits.

Environmental performance evaluation
Indicators, both environmental and sustainability indicators, make a good starting point for an assessment and evaluation of changes in performance. Quantitative data, facilitating environmental systems analysis, have not generally been discussed in literature in the terms of environmental indicators, although the link is apparent. When it comes to the strongly evolving concept of sustainability impact assessment, the link between sustainability indicators and suggested assessment methods are explicit in literature and initiatives in society and industry.

There are a large number of tools available for evaluating environmental impacts. An overview of many of these tools was given by Finnveden and Moberg (2005), where the tools were characterised in order to understand their relationships and their appropriateness in different situations. The characteristics include whether the tools are procedural or analytical, the types of impacts included, the object studied using the tools and whether the tools are used for descriptive or change-oriented studies. Examples of tools are Material Flow Accounting (MFA), Input-Output Analysis (IOA), Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), Life-Cycle Assessment (LCA), Life-Cycle Costing (LCC), Cost-Benefit Analysis (CBA) and Ecological Footprint (EF). MFA is a family of different methods, where different MFA methods have different objects in focus, e.g. Total Material Requirement (TMR), Material Intensity Per Unit Service (MIPS) and Substance Flow Analysis (SFA). Most of the overviewed methods have not been developed for nor so far been used very much on an organisational/company level (Finnveden and Moberg 2005). The Environmental Performance Evaluation (EPE) methods, facilitated by the use of environmental indicators, can be seen as important environmental systems analysis tools for companies.

Thomassen and de Boer (2005) discussed the link between environmental indicators and environmental systems analysis in dairy production systems. They evaluated the effectiveness of indicators derived from three methods that are used widely in animal production, i.e, Input-Output Analysis (IOA), Ecological Footprint (EF) analysis, together with Life-Cycle Assessment (LCA). The evaluation of the effectiveness was based on an assessment of the relevance, quality, and availability of data. They came to the conclusion that, to have a good insight into the environmental impact of a dairy production system, Input-Output Accounting indicators and LCA indicators are required. Indicators derived from Ecological Footprint analysis were not found effective, due to limited relevance and low quality.

Sustainability impact assessment is being increasingly viewed as an important tool to aid in the shift towards sustainability. There are quite a few studies and initiatives dealing with sustainability impact assessment. Bastianoni et al. (2001), Cloquell-Ballester et al. (2005), Dow Jones Sustainability Indexes (2005), Krajnc and Glavič (2005) and Pope et al. (2004) provide some examples. Many of the initiatives are related to the previously mentioned sustainability indicator frameworks (e.g. GRI, OECD PSR and UNCSD). In addition, the approaches for sustainability impact assessment are, in many cases, derived from the Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) (Pope et al. 2004). Pope et al. (2004) argue that sustainability impact assessment needs a clear vision of what sustainability means. Further, this vision needs to be translated into context specific sustainability criteria, which, in turn, should be derived from sustainability principles. The Natural Step System Conditions (Robèrt 2000) is mentioned as an example of a set of sustainability principles.

Environmental and sustainability management accounting
Physical environmental and sustainability indicators are closely connected to the development of Environmental Management Accounting (EMA) and Sustainability Management Accounting. EMA represents a combined approach that provides for the transition of data from financial accounting, cost accounting and material flow balances, in order to increase material efficiency, reduce environmental impact and risk, and reduce the costs of environmental protection. EMA is carried out by private or public corporations, but not nations, and has a financial as well as a physical component. The United Nations Division for Sustainable Development (UN DSD) has promoted EMA in co-operation with a number of government agencies and non-governmental experts (Jasch 2003). Starting with efforts to assess the financial effects of sustainability performance, indicators provided by the Global Reporting Initiative (GRI 2002) for sustainability reporting and the UN DSD method for EMA, has been enlarged with several cost categories (Jasch 2005).

While sustainability reporting has experienced an impressive upswing in recent years, partly due to the Guidelines published by the Global Reporting Initiative (GRI 2002), sustainability accounting is still only in a very early stage of development (Jasch 2005).

1.1.4 Design for Environment (DfE)

By now, it is generally agreed that today's environmental problems are associated to a great extent with the industrialised world's consumption of products, i.e. goods and services. Consumption leads to different kinds of environmental impacts from all parts of a product's life cycle, viz. raw material

extraction, production and manufacture, distribution and use, reuse, recovery (or recycling) and final disposal, including transportation throughout the cycle.

From the mid 1990s, there has been an explosion in research and publications in design for environment (DfE). The reported research ranges from detailed analysis of, for example, one small part of a subcomponent, to corporate level discussions of DfE and its place in the drive for sustainability (Simon et al. 2000). Principles and methods for DfE are discussed in Behrendt et al. (1997), Brezet and van Hemel (1997), Fiksel (1996), Hanssen 1997, ISO/TR 14062 (ISO 2002), Nielsen and Wenzel (2002), Ryding et al. (1995), Simon et al. (2000), UNEP (2002), van Weenen (1997a) and van Weenen (1997b), among others.

One of the main challenges to any industry investing in sustainability is to continue satisfying the needs and wants of the market it serves, with minimal contributions to the world's waste and pollution streams (Argument et al. 1998). To balance this, there is a need to begin addressing the true need for a product and, if the function of the product can be provided by other more efficient means. Products or services that meet essential needs are discussed by Roy (2000), to give one example.

Definitions used for environmental and sustainable related product development

Design for environment (DfE) is a work procedure for the product development of new or modified products. The aim of DfE is to minimize any adverse environmental impacts from a product, while the functionality or value of the product is retained or increased. This means that product developers have to consider both the environmental impact and the benefit of their products. In DfE, the environment is given the same status as more traditional industrial benefits, such as functionality, customer value, profit, aesthetics, image and overall quality. The concept of DfE includes the whole life cycle of products and, in the end, DfE should lead to a more sustainable production and consumption. Other terms referring to the same approach are eco-design, life cycle design, the environmental part of product stewardship, etc.

$$\text{DfE reduces the ratio} \quad \frac{\text{Environmental impact}}{\text{Benefit}}$$

Argument et al. (1998) list a few definitions from literature which are in line with this definition. In addition, they define the outcome of DfE, an eco-efficient product, as the following: 'A product or process that simultaneously meets cost,

quality, and performance goals, minimises environmental impacts and maximises conservation of valuable resources.'

Simon et al. (2000) consider eco-design as a broader term than DfE, implying a balanced view of the whole product life cycle. They claim that many DfE tools for designers concentrate on the end of the products life cycle. This is not always the case. In this thesis, the terms DfE and eco-design are considered to describe the same, broad, life-cycle perspective of product development.

As an extension of eco-design, it is discussed how a sustainable product development (SPD) could be described. A definition of SPD is given in Argument et al. (1998) as the following: 'Sustainable product design is a design management practice, which aims to balance the 'triple bottom line': environmental, social and economic needs. '

A combination of products and services are often discussed, in order to obtain SPD. According to Roy (2000), sustainable product-service systems (PSS) attempt to create designs that are sustainable in terms of an environmental burden and resource use, whilst developing product concepts as parts of sustainable whole systems that provide a service or function to meet essential needs.

Prerequisites, drivers and barriers for (DfE) environmental and sustainable related product development

Simon et al. (2000) refer to three elements that are necessary for organisations to learn and acquire the capability of eco-design. These elements are an appropriate environmental expertise, good internal communication networks and receptive values in the design team. The barriers to implementation of eco-design are often organisational rather than technical. The marketing of green products requires organisational changes to effectively collect and diffuse environmental knowledge. Five factors were identified as critical to success in eco-design viz. an initial and sustained motivation, a communication and information flow, whole-life thinking, hands-on eco-design using the correct tools and, finally, a position on a competitive market.

A large principle driver for radical ideas is the enormous challenge, posed by the likely need to reduce the environmental burden and resource-use in the industrialised world to between 25% and 5%, or even less, for each unit of service rendered. That is, between a factor four and a factor 20 improvements in eco-efficiency will be required to move towards an environmentally sustainable world with a doubled population (Roy 2000). A study of van Hemel and Cramer (2002) indicates that this type of principle driver is of interest for industry. However, companies consider it important that there are more hands-on drivers. Argument et al. (1998) surveyed the opinion of large industrial companies with regard to the reasons for DfE. Legislation was reported as being

the biggest industrial influence when designing environmentally compatible products. Customer demands were the second largest influencer at that time.

In order to learn which factors stimulate SMEs towards greening their products and which factors hamper them, the eco-design behaviour of 77 Dutch SMEs was studied in 1997 (van Hemel and Cramer 2002). Contrary to earlier literature on environmental management in SMEs, it was concluded that internal stimuli are a stronger driving force for eco-design than external stimuli. Among the most influential internal stimuli were the opportunities for innovation and the potential market opportunities. It was additionally revealed that the most influential external stimuli were customer demands, government legislation and industrial sector initiatives.

When it comes to governmental initiatives, the Netherlands was among the first countries to develop and adopt comprehensive product-oriented environmental policies. A description of The Netherlands Environmental Policy Plan (NEPP) set in 1989 and its development during the 1990s is outlined in van Berkel et al. (1999). From then on, the focus of Dutch environmental policies has been on products, through a life-cycle approach.

The European Union has developed an Integrated Product Policy (IPP) built on life cycle thinking, in order to reduce resource use (Kögler and Goodchild 2006). The aim of the IPP is to minimise the impact of products on human health and the environment throughout their life cycles, from 'cradle-to-grave', to improve sustainable production and consumption and advance the government's environmental quality objectives (Reinhard et al. 2003). The Swedish IPP strategy, developed by the Swedish Environmental Protection Agency (SEPA), is founded on three fundamental elements, viz. a more holistic approach, better conditions for market stakeholders and greater cooperation among stakeholders (Reinhard et al. 2003).

As in many environmental areas, there has been a gap between academic research and the industrial requirements of eco-design. For eco-design, this gap has been explored and described in the UK and the Netherlands by Argument et al. (1998). The most significant gaps were found in the areas of environmental concerns and research preferences. Industry was more focused on present and immediate problems while, on the other hand, academics were more concerned with moving towards sustainability. For research preferences there was an overwhelming consensus among the researchers on the need for general environmental databases and the need for training packages that could be facilitated through the use of guidelines and manuals. There was, however, little agreement from industry on this. Industrialists were more focused on immediate needs, such as new technologies, LCA, waste disposal and emissions research.

Concepts and methods for environmental and sustainable related product development

Brezet and van Hemel published a UNEP report 1997, 'Ecodesign, A promising approach to sustainable production and consumption' (Brezet and van Hemel 1997) which has had an immense importance for eco-design work. The process described in this report is the following: an initial environmental innovation scan (or review), the identification of improvement options, a feasibility study of these and, finally, a possible implementation in a design. This process has gathered strong support in the Netherlands and elsewhere, inspiring many researchers and industries.

Eco-design involves a combination of general principles (eco-design strategies) to minimise total environmental impacts over the whole life cycle of a product. In Brezet and van Hemel (1997), the eco-design strategies have been listed and described. One of the strategies has been given the symbol '@' because it is seen as having an entirely different nature than the other seven strategies. The eight strategies are:

@ New Concept Development.
1. Selection of low-impact (e.g. renewable, recycled) materials.
2. Reduction of materials usage.
3. Optimisation of production techniques.
4. Optimisation of distribution systems.
5. Reduction of impact during use.
6. Optimisation of initial lifetime.
7. Optimisation of end-of-life systems.

The suggested 'Environmental Design of Industrial Products' (EDIP) work procedure for integrating environmental issues into product development is described by Nielsen and Wenzel (2002). The main phases of general product development, here listed as idea phase, analysis, goal definition, concept development, detail development and establishment of production, are the basis. The potential for environmental improvements is big at the beginning of product development, when ideas and conceptual solutions are open and then it decreases gradually as the process proceeds.

The term 'product development', as used in the traditional sense of working in product development teams with tools, such as Failure Mode and Effects Analysis (FMEA) and Quality Function Deployment (QFD), have not yet been consciously applied to the graphic arts industry for work with printed products. Graphic arts companies, with the exception of certain newspaper companies, do not normally carry out product development in the traditional sense of developing new/modified products that are then mass-produced. One of the likely reasons for this has been that printed products are generally very short-lived. However, the graphic arts production itself has been described in a systematic way by e.g. Johansson et al. (1998) and Rosenqvist (2000).

Eco-design has its limitations, when it comes to developing sustainable products. The optimisation of social, ethical and economic issues is not included in eco-design in its present form. If sustainability is the aim, then merely reducing the environmental impact of a product, using an eco-design approach, is not enough.

There has been a concept development of a sustainable product development (SPD). These sustainable design strategies include the creation of leading edge eco-designs and may also involve organisational and social innovations (Roy 2000).

Based on the research and experiences associated with an Irish initiative, a method for sustainable product and/or service development (SPSD) was developed (Maxwell and van der Vorst 2003). SPSD is an evolution of the existing concepts of eco-design and sustainable product development (SPD). It incorporates services and products as well as all Triple Bottom Line (TBL) elements. Essential features for a successful SPSD implementation are specified and one of the most powerful ones is the emphasis on supply chain dynamics and supply chain management (SCM).

In order to meet the need for a factor of 20 improvements in eco-efficiency of processes and products further development must lead to changes in socio-technical systems and new product-service systems (PSS) (e.g. Roy 2000 and UNEP 2002). The key to sustainable PSSs is that they are designed and marketed to provide customers with a particular *result* or *function* e.g. clean clothes, mobility, warmth, etc., without them necessarily having to own or buy physical products. Some of these systems, such as public libraries and transport, are similar to what already exists, but they can be greatly improved on, especially through the use of advanced information and communication technologies. Other concepts, such as car sharing, heat supply services or leasing products, are more recent. These types of ideas for more sustainable goods and services pose major marketing and design challenges as well as cultural and political obstacles. (Roy 2000)

Links between eco-design and the EMS

The links between eco-design and environmental management systems (EMSs) have been discussed by many researchers, e.g. Ammenberg 2005, Simon et al. 2000 and van Berkel et al. 1999.

Companies often start with process-oriented or facility-oriented EMSs, which ought to lead to the development of a Product-oriented Environmental Management System (P-EMS or POEMS) as a logical extension (van Berkel et al. 1999). The idea of P-EMS is to enable producers to make environmentally responsible decisions on product development and product strategies, in

collaboration with suppliers and customers (van Berkel et al. 1999). The Dutch government promotes P-EMS as part of its product-oriented environmental policies.

LCA and related methods – one of the basic prerequisites for eco-design

Life cycle assessment (LCA) is a technique that addresses the environmental aspects and potential environmental impacts, e.g. the use of resources and the environmental consequences of releases, throughout the life cycle of a product, from raw material acquisition, through production, use, end-of-life treatment, recycling and final disposal, i.e. cradle-to-grave. LCA assesses the environmental aspects and impacts of product systems in a systematic way, in accordance with a stated goal and scope. It is a relative approach based on a functional unit. There is no single method for conducting LCA. (ISO 2006)

There is still a debate on the value and validity of life cycle assessment (LCA) as a tool for public policy-making. However, life cycle thinking has become widely accepted as valuable for product design and eco-labelling (Ehrenfeld, quoted in Simon et al. 2000). Quantitative methods such as LCA are quite demanding and time consuming. However the work results in well-documented product environmental profiles, which can be used for future work with other products in the same family group (Nielsen and Wenzel 2002). Given the demanding and time consuming nature of LCA, there is a strong desire in industry for simple, easily applied measurements of environmental performance. Many companies have developed systems of metrics for internal use that reflect corporate policy, e.g. Electrolux score values for energy efficiency, returnable content and choice of materials (Simon et al. 2000).

From a designer's point of view, obtaining a single indicator that evaluates the environmental behaviour of materials in such a way that it can be incorporated directly into a multicriteria decision problem, along with the other design considerations, could be an ideal situation. Since there is pressure for simple-to-use methods for the evaluation of environmental performance in eco-design, there have been studies trying to develop and/or test methods that allow for evaluations that are quick and easy but also accurate. For example, Bovea and Gallardo (2006), Hochschorner and Finnveden (2003) and Hur et al. (2005) evaluated simplified LCA methods. From the study by Bovea and Gallardo (2006), where five different life cycle impact assessment methods were compared, it was concluded, as many times before, that using a single environmental score requires so many assumptions that they must be used with extreme caution. A single score often hides important information and offers a low degree of transparency, when communicating results (ibid.). It must be considered that there is no credible way of simplifying the background information to provide simplified tools.

The need to establish a stronger link between life-cycle assessment (LCA) and managerial decisions has been put forward in the development of life-cycle management (LCM) and life-cycle costing (LCC) (Durairaj et al. 2002, Saur 2003 and Seuring 2004 are some examples). The emphasis in LCM is placed on the product design phase, since it is indicated that 80% of the environmental burden and cost of a product is determined during this phase (Seuring 2004). Similar to this, Argument et al. (1998) argue that 75% of the resources used to manufacture a product can be specified during the design process.

1.1.5 Environmental considerations in the graphic arts industry

There have been quite a few environmental studies and Life-Cycle Assessments (LCAs) in the field of the graphic arts industry. Examples of general environmental studies and reports are Andersson et al. (1998), GMR (2000), GMR (2002), Swedish Environmental Protection Agency (2000) and Virtanen and Jäntti (1995). Reports related to the Best Available Technique (BAT) in the graphic arts industry are, for example, Brodin and Korostenski (1999), Fleck et al. (1999), and Silfverberg et al. (1998).

When it comes to indicators, the printing industry has been represented in for example two EU environmental indicator projects. They are Measuring the Environmental Performance of Industry (MEPI) (Berkhout et al. 2001, Berkhout and Hertin 2001) and Cleaner Technology Performance Indicators for SMEs, where a study of the lithographic printing industry was included (Cadra 1998). Other studies related to environmental indicators for the graphic arts industry have been for example Cook (1997) and GA (1999). These studies were more or less contemporary with our initial indicator studies and were taken into consideration during our research.

Literature on subjects related to Design for Environment (DfE) were Skovgaard et al. (1997) and Tischner and Nickel (2003), for example. Since 1992, the United States Environmental Protection Agency (EPA) has been hosting 'The Design for Environment (DfE) Program' (EPA 2005), which has resulted in projects about screen, offset, gravure and flexographic printing (EPA 1994, EPA 1995, EPA 2001 and EPA 2002). Experiences gained from early initiatives in the field of DfE were considered in our research, although early work in the United States concentrated on a Cleaner Technologies Substitutes Assessment (CTSA) approach, which was only one of our aims with DfE. Reports related to environmental labelling of printed products and companies are EUEB (2005), which describes suggested, newly developed criteria for the EU eco-labelling of printed paper products and Nordic Ecolabelling (2005), which describes the criteria for the Nordic eco-labelling (the Nordic Swan) of printing companies.

Most of the published LCA studies in the graphic arts industry field deal with the offset printing technique. The reason for this is probably that this is the most common printing method for publication products. LCA studies that have focused on offset are, for example, Dalhielm and Axelsson (1995), Johansson (2002), Larsen et al. (2004) and Strömberg (1998). Studies that have focused on both offset and gravure printing are, for example, Axel Springer Verlag et al. (1998) and Drivsholm et al. (1997). When it comes to LCA studies on comparisons of conventional printing and digital printing or electronic media, Lindblad (2001) and Hischier and Reichart (2001), among others, can be mentioned.

The results of environmental studies, including life-cycle studies (LCAs), show that the production steps, including material and resource usage, in the production of pulp and paper, printing and transport are of great importance for the total environmental impact of printed paper based products throughout their life-cycles. The greatest single environmental impact, at least for some typical printed products, has been identified as arising from the use of paper (forestry, pulp and paper production), that have been reported as contributing to 30% – 70% of the total environmental impact of printed paper products. However, neither the printing process, with its use of energy, of non-renewable, and hazardous materials nor transport can be neglected. One of the more recent LCAs indicates that the printing process contributes significantly when compared to paper, if all process chemicals are included on a more comprehensive basis (Larsen et al. 2004). The user phase of the products is, not of great importance, in the case of printed products. This is, of course, different from those products, which make demands on either electricity or fuel during use.

The relationship with the forestry and the pulp and paper industries is very important to the printing industry. One reason for this is that the consumption of paper, when producing printed publication products, represents a significant environmental aspect. Environmentally conscious printing industries and their customers follow, or take part in, the development of sustainable forestry systems, where the CSA (CSA 2002), FSC (www.fsc.org), PEFC (www.pefc.org) and the SFI (SFI 2004) systems are the most common. In addition to sustainable forestry, production processes in the pulp and paper mills are of great importance to the environmental impact of printed paper products from a life cycle perspective. In the case of pulp and paper production, there are extensive activities involving the systematic and periodical collection of data that are available for different types of indicators, e.g. CEPI (2005) and www.forestindustries.se.

In addition to all these environmental studies and reports listed above, we have made several investigations which were documented in different reports (Enroth

et al. 1998, Enroth and Widing 2000, Enroth et al. 2003, Widing et al. 1999, Widing and Enroth 2000, Widing et al. 2000, Widing and Enroth 2001). Among other things, this was done in order to define one of the important requirements for industry-specific work and for the research presented in this thesis – an identification of significant environmental aspects for the graphic arts industry and printed products. Industry-specific work procedures and tools for environmental work in the graphic arts industry should reflect these aspects.

Based on literature surveys and the investigations in our subsequent research work, it has been possible to claim that the following environmental aspects can generally be regarded as significant for the graphic arts industry and for its products (not in order of priority) (Widing et al. 1999, Widing and Enroth 2000):

- The use of printing paper (or other printing substrates)
- The use of non-renewable materials
- The handling and use of chemical products, including printing ink
- The use of energy
- Transportation
- Emissions of volatile organic compounds (VOC) to the air
- The handling and use of electronics

In addition, the environmental impact is influenced by the choice of printing method, since applicable machinery and materials, such as specific printing form and chemicals, needed for the production process differ.

Generally, graphic arts companies in Sweden and in a growing part of the industrialised countries are, to a great extent, concerned with environmental matters (GFF 1999). In Sweden, the focus of environmental efforts in the graphic arts industry has shifted from conforming to environmental legislation to meeting the environmental demands of customers. This is illustrated by the fact that, early on, the printing industry in Sweden adopted a front position with regard to the number of companies possessing certified environmental management systems (Zackrisson et al. 2000). Graphic arts companies also have the greatest number of licences for production, according to the Nordic Swan product eco-labelling scheme (Enroth 2001). This is in comparison to all other types of products for which the Nordic Council of Ministers has formulated eco-labelling criteria. The total number of types of product groups with eco-labelling criteria is 66 (January 2006). In Sweden at present, the total number of licences is 709. Of this, 223 (31%) of the current licences refer to printed products (www.svanen.nu). The corresponding share of *all* Nordic Swan licences, mainly in Scandinavia but also in The Netherlands and Germany, is 38% for printed products (SIS Ecolabelling 2006). Some years ago (2001), this figure was as high as more than 50%. Concurrently, the highest number of licenses referring to printed products in Sweden was approximately 320 at that time.

The most important driving force for environmental work in the Swedish graphic arts industry at the end of the 1990s was customer demands. In addition, the pressure from authorities has been apparent. In 1999, the previous environmental legislation involving 15 different laws were revised and put together in the Swedish Environmental Code (SFS 1998). Harmonisation with EU legislation has affected the printing industry. Such legislation includes the Solvent Emissions Directive 1999/13/EC, the IPPC Directive 1996/61/EG and the IMPEL network (The European Union Network for the Implementation and Enforcement of Environmental Law) (Swedish EPA 2000).

In the latter 1990s, there was a general growing level of environmental concern in Swedish society and companies (Axelsson et al. 2003 and Zackrisson et al. 2000). Information products are utilised in business-to-business relations and also aimed at private consumers as a target group. Therefore, company policy decisions and public opinion contributed to the extensive customer demands for an environmental awareness in the graphic arts industry and its products, which are illustrated, for example, by the high number and share of Nordic Swan licenses presented earlier.

At the same time, while managing the environmental and evolving sustainability demands from the various stakeholders, the graphic arts companies, which are often SMEs, have to handle the huge developments in Information and Communication Technologies (ICTs). These developments extensively affect production, the information product range and characteristics, the timescale for production and the amount and skills of people in the companies, among other things. These combined pressures mean that fewer people in small companies must be able to manage extensive sustainability demands, more advanced technological developments and ordinary production simultaneously, within shorter and shorter timescales. This demands applied industry-specific, efficient work procedures and tools.

To be able to work efficiently with environmental and sustainability matters in industry and in other organisations, there has generally been a growing need for tools and environmental information in the form of relevant, easily understood and comparable data. Such information is essential to make it possible to quantify, follow-up, evaluate, manage, improve and communicate environmental work, not only internally but also externally, among stakeholders, such as customers, investors, financing institutions, authorities and competitors.

This thesis was initiated because of the general, growing need for environmental information and because the Swedish graphic arts industry and the printing sub sector, in particular, have at regular intervals been subject to strong pressure from customers for documented environmental work and improvements in the environmental performance of activities and products. The foundation of the

research comprising this dissertation is the development of environmental management in the graphic arts industry.

1.2 Aims of the thesis

The main aim of this thesis is to develop and test industry-specific, applied work procedures and tools for environmental and emerging sustainability work in the graphic arts industry. This includes methods to quantify, follow-up, evaluate, manage, improve and communicate the environmental performance of activities in the graphic arts supply chain and printed products.

This may contribute to a more eco-efficient and sustainable production in the graphic arts industry. By eco-efficient, here, is meant producing more value, while using fewer resources and doing the right things from an environmental point of view during the limited time the companies have available for each job.

Industry-specific, here, implies that the procedures and tools for environmental and sustainability work are compatible with general work procedures, the techniques and the significant environmental and sustainability aspects specific to the graphic arts industry.

Each paper included in the thesis has more specified aims, which are presented in Table 2 (in Section 2.2).

1.3 Limitations of the thesis

The research was mostly carried out in Sweden and mainly concerns Swedish conditions. However, in some of the later studies (Paper VI and Paper VII) companies from different parts of Europe and North America were involved. The research, including data gathering, was carried out during the period between 1998 and 2006.

The research presented in the thesis has mainly focused on printed, publication products. Thus, electronic media products are not included.

In the thesis focus is put on environmental sustainability; all dimensions of the sustainability concept have been included only in Paper VII.

1.4 Overview of the thesis

In order to achieve the aims of the thesis, a selection of work areas were chosen as the basis for developing the industry-specific work procedures and tools for environmental and sustainability work in the graphic arts industry. The selected work areas are the following: environmental management (being a part of sustainability management), environmental and sustainability strategies, environmental and sustainability indicators and design for environment (DfE) (or eco-design).

An overview of the areas of work in the dissertation and how they are currently related to each other are illustrated in Figure 1.

The environmental management of an organisation is ideally based on an environmental strategy, facilitated by environmental indicators and includes eco-design procedures for handling the product (goods and services) development of the organisation. Some of the eco-design factors, e.g. functionality, customer value, profit and aesthetics, are not handled exclusively within the boundaries of an organisation's environmental management. The boundary of the environmental management in an organisation is not always identical to the boundary of a possible environmental management system (EMS), although this might be an ideal case.

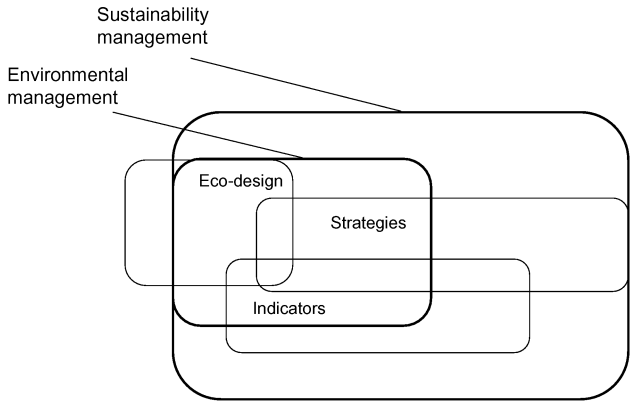

Figure 1 An overview of the areas of work in the dissertation and how they are currently related to each other.

Proactive organisations are expanding their environmental management to sustainability management. Sustainability management is preferably based on a sustainability strategy and facilitated by sustainability indicators. In future, the development of an organisation's products (goods and services) will be handled

by sustainability product development (SPD) procedures. Since Figure 1 illustrates the areas of work in this thesis, SPD has not been included.

This research included the following tasks:

- An evaluation of environmental management systems (EMSs) was made in order to develop future environmental management (Paper I).
- The developing of industry-specific (the term trade-specific has been used in Paper II and business-specific in Paper III) environmental indicators for the graphic arts industry, aimed at improved and more efficient follow-up, evaluation, management and communication of the environmental work and the performance of their activities and products. In addition, this research has included the development of conditions for benchmarking, which were databases and reference values (Paper V and Paper VI).
- The developing of industry-specific work procedures and tools for design for environment (DfE), in order to promote a focus on the products and their functionality in future environmental work in the value chain of the graphic arts industry (Paper IV).
- The developing of a working method to formulate and realise corporate sustainability strategies for the graphic arts industry. One of the aims here was to contribute to the process of bringing conceptual sustainability work into practice (Paper VII).

The initiating evaluation of EMSs was used as a starting-point in this thesis for developing environmental and sustainability management in the graphic arts industry.

2 Methods

2.1 General considerations

The research presented in this thesis was based on survey research methods, case studies and multi-company studies. Within the framework of these methods, quantitative and qualitative techniques for data gathering were used as complementary techniques.

This research has an interdisciplinary character in that it is striving to integrate the perspectives of the media technology and graphic arts discipline together with the natural science environmental discipline. Furthermore, the first steps along the extension of environmental research to sustainability research in the graphic arts and media industry taking place in this thesis, brings in influences, for example, from social science and organisational theory in the research. Many researchers have discussed the interdisciplinary character of sustainability managerial research (Baumann 2004, Seuring 2004, among others). The differences among multidisciplinary, interdisciplinary and transdisciplinary are discussed by Lawrence and Després (2004). According to their literature review, multidisciplinary describes a situation when each discipline works in a self-contained manner. Interdisciplinary has been described as a "mixing of disciplines", while transdisciplinary has more to do with a "fusion of disciplines".

2.1.1 Survey research methods

There are many data collection and measurement processes that are called surveys. For the majority of occasions when surveys are undertaken, the goal is to develop statistics about a population (Fowler 2002). Referring to Fowler (2002), a total survey design constitutes the following pieces:

- Sampling considerations (the choice of whether or not to use a probability sample, the sample frame, the sample size, the sample design, the rate of response).
- Question design and evaluation.
- Interviewers influences, e.g. selection of interviewers, amount and kind of training, supervision and given procedures.
- Data collection mode, e.g. telephone, letter, e-mail, personal interview, etc.

In some of the studies presented in this thesis, we used survey research methods. This was in the evaluation of certified environmental management systems (EMSs) (Paper I) and in the initial phase of working with Design for Environment (DfE), when identifying the needs for DfE tools (Paper IV).

A major reason for using probability sampling methods is to allow the use of statistical techniques. The most basic manner of calculating statistics about samples assumes that a simple random sample was drawn. When a simple random sample is drawn, each new selection is independent, unaffected by any selections that came before (Fowler 2002). However, stratification is often valuable since this will ensure that the sample has the same proportions in each class as in the whole population. We used stratified samples for our semi-structured interviews when evaluating EMS (Paper I and Zackrisson et al. 2000). In our study, a representative distribution was sought between the main groups industry and service/trade; also between small sized (<100 employees) and large (>100 employees) companies in each group.

The effect of non-response on survey estimates depends on the percentage of those not responding and the extent to which those not responding are biased, that is, systematically different from the whole population. In letter surveys with a response rate between 5% and 20%, the final sample has little relationship to the original sampling process, since those responding are essentially self-selected (Fowler 2002). However, there are occasions when such a self-selection process is valuable, e.g. for identifying volunteer samples, which was the case in the initial survey in our DfE study (Paper IV, Enroth et al. 1998).

There are occasions when the goal of information gathering in a survey is *not* to generate statistics about a population but to describe a set of samples in a more general way. For these purposes, samples which are readily available or are volunteered may be useful (Fowler 2002).

2.1.2 Case studies

A case study is an empirical inquiry that investigates a contemporary phenomenon with its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. (Yin 2003)

Referring to Yin (2003), there are many different applications for case studies. The most important application is to *explain* the presumed casual links in real-life interventions that are too complex for a survey or an experimental design. Another application is to *describe* an intervention and the real-life context in which it occurred. Furthermore, the case study may be used to *explore* those situations in which the intervention being evaluated has no clear, single set of outcomes. Case studies, as a research strategy, have a distinct advantage when a 'how' or 'why' question is being asked about a contemporary set of events, over which the investigator has little or no control (Yin 2003).

According to Yin (2003), there are five components of a research design that are especially important:

- The questions of a study.
- Its propositions, if any.
- Its unit(s) of analysis.
- The logic linking the data to the propositions.
- The criteria for interpreting the findings.

The main advantage of case studies is that they examine what happens under real-life conditions. They also allow building up in-depth knowledge of the process itself. The strength of case studies is their unique ability to handle many different types of data (Merriam 1994).

We used case studies when describing and developing industry-specific work procedures and tools for the design for environment (DfE) (Paper IV) and when developing a working method to formulate and realise corporate sustainability strategies for the graphic arts industry (Paper VII).

It is important to choose the cases carefully in order to assess the validity of the results. Yin (2003) describes different kinds of cases as (1) a critical case, often used for testing a formulated theory, (2) an extreme or unique case, (3) a representative or typical case, where the objective is to capture the conditions of a commonplace situation, (4) a revelatory case, when a phenomenon previously inaccessible to scientific investigation is studied and (5) a longitudinal case, studying the same case at two or more different points in time.

As clarified in the Section 2.2, the companies included in Paper IV could be seen as 'representative or typical cases' and the companies included in Paper VII could be seen as 'critical cases' using the terminology of Yin (2003).

A generalisation can be made from case studies, based on an 'analytic generalisation' ('replication' logic) contrasted with another way of generalising results; this is known as 'statistical generalisation' ('sampling' logic). In analytic generalisation, a previously developed theory is used as a template with which to compare the empirical results of the case study. If two or more cases are shown to support the same theory, replication may be claimed. (Yin 2003)

As discussed in Section 5.1.1, we have e.g. used two cases in our strategy study, where we predicted similar results. This can be referred to as a literal replication logic, which strengthens the external validity of the study (Yin 2003).

2.1.3 Multi-company studies

The multi-company studies used in research to build this thesis can be described as somewhat in between survey research and case studies.

Multi-company studies were used when developing industry-specific indicator models for the graphic arts industry (Paper II and Paper III). Moreover, this type of study was used when developing the use of industry-specific indicators and conditions for benchmarking (Paper V and Paper VI).

For the initial part of our research dealing with industry-specific indicators (Paper II and Paper III), we mainly wanted to study *how* industry-specific indicators, reflecting common significant aspects, could be defined and related to a reasonable inventory process and calculated to provide indicators for a company in the graphic arts industry. For this purpose, multi-company studies of a small number of companies (4-6) were used. To some extent, these studies are related to case studies using 'critical cases', referring to the terminology of Yin (2003). Furthermore, the studies could be described as surveys using a number of volunteer companies, as mentioned by Fowler (2002).

For the following indicator studies (Paper V and Paper VI), we had the added task of gathering enough data to develop the prerequisites for benchmarking. For this purpose, multi-company studies using 9 to 19 companies were used. These studies can be described as similar to surveys, although a probability sampling of the companies was not used. The goal of information gathering in these cases was not strictly to generate statistics, since we had to deal with the preconditions placed on the studies when the participating companies are being selected according to their willingness, interest and motivation to participate. To some extent, these later indicator studies could be related to case studies using 'representative or typical cases', referring to the terminology of Yin (2003).

2.1.4 Validity and reliability

Four tests are commonly used to establish the quality of any empirical social research, viz. construct validity, internal validity, external validity and reliability (Yin 2003).

Construct validity describes the accuracy of measurement and internal validity describes the plausibility of casual relationships. External validity describes if the findings of a study can be generalised. Reliability is the extent to which findings can be repeated, or reproduced, by another investigator. (Yin 2003) Communicability and applicability can be used as indicators of the external validity of case studies (Wallén 1996).

Different types of triangulation are often used to test validity of qualitative research. Triangulation is broadly defined as 'the combination of methodologies in the study of the same phenomenon' (Jick 1979). The principle is that the accuracy of research judgements can be improved by collecting different kinds of data bearing on the same phenomenon. For example, the strengths of

quantitative and qualitative can be used. There are different types of triangulation described: method triangulation (within- and between-method), data triangulation, theory triangulation and investigator triangulation. Within-method triangulation essentially involves cross-checking for internal validity or reliability while between-method triangulation tests the degree of external validity. (Jick 1979)

As discussed in Section 5.1.1, we have e.g. used method triangulation in the EMS study (Paper I) where questionnaires and semi-structured interviews were used in the study.

2.2 Specific considerations in this research

In Table 2, the papers included in the dissertation have been compiled to give an overview of used methods and techniques for data gathering, together with information on time/region for the research and the main aims of the different studies.

Data gathering techniques
In general, we used the following quantitative and qualitative techniques to gather data, which refers to all the information that was gathered during the research:

- Surveys, in the form of questionnaires, interviews and literature surveys.
- Different types of inventories regarding, for example, flows of energy, material and emissions, environmental impact, and the activities and products of graphic arts companies.
- Participative observations, in conjunction with e.g. visits for company interviews and training.
- Project meeting discussions, during which the views of project participants and focus groups were canvassed.

The interviews used in this research can be defined as semi-structured interviews, since they were based on common questionnaires and since the questions could be adapted to each individual company and be followed up by in-depth questions, if needed (Merriam 1994). The semi-structured interviews in both the EMS-study (Paper I) and the work with DfE (Paper IV) were documented in consultation with each company in order to ensure validity.

Participative observations were used in the DfE study (Paper IV), when developing and testing industry-specific work procedures and tools for DfE, and when developing and testing a working method to formulate and realise corporate sustainability strategies for the graphic arts industry (Paper VII).

Focus groups were used in the research dealing with sustainability strategies

(Paper VII). Focus group methodology is a way of collecting qualitative data, which involves engaging a number of people in informal group discussions focused around a particular topic or set of issues (Wilkinson 2004). Focus groups have a number of advantages over one-to-one interviews. Most obviously, they provide a way of collecting data relatively quickly from a large number of research participants. Furthermore, focus groups are more 'naturalistic' than interviews, i.e. closer to everyday conversation, and allow group members to interact with each other creating a synergistic effect.

All the collected data were analysed, compiled and reported back to the companies for verification purposes.

The selection of companies in the studies

The companies included in the multi-company studies (Paper II, Paper III, Paper V and Paper VI) and the case studies (Paper IV and Paper VII) were, with some exemption for the study in Paper VI, selected according to their willingness, interest and motivation to participate and develop their environmental or sustainability work. Most of the companies involved in the studies have been working with environmental tasks for quite a long time in some kind of structured way. The companies included in Paper VII could be seen as 'critical cases', using the terminology of Yin (2003). These companies showed a proactive and, in some areas, very extensive and high quality environmental work.

When developing the model of industry-specific environmental indicators for the graphic arts industry, we have mainly worked in close collaboration with the newspaper industry. Newspaper companies and newspaper printers but also commercial printers of different sizes were involved in these multi-company studies (Paper II, Paper III and Paper V). Some of the companies participated in more than one of the indicator studies. The printing houses we worked with when developing a work procedure and tools for DfE, represent those companies in the sector of commercial printing that are most common in Sweden, with regard to printing techniques and size (Paper IV). Regarding these aspects, these cases could be seen as 'representative or typical cases', using the terminology of Yin (2003) The reason for including an advertising agency in our work with DfE is because this group of companies has a large influence on graphic arts products and, hence, on future DfE works. The companies that participated in Paper VI were mostly large printing companies with very large printing capacities, being suppliers to a major print buyer.

Table 2 Compilation of papers included in the dissertation, with information on time/region for the research, the specific aims and the methods and techniques used for data gathering in the different studies.

Paper	Time/Region	Aims	Used methods
Paper I	Data from 1998. Sweden.	Evaluation of EMS efficiency searching for answers principally to the following questions: • Do companies give priority in their work to environmental aspects that have a major impact on the environment? • What actual environmental improvements have the environmental management systems achieved? • What are the costs involved with environmental management system work? Has it been possible to make any financial savings?	• Questionnaire to all 360 companies in Sweden with a certified environmental management system in Nov 1998 (49% response frequency). • Semi-structured interviews with 19 companies, selected by stratification from the group of certified companies.
Paper II	Data from 1998. Sweden.	• Clarify which parameters give relevant information regarding the environmental impact from the graphic arts industry. • Clarify parameters that are possible for SME in the graphic arts industry to measure. • Make recommendations regarding general environmental indicators for the graphic arts industry. • Provide the graphic arts industry with a powerful and reliable tool for environmental work. • Indicate the prerequisites for making comparisons between companies.	• Literature study. • Multi-company study with two commercial printing companies and two newspaper companies. • Extended inventory and analysis of energy, material and emission flows. • On-going workshops with project participants.
Paper III	Data from 2000. Sweden.	• Establish an industry-specific indicator model and a working procedure including an inventory tool for following-up of environmental work in the newspaper industry. • Illustrate the relationships between the industry-specific indicator model and commitments on a governmental level in form of the Swedish National Environmental Quality Objectives. • Extend the model of environmental indicators to comprise also some economic and social aspects.	• Literature study. • Multi-company study, with 9 newspaper companies where indicator data was later gathered from 6 companies. • Extended inventory and analysis of energy, material and emission flows. • On-going workshops with project participants.

Paper	Time/Region	Aims	Used methods
Paper IV	Data from 1998-2000. Sweden.	• Identify the needs of tools for design for environment (DfE) in the graphic arts industry. • Develop, test and implement a work procedure and applied tools for DfE in the graphic arts industry. • Develop a manual for applying DfE in the graphic arts companies, a checklist for applying DfE to printed products and a simple tool to allow an environmental assessment of printed products.	• Surveys (questionnaire to 780 companies with 17% response frequency and semi structured interviews in four companies). • Case studies of four SME companies (three offset printing companies and one advertising agency). • Participative observation. • Literature study. • Product range inventories. • Life Cycle Inventories (LCI). • On-going workshops with project participants.
Paper V	Data from 2001. Sweden.	• Adjust the model of industry-specific indicators and the inventory tool. • Develop a database for efficient processing of data. • Collect enough data to establish reference values. • Illustrate the practical use of the industry-specific indicators, e.g. for realising continual improvement of environmental performance.	• Multi-company study, with 14 newspaper companies. • Inventory and analysis of energy, material and emission flows. • On-going workshops with project participants.
Paper VI	Data from 2000 and 2002. Europe and USA.	• Identify the common significant environmental aspects of gravure and offset printing of publication printed products. • Define quantifiable environmental indicators reflecting the significant aspects. • Collect and compile data for the indicators. • Establish quantified starting points for environmental improvements. • Contribute to a platform for benchmarking.	• Multi-company study, with 14 and 19 gravure printers in 2000 and 2002, 8 and 9 offset printers in 2000 and 2002. • Literature study. • Questionnaires. • Inventory and analysis of energy, material and emission flows.

Paper	Time/Region	Aims	Used methods
Paper VII	Data from 2002 and 2003. Sweden, supply chains in Europe and USA.	• Develop, test and implement a working method to formulate and realise corporate sustainability strategies for the graphic arts industry. • Describe practical results. • Contribute to the process of bringing conceptual sustainability work into practice in industrial applications.	• Case studies of two companies representing different sections of the supply chain for printed products. • Literature study. • Modified SWOT analysis and inspiration from the PDCA (Plan Do Check Act) method used in ISO 14000 standards. • On-going workshops with focus groups. • Participative observation.

Assessment principles used

Both the of industry-specific indicators and the recommendations for reducing environmental impact in the industry-specific DfE tools were based on a combination of basic assessment principles and information about the environmental impact of various types of consumables, techniques, waste treatment, etc., related to the graphic arts industry, see Section 1.1.5.

Among others, the Swedish Environmental Quality Objectives (Swedish EPA 2006) the Swedish Environmental Code (SFS 1998:808) and the green indicators for a sustainable development as formulated by the Swedish Ministry of the Environment at this time (SOU 1998:170) were used as guiding principles when judging which environmental choices should be considered as being better than others. In the Swedish Environmental Code, we focused on resource management and eco-cyclic principles in addition to the product choice principle. In addition to national environmental principles formulated by Swedish authorities, our recommended set of industry-specific indicators was influenced by international concepts for environmental and sustainability indicators, e.g. GRI, OECD PSR, UNCSD and WBCSD. Special attention was given to the concepts aimed at an industry application, e.g. GRI and WBCSD, see Section 1.1.3. For the developed industry-specific DfE tools, the eco-design strategies (e.g. Brezet and van Hemel 1997) were a complement to the guiding principles mentioned above.

Evaluation of EMS (Paper I)

In the study described in Paper I covering all types of industries and organisations in Sweden, we evaluated the environmental and financial efficiency and defined areas of improvements of early certified environmental management systems, according to ISO 14001 and EMAS. Almost 200 Swedish companies contributed their experiences. The study was carried out in 1999.

The study comprised a questionnaire sent to all ISO-certified and EMAS-registered companies in Sweden (360 companies in November 1998 with a 49% response frequency), as well as semi-structured interviews with 19 companies selected by a stratification process from the entire group. The questionnaire and the documents used as a basis of the interviews are published in Zackrisson et al. (2000).

We interviewed the environmental officers or environmental co-ordinators of the companies with the interviews lasting from 2 to 5 hours. The interviews were documented in consultation with each company. In order to analyse the information from these interviews, we categorised it into quantitative and qualitative parameters. In total, 40 parameters were used. A selection of these parameters is described in Table 3 (Paper I). Various statistical methods were used to analyse the quantified parameters. A regression analysis was applied to study the correlation between two continuous parameters. When a continuous parameter was compared between two groups, a two-sided t-test for different variances was carried out.

Table 3 Selections of parameters used to analyse the results of the interviews (Paper I).

Parameter	Unit	Comments
1. Errors in identification	I-Errors/No	Describes whether serious mistakes have been made in the identification of environmental aspects. In this study, the criterion for 'serious' is that the environmental aspect has both a major environmental impact and a considerable effect on the financial outcome, as well as that the company agrees that a mistake has been made.
2. Errors in environmental assessment	EA-errors/No	Describes whether serious mistakes have been made in the assessment of environmental aspects. In this study, the criterion for 'serious' is that the environmental aspect has both a major environmental impact and a considerable effect on the financial outcome, as well as that the company agrees that a mistake has been made.
3. Target area production	% related to the plant and upstream	Describes the percentage of the stated targets that affect the company's own production and the sub-contractors' production.
4. Target area transport	% related to goods transport, business trips, travel to/from work	Describes the percentage of the stated targets that affect different types of transport.
5. Target area product	% related to the product use or disposal phase	Describes the percentage of the stated targets that affect the environmental impact of the company's own product or service during the use or disposal phase.
6. Target attack method	% source reduction	Describes the percentage of the stated targets that try to reduce the source of the problem's origin, e.g. by reducing consumption, reusing material, etc. The opposite is end-of-pipe solutions, e.g. chimneys and waste recycling.

Parameter	Unit	Comments
7. Target payback	% of targets with maximum one year's payback	Describes the percentage of the revenues and/or savings for the stated targets that exceed or is expected to exceed expenses after just one year. If revenues in relation to expenses are expected to be large, it is assumed that payback time is less than one year.
8. Target payback cause	% of one year's payback that is only due to revenue increase	Explains why payback, according to the above, is achieved after just one year. The percentage indicates targets with one year's payback, according to the above, due to increased revenue alone.
9. Target follow-up	% relative measures	Gives one rating for the follow-up of environmental targets by giving a mean average for all stated targets according to the following: 100% = measure related to something relevant, e.g. production size. Relation to years has only been accepted when this is considered relevant. 50% = non-related measure, e.g. the number of chemical products. 0 % = only verification of that measures/activities have been carried out. No value has been calculated for companies having less than 3 targets.
10. Target results physical	To what extent has emission or resource reduction been achieved: 0%=no physical set targets, 50%= physical set targets, 100%=physical reached targets. Mean average for all targets.	Gives one rating for the results of the environmental target work by explaining to what extent emission or resource reduction has been achieved. Targets such as "introduce a waste sorting system", that have been reached but where there is no quantitative target, are considered to be 50%. An ambitious target that has been partly reached is considered to be 90%. No value has been calculated for companies having less than 3 targets. Note that work with indirect environmental effects through for example staff training, is not rewarded by this parameter.

The developing of industry-specific environmental indicators (Paper II, Paper III, Paper V and Paper VI)

The development of industry-specific environmental indicators for the printing industry was made in an iterative process. The selection of measurements and indicators has been made on the basis of (i) literature studies of environmental aspects in the graphic arts industry, (ii) extended inventories or environmental reviews, e.g. of emissions, flows of energy and material, and generated waste in the case of companies studied, (iii) the calculation and analysis of a wide range of indicators for the same companies and (iv) discussions in project reference groups. With the results of the extensive, detailed inventories, it was possible to show proportions among the different types of material flows.

The extended inventories that were used in our introductory indicator study (Paper II) examined a lot of aspects of concern e.g. the use of energy was measured and specified as different types, all material flows were more or less quantified, inventories of transport of the printing substrate to the printing

industry and the transport of printed products from the printing industry to the customer were made.

The selection of indicators to be included in the general industry-specific model was based on the following criteria. The indicators should:

- Be relevant, from an environmental point of view.
- Be based on scientific and technical principles.
- Be well defined, with instructions for inventorying and calculation.
- Be able to be quantified with reasonable resources.
- Consist of as few indicators as possible, while being comprehensive.
- Be easily understood.
- Be able to be measured and followed-up in time periods.
- Be possible to influence.
- Be comparable among different time periods and different companies.

There are sometimes conflicts among these different criteria raised for selecting and working with indicators.

In our research concerning indicators, we used the term 'utility' to express the value of a company. A number of alternative measurements of utility were tested (Paper II). The selection of measurements for utility in the industry-specific indicator model was mainly based on the requirement that:

- The parameter gives a fair picture of the utility of the company.
- It is possible to measure the parameter.
- Companies are willing to communicate the information officially.

Alternative measurements, representing the physical products, were:

- Total weight of the products
- Total area of the products
- Total amount of printed products

Alternative financial measurements were:

- Annual turnover
- Added value
- Number of full-time employees

Generally, in our indicator research when the companies were asked for environmental data relating to their production, we asked for data representing the entire annual production. Although product specific data would in some cases have been more relevant, we took into account the practical aspects, in order to make the inventory process at each company practical. Nevertheless, the collected data are high quality, industry-specific data, since they are reviewed and compiled by researchers with industry-specific knowledge and familiarity with the data, due to a close dialogue with the participating companies.

The developed industry-specific indicators are compiled in 'models'. The industry-specific indicator models describe the environmental performance of graphic arts companies. The models consist of a number (a set) of well defined, general environmental indicators for the graphic arts industry, reflecting the significant environmental aspects. Furthermore, the models include a method for inventorying and defined manners of calculating, storing and benchmarking data.

The developing of industry-specific work procedures and tools for DfE (Paper IV)
In this thesis and in our research dealing with design for environment (DfE), the term 'product' is used in a wider sense to include both goods and services.

The industrial benefit of a product in this thesis relates to values, such as functionality, customer value, profit, aesthetics, image and the overall quality of the product, including environmental compatibility.

The initial part of the DfE study (Paper IV) when identifying the interest and needs of tools, and clarifying the current product development situation in commercial printing companies, comprised a questionnaire sent to 780 companies in the graphic arts production chain (with a 17% response frequency) and semi-structured interviews in four companies.

When developing industry-specific work procedures and tools for DfE in the graphic arts industry we used case studies of four small and medium sized companies (three offset printing companies and one advertising agency). For specific information regarding data gathering techniques in these case studies, see Table 2.

The developing of a working method to formulate and realise corporate sustainability strategies (Paper VII)
The main research question in this study base on two case studies was how the conceptual frameworks for formulating and realising a corporate sustainability strategy can be brought into practice.

A working method to formulate and realise a corporate sustainability strategy was established and tested. This resulted from ongoing workshops with project groups from the companies studied, together with analysing the stages between the workshops. This iterative process is seen as part of the results and is further described in Section 3.1. The project groups can be described as expert groups or focus groups.

The established working method is mainly inspired by the Plan-Do-Check-Act (PDCA) methodology in ISO 14001, the International Standard for

Environmental Management Systems (ISO 2004) and the SWOT methodology. Our SWOT was modified, in the sense that we focused the analysis on the external factors (opportunities and threats in society) that the companies face. Furthermore, we grouped, prioritised and thereby allocated the relative importance of the individual SWOT factors.

Data gathered in the workshops, e.g. all identified external and internal SWOT factors, how these factors are categorized and prioritized, the suggestions for objectives, targets and action plans, were documented in pre-formulated, template protocols. These template protocols were revised and improved on, according to agreements made in the project groups during the case studies. Furthermore, general notes were taken at each workshop, documenting the iterative process.

To be considered as successful, a working method for formulating and realising a corporate sustainability strategy should prove useful for organisations in real life and enable an organisation to formulate a strategy, based on a shared vision within a reasonable timeframe. When it comes to realising a sustainability strategy, the degree of success also depends on the ability of the strategy to contribute to an improved sustainability performance. These two considerations of success have different time perspectives.

3 Results

This chapter summarises the results of the Papers included in this thesis. In addition, in some cases, the results of the Papers are related to results in the research reports behind the papers.

3.1 Environmental management and strategy

3.1.1 Evaluation of environmental management systems

Data were gathered from a questionnaire and semi-structured interviews (Paper I) in order to enlighten the 3 pre-stated questions, viz. whether companies give priority in their work to environmental aspects that have a major impact on the environment, what are the actual environmental effects and what are the financial effects that certified EMSs in Sweden have had so far. A selection of the interview results are summarized in Table 4.

Table 4 Interview results for the parameters described in Table 3 (Paper I).

Parameter	Results
1. Errors in identification	A small amount, 26%, of companies has failed to identify some environmental aspect that would have been of significance to the company.
2. Errors in environmental assessment	A small amount, 32%, of companies has failed to assess some significant environmental aspect as being important.
3. Target area production	Most of the companies' targets (average 72%, median 80%) focus on problems in their own or their subcontractors' businesses. The equivalent percentages for just the industrial companies are average 83%, median 80%. There are no significant differences between large and small-sized industrial companies. Service and trade companies have, as expected, considerably fewer production targets, average 41%, median 38%. The difference between the industrial companies and the service and trade companies is significant according to the t-test.
4. Target area transport	Only a few of the companies' targets (average 10%, median 0%) focus on transport. There are no significant differences between large and small-sized industrial companies or between industry and service and trade.
5. Target area product	Few of the companies' targets (average 18%, median 0%) focus on problems related to the use and disposal phase of their own products. The equivalent percentages for just the industrial companies are average 8%, median 0%. There are no significant differences between large and small-sized industrial companies.
6. Target attack method	Many of the companies' targets, average 77%, deal with source reduction. There are no decisive differences between industry and service and trade.
7. Target payback	Over half (average 59%, median 60%) of all environmental targets give or are expected to give a financial profit after just one year. There are no significant differences between large and small-sized industrial companies or between industry and service and trade. However, the variation between individual companies is large, 0 to 100%.

Parameter	Results
8. Target payback cause	Just over half (average 52%, median 66%) of the financially profitable targets according to the above are such, simply because they give, or are expected to give, increased revenues. On the other hand, the other half achieves rapid profits thanks to savings in expenses. There are no significant differences between large and small-sized industrial companies or between industry and service and trade. The variation between individual companies is large, however, 0 to 100%.
9. Target follow-up	The rating for the target follow-up gives a mean average of approx. 60% for all the companies' targets. There are no significant differences between large and small-sized industrial companies or between industry and service and trade. However, variation between individual companies (and targets) is considerable, 0 to 100%. According to a regression analysis, there is correlation between the Target follow-up parameter and the Target results physical parameter.
10. Target results physical	The rating for the results of the environmental target work gives a mean average of 66% for all the companies' targets. The variation between individual companies (and targets) is considerable, 10 to 100%. For just the industrial companies, the average is 70%, median 69%. There are no significant differences between large and small-sized industrial companies. The t-test indicates that on average, EMAS companies have better environmental results (according to the parameter Target results physical) than the non-EMAS companies, average 80% and 57% respectively.

The study, described in Paper I and Zackrisson et al. 2000, analyses, among other things, the processes used in the companies when identifying, assessing and then prioritising the significant environmental aspects, viz. for which aspects the environmental targets were formulated. To be able to judge the Parameter 1 "Errors in identification" and Parameter 2 "Errors in environmental assessment", see Table 3 and Table 4. The relevant aspects were listed beforehand by the interviewing researchers, based on previous environmental assessment studies and industry specific knowledge. The errors found, according to Parameter 1 and 2, were agreed to by the company in each case.

The identified significant environmental aspects corresponded well, in general, with the areas within which companies had established environmental targets, see Table 5. The study indicated that most of the companies had environmental targets in the majority of the areas that were regarded as important in the study, although there was room for improvement with regards which environmental aspects the companies had chosen to work with.

Waste was the most common environmental target area. The results from the questionnaire and the interviews indicated that the majority of companies felt the greatest environmental improvements had been achieved in the area of waste. Better waste treatment and less waste were the most frequent answers.

Table 5 Common significant environmental aspects and environmental targets, according to the questionnaire. The number of companies that specified each area is given as a percentage. (Paper I)

Common significant environmental aspects	Common environmental target areas
Energy consumption (71%)	Waste (78%)
Waste (69%)	Energy consumption (73%)
Transportation of goods (67%)	Emissions from the plant (62%)
Emissions from the plant (62%)	Transportation of goods (49%)
Chemical management (55%)	Chemical management (48%)
Input goods/raw materials (55%)	Input goods/raw materials (48%)

Some of the most important observations concerning the environmental efficiency of EMS were:

- On average, nearly 70% of the physical targets of the certified companies, regarding emission or resource reduction, were achieved, see Parameter 10 in Table 3 and Table 4.
- The environmental performance of EMAS-registered companies seemed to be better than that of companies only having ISO 14001.
- Companies using environmental indicators to follow up environmental objectives and targets seemed to attain a better environmental performance than others. The interview results showed that the better a company's target follow-up, the better its estimated environmental results.
- Half the environmental objectives and targets would also have been achieved without EMS. When the companies were asked to indicate on a scale of 1 to 6 the extent to which the EMS has reduced the environmental impact from the company, most of the answers tended to be somewhat closer to “not at all” than “to a very great extent”, see Figure 2.

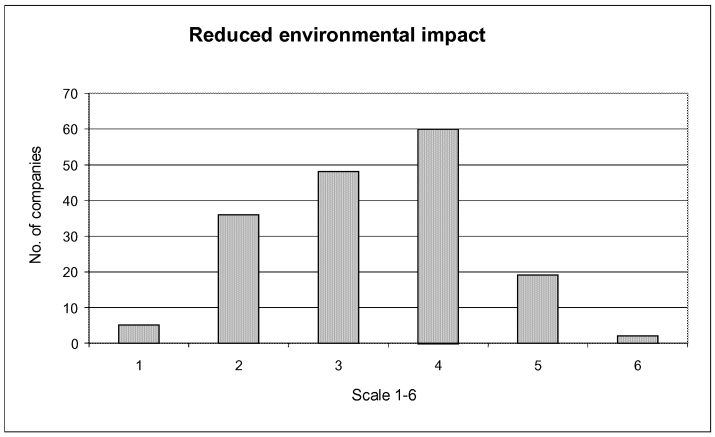

Figure 2 Assessment by companies of the extent to which the environmental impact from the company has been reduced as a result of its environmental management system. On a scale of 1-6, where 1 is "not at all" and 6 is "to a very great extent". (Paper I)

Some of the most interesting observations concerning the financial efficiency of EMS were:

- Half of all the environmental objectives and targets gave payback within one year, through cost savings or increased revenues.
- The largest cost savings were made through reduced expenses for energy, waste treatment and raw materials.
- Several companies thought that their position on the market had been strengthened thanks to EMS. On a scale of 1 to 6, most of the companies reported that their market position had improved. Most of the answers tended towards "to a very great extent" rather than "not at all", see Figure 3. One third of the companies answering the questionnaire showed an increase in revenue as well.

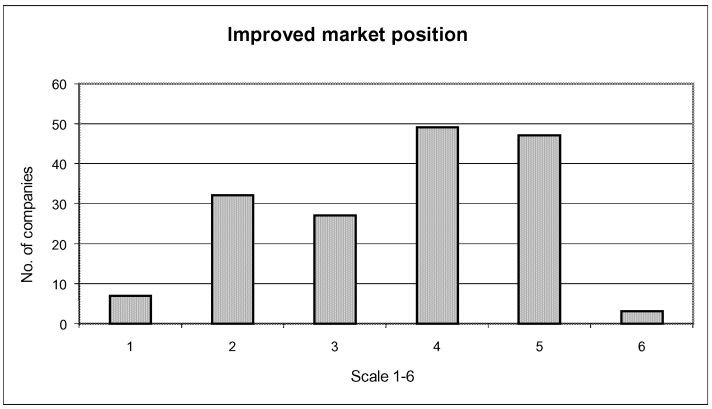

Figure 3 The companies' assessment of an improved market position, as a result of their environmental management systems, on a scale of 1 to 6, where 1 is "not at all" and 6 is "to a very great extent". (Paper I)

Using the results of this study, it was possible to estimate the cost of introducing and operating environmental management systems in Sweden. For example, compared with the turnover, expected to be around SEK 50 million, of a company with 50 employees, we could see that a company should not be deterred too much by having to spend the equivalent of 0.4% of its turnover and 1.5% of its working hours on implementing the system; and the equivalent of 0.08% of its turnover and 0.8% of its working hours on operating it. Yet a small-sized company with 10 employees might find that the costs for the implementation phase and the operating of an environmental management system would constitute a decisive barrier. However, it ought to be possible for these costs to decrease in the future.

By the time this evaluation of certified environmental management systems in Sweden took place, the following four areas were identified as a priority to make EMS more efficient (Paper I):

- Clarify the identification process and assessment of environmental aspects.

  If the environmental efficiency of environmental management systems is to make headway, it is essential to identify and give priority to the correct significant environmental aspects. This will enable the companies to focus their resources on the areas that give the maximum environmental benefit in relation to the financial input.

  A thorough, professional assessment of environmental aspects forms the

basis for all the environmental work of a company, as well as the basis for effectively achieving improvements, which is essential if the environmental management work is to progress and develop. Based on this and the fact that working with significant environmental aspects was what companies felt was the most difficult task of environmental management work, there was real reason for companies to receive support in this area in the future.

- Improve the follow-up of environmental work.

  The tools necessary for continuing with improvements were, according to the questionnaire responses, chiefly linked to better follow-up of the environmental targets with, for example, environmental indicators. This could lead to better environmental results and improved external communications. Backup was needed here in the form of real examples of environmental indicators, measuring methods and data for comparison in each industry.

- Link EMS to product design and put more focus on the manufactured products (goods and services) with a life cycle perspective.

  At the time of the EMS evaluation, the study showed that the focus of companies was mainly on waste, energy and emissions. This was often linked to cost savings and had pedagogic consequences. To ensure continual improvements in future environmental management systems and increase financial profits, the focus of attention needed to be shifted to the companies' own products.

  Proactive environmental efforts should focus on products and their functionality. For companies that manufacture goods or supply services, rather than producing raw materials, environmental analyses often reveal that the greatest environmental impact these companies produce is due to the use and/or disposal of the products themselves (Zackrisson 2005). The EMS evaluation however showed that few of the environmental targets these companies set up as part of their environmental management systems actually dealt with the total environmental impact of manufactured products.

- Streamline and co-ordinate different management systems.

  It would be expedient to have fewer bureaucratic routines for environmental management systems. Many companies announced increased co-ordination in their quality and health and safety systems as well as a switch to electronic documentation management in order to simplify and streamline their business management.

The conclusions from this evaluation, together with other influences, inspired our research with developing tools for environmental management in the graphic arts industry. Out of the four identified areas that needed to be developed, we continued the research presented in this thesis, mainly by developing two of the areas for the graphic arts industry, viz. environmental indicators and design for environment (DfE) or eco-design of printed products. The research with indicators is described in the Papers II, III, V and VI and the research with eco-design for printed products is described in Paper IV. In addition to this, a developed working method for formulating and realising a corporate sustainability strategy for the graphic arts industry is described in Paper VII. The processes of identification and assessment of environmental and sustainability aspects for the graphic arts industry were integrated into our work with indicators, eco-design and strategies.

3.1.2 Developing sustainability strategies

A sustainability strategy can be seen as a basis for sustainability management in an organisation. One of the fundamental prerequisites for efficient sustainability management, or environmental management as part of it, is that a shared vision deals with the significant sustainability aspects for the company.

Many have discussed the definition of a strategy and methods for making strategies, see section 1.1.2. The definition of a strategy used in this thesis is the following: 'A strategy comprises both long-term objectives and a way of achieving these by the use of concrete working programmes. The long-term objectives are summarised in a vision.' see Figure 4.

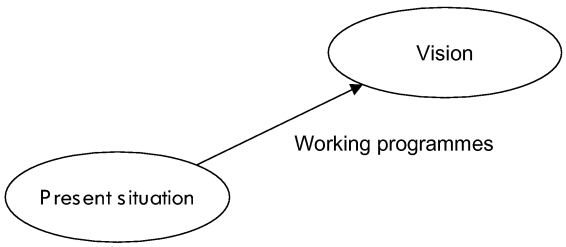

Figure 4 Strategy – vision, including long-term objectives and a way of achieving the objectives. (Paper VII)

The working method established in this study consists of six stages. The first stage is to carry out an analysis of the current business climate in society and in a particular company. To accomplish this first stage, a modified SWOT analysis is used. In the second stage, the significant aspects in each of the areas of the sustainability concept are identified for the particular company. In the third stage, a vision and objectives are formulated for the identified significant

aspects. In stage four, the objectives are divided into detailed targets. Stage five deals with the implementation of the strategy. In stage six, the implementation is followed up. The established corporate sustainability strategy working method and inputs to the different stages of the method are illustrated in Figure 5.

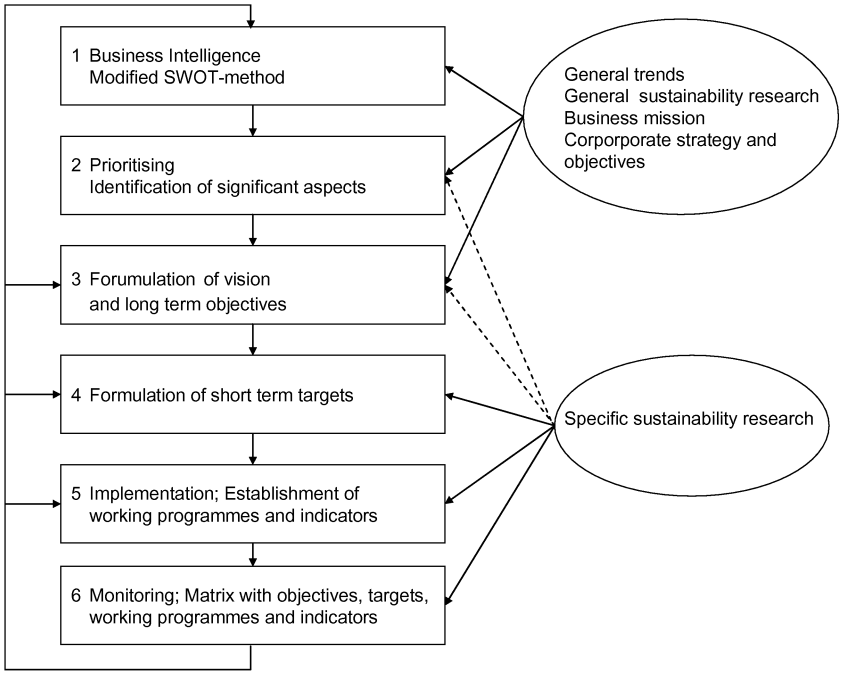

Figure 5 The established corporate sustainability strategy working method. (Paper VII)

To illustrate the outcome of the first stage of the strategy working method (the business intelligence process) in the form of a modified SWOT analysis, an example is given in Table 6. The modified SWOT analysis focuses on external factors (opportunities and threats in society).

In Table 6, some of the results from the modified SWOT analysis done in one of the studied companies for the social dimension of the sustainability concept are given.

The modified SWOT analysis is followed by several prioritising and creative stages. The aim of the modified SWOT analysis is to help the company to identify its significant aspects in each of the areas of the sustainability concept.

Another outcome of the SWOT analysis is to inspire the establishment of working programmes.

The identification of significant aspects in the second stage of the working method is based on the prioritised and analysed external factors (opportunities and threats) and based on all the different inputs, as illustrated in Figure 5. As an example of specific sustainability research, different kind of reviews and impact assessments can be mentioned.

Table 6 An example of the results from the modified SWOT analysis, where prioritised external social factors, two prioritised opportunities and two prioritised threats are illustrated, together with the strengths and weaknesses that might have an impact on these external factors. Suggested preliminary measures that logically fell out of the scope of the analysis are listed too. (Paper VII)

Prioritised Opportunities/Threats Social	Strengths	Weaknesses	Preliminary Suggested measures
• Attractive employer. • Great potential in training personnel. • Lack of skilled people for recruitment. • Printing Industry low popularity factor.	• Sound finance. • Brand name. • Entrepreneurship. • Personnel loyalty. • Technical knowledge. • Working conditions. • Environmental performance. • Relations with labour unions.	• Inadequate objectives. • Insufficient routines for planning and responsibilities. • Age structure in management. • Employee training programme and internal carrier. • Non-uniform company culture.	• Development of management principles e.g., according to ISO 9001. • Strengthen internal and external communication. • Extend the employee training programme. • Recruitment to certain positions.

The results of stages three and four and the starting up of stage five of the working method are described as an example from one of the companies in Table 7. The work with one of their formulated long-term objectives, i.e. their objectives in the social area, has been illustrated using a matrix.

Table 7 An illustration of the work in one of the studied companies, with one of the long-term objectives, using a matrix showing the relationships among the objective, the more detailed targets, the working programmes and the indicators for following up the different activities building up the working programmes. (Paper VII)

Long-term objectives	Short-term targets	Working programmes (activities)	Indicators
To engender an improved and congenial place of work	To initiate distinct and supportive management	•To delegate responsibility (management by objectives instead of management by details). •To bring the gender equality plan up to date. •To initiate visible leadership. •To develop managers' leadership skills. •To give attention to excellent results. •To make a description of the desired company culture.	•The no. of people working under 'management by objectives'. •Indicators from the plan. •Employee perception based on a staff questionnaire. •Yes/No.
	To have motivated employees	•Employee welfare. •Initiate performance reviews. •To develop/maintain employees' skills and expertise, introduce routines. •Improve communication, introduce routines.	•Frequency of social functions. •Employee perception based on a staff questionnaire. •No. of reviews carried out. •Yes/No. •Yes/No.

This established working method for formulating and realising a corporate sustainability strategy is a general one and may be applicable to different types of industries and organisations. However, in order to identify the significant aspects and focus the strategy work on the relevant actions, i.e. to make the strategy successful, the process of formulating and realising the strategy needs to be based on industry and company specific sustainability knowledge.

3.2 Environmental indicators for the graphic arts industry

The developed general, industry-specific indicators for the graphic arts industry were formulated with environmental impact measurements as the numerator and measurements for utility used as the denominator (Paper II, III, V and VI):

$$Environmental\ indicator = \frac{Environmental\ impact}{Utility}$$

This means that the lower the indicator figure, the better the environmental performance. This is true for all suggested environmental impact measurements but not always for the suggested financial and social aspect measurements.

It is important to define the scope and limits, the system boundaries, for indicators when they are formulated, used and later communicated. As a rule of thumb when using related indicators, we have used the principle that the environmental measurements should have the same system boundaries as the data of utility to which they will be related. In our indicator studies, the system boundaries were placed around the company property, which means that they embrace all that is taken in and out through the company gates. Exceptions are, however, made for emissions caused by the use of purchased electricity and district heating (Paper II, Paper III and Paper V). When these are counted, the system boundary is moved upstream to the actual production of the electricity or the district heating. In addition, exceptions are made for transport and emissions from transport, since these can be expected to cause a significant environmental impact. In our studies of indicators, the use and handling of the products in the waste treatment phase were excluded, in accordance with the defined system boundaries.

The general indicators developed for the graphic arts industry take into account the environmental aspects, including the flows of resources that are regarded as being the most important or significant for offset, flexographic, gravure and digital printing.

3.2.1 Industry-specific environmental indicator models

A number of general environmental indicators for the graphic arts industry, reflecting the significant environmental aspects were defined in two compatible industry-specific indicator models. The main model, for which the development

and use were described in Paper II, Paper III and Paper V, was originally developed for companies using the offset printing and flexographic printing techniques (Paper II). Special focus, when modifying and adjusting the model and collecting enough data for establishing reference values, was on the application for the newspaper industry, including the coldset offset printing technique (Paper III and V). In addition, this model is valid for other printing techniques, such as digital and gravure printing, with some adjustment of the definitions of the environmental measurements. For gravure printing, examples of such adjustment are described in Paper VI.

The definitions of environmental impact measurements in the main model are described in Table 8. In addition, we added some financial and social aspect measurements to the model, which are described in Table 9. With the exception of measurements concerning the distribution of the newspaper and the social aspect measurements, the model is also applicable to the commercial printing sector.

'Total weight of products' expressed in tonnes and 'Annual turnover' expressed in SEK ´000s (EUR 1= SEK 9.30, February 2006) are used in the main model as measurements for utility. Here, one recommended measure for utility represents the production, while another is financial.

Multi-company studies of newspaper companies were used as a basis for developing our original industry-specific model (Paper III and Paper V). In accordance with our first study, dealing with developing industry-specific indicators (Paper II), the following studies were used to illustrate the possibilities and difficulties in real life for investigating data and calculate the suggested indicators. The studies also provided information on whether the suggested indicators could actually illustrate the issue they were formulated to illustrate. Further on, we wanted to do some simplifications, since we then had some experience from the use of the original concept presented in Paper II. At this time, we started a discussion on industry-specific, significant and possible financial and social indicators with the newspaper companies. The companies tried to quantify different suggested measurements, which ended up in the definitions shown in Table 9. Among the suggested social indicators, the measuring of stakeholder opinions was prioritised.

Table 8 Industry-specific environmental indicator model for the graphic arts industry, including the newspaper industry. Definitions of environmental impact measurements. (Paper V)

ENVIRONMENTAL IMPACT MEASUREMENT	DEFINITION	UNIT
ENERGY		
Use of energy	Electricity, heating and fuel, specific energy source types.	MWh
Non-renewable energy	Energy based on sources that are not renewable within 200 years. E.g. coal, mineral oil, peat and uranium for nuclear power.	MWh
MATERIALS		
Materials, total consumption	Printing paper (printing carrier), total consumption.	Kg
Non-renewable materials	Film + metal + mineral oil in printing ink + UV ink + other plastic-based inks (e.g. toner for digital printing)	Kg
Printing paper not accepted by environmental labelling criteria	The criteria for the EU Flower, Nordic Swan or Swedish Society for Nature Conservation's Good Environmental Choice are considered.	Kg
Hazardous materials	The definition of hazardous here relates to the Swedish observation list and labelling of chemicals.	Kg
TRANSPORTATION		
Transport to the company	Transport of printing carrier from the place of production (paper mill). Registered in tonnes per km and taking into account the means of transport. Calculated with regard to CO_2 from fossil fuels, using accepted emissions factors.	Kg CO_2
Distribution of the newspaper	Fuel consumption, specific type of fuel for distribution to readers within the ordinary area of distribution. Calculated with regard to CO_2 from fossil fuels, using accepted emissions factors.	Kg CO_2
Business travelling	Specific means of transport, e.g. car, train, aircraft. Registered in passenger km. Calculated with regard to CO_2 from fossil fuels, using accepted emissions factors.	Kg CO_2
EMISSIONS TO AIR (excluding emissions from transport)		
CO_2 emissions	CO_2 emissions from fossil fuels from production and use of energy bought in and, possibly, produced by the company itself.	Kg
NO_X emissions	Emissions from production and use of energy and, possibly, own emissions.	Kg
SO_2 emissions	Emissions from production and use of energy and, possibly, own emissions.	Kg
VOC emissions	Emissions of volatile organic compounds (VOCs). Organic solvents/products, e.g. damping solutions and cleaning agents, at a vapour pressure of at least 0.01 kPa are volatile at 20 °C.	Kg
WASTE		
Waste, total	Total amount of waste including paper waste and used metal, for example.	Kg
Landfill waste	The amount of waste sent to landfill.	Kg
Hazardous waste (excluding electronic waste)	Hazardous waste according to Swedish legislation.	Kg
Electronic waste	Total electronic waste, including both the hazardous and the non-hazardous parts.	Kg

Table 9 Industry-specific indicator model for the graphic arts industry. Definitions of financial and social aspect measurements, adapted to the newspaper industry. (Paper V)

FINANCIAL AND SOCIAL ASPECT MEASUREMENT	DEFINITION	UNIT
Cost of environmental work	All environmental protection costs, except investments according to definitions from SCB, Statistics Sweden, e.g. own labour costs, consultants, fees for environmental control and waste treatment.	EUR
Proportion of customers (readers and advertisers) who consider environmental issues to be important	Given a scale of 1-6 in a questionnaire sent to stakeholders, answers "5" and "6" are considered to mean "important" in comparison with the overall responses.	%
Proportion of customers (readers and advertisers) who consider the newspaper's monitoring of environmental issues to be satisfactory	Given a scale of 1-6 in a questionnaire sent to stakeholders, answers "5" and "6" are considered to mean "to a sufficient extent and in a satisfactory fashion" in comparison with the overall responses.	%

A selection of the general environmental indicators was tested for monitoring the environmental impact of companies using gravure and heatset offset printing techniques for the production of publication printed products (Paper VI). This common selection of quantifiable indicators, together with information on the existence or not of a certified environmental management system (EMS) in the companies, are presented as a useful short version of the industry-specific environmental indicator model, see Table 10. This selection of indicators was tested by a print buyer working with a large number of suppliers from different countries, setting a reasonable level for supply chain collaboration.

The focus of Paper V, which was to collect enough data to establish reference values and to illustrate the use of industry-specific indicators, resulted in a thorough set of data on the suggested main indicator model and users' experiences, see Section 3.2.2 and Section 3.2.3 respectively.

Table 10 Definitions of quantifiable, common environmental indicators for gravure and heatset offset printing. The indicators reflect general significant environmental aspects of the two printing methods. (Paper VI)

ENVIRONMENTAL INDICATORS	UNIT	DEFINITION GRAVURE PRINTING	DEFINITION OFFSET PRINTING
Use of Paper	tonnes/year	All paper used for the production. Data are balanced with regards to storage.	See Gravure printing.
Paper Waste	tonnes/year tonnes/tonne product	All paper rejected in connection with printing and finishing, e.g., paper wrapping, paper used for adjusting the press, waste from cutting, etc.	See Gravure printing.
Use of Energy	kWh/tonne product	The use of energy, process energy (i.e. the use of energy by presses, dryers and toluene-recycling units) and energy used for heating the print shop. All types of energy are added together.	The use of energy, process energy (i.e. the use of energy by presses and gas for heatset drying) and energy used for heating the print shop. All types of energy are added together.
Consumption (loss) of Volatile Organic Compounds (VOC), including Toluene	kg/tonne product	The amount of toluene is calculated as the amount of purchased toluene (in ink, etc.) minus sold recovered toluene minus the amount of toluene in ink and rags sent for destruction. (Data are balanced with regards to storage.) This calculation gives the emission of toluene after passing adsorbers, the emission of toluene via the general ventilation system (not via a recovery unit) and the loss of toluene with the product.	Volatile organic compounds (VOC) are organic compounds that, at a temperature of 20°C (293.15K), have a vapour pressure of at least 0.01 kPa (according to EU Directive 1999/13/EG). The amount of VOC is calculated as the purchased quantity, balanced with regards to stock keeping minus the amount of VOC destroyed in the heatset dryer.
Hazardous Waste	kg/tonne product	The waste fractions that are handled as hazardous waste in any specific company. Excludes electronic waste.	See Gravure printing.

In order to connect the significant environmental aspects and practical environmental work in the graphic arts industry to environmental commitments on a governmental level, relationships among the indicators in the developed main model and the Swedish National Environmental Quality Objectives were illustrated (Paper III). The strongest connections between suggested

measurements for environmental impact in the indicator model and the Swedish National Environmental Quality Objectives are summarised in Table 11.

Table 11 The strongest connections between suggested measurements for environmental impact in the main indicator model and the Swedish National Environmental Quality Objectives. (Adapted from Paper III.)

ENVIRONMENTAL IMPACT MEASUREMENT	SWEDISH ENVIRONMENTAL QUALITY OBJECTIVE
ENERGY	Limited influence on climate Natural acidification only
MATERIALS	(see the specific measurements in this area)
Materials, total consumption	Sustainable forests
Non-renewable materials	Limited influence on climate
Printing paper not accepted by environmental labelling criteria	Sustainable forests
Hazardous materials	A non-toxic environment
TRANSPORT	Limited influence on climate Natural acidification only
VOC emissions	Clean air A good urban environment
WASTE	A good urban environment A non-toxic environment

3.2.2 Data on industry-specific environmental indicators

Data on the industry-specific environmental indicators, resulting from the case studies in Paper II, III and V, are listed in Table 12. The mean values from the different studies are in the same range, which indicates the current performance of graphic arts companies using coldset offset printing technique according to these indicators.

Table 12 Data on industry-specific environmental indicators for the graphic arts industry. (The total weight of the products in tonnes is used as a measurement for utility.) Most data represent the coldset offset printing of newspapers (Paper II, III and V). See notes in the table for further details about data.

INDICATOR, related to weight of products	UNIT	Range 1998 4 comp.[1)]	Mean 2000 6 comp.[2)]	Mean 2001 14 comp.[3)]	Mean 2002 19 comp.[4)]
ENERGY					
Use of energy	MWh/tonne	0.52-0.55	0.76	0.73	0.79
Non-renewable energy	MWh/tonne	0.13-0.33	0.39	0.32	0.35
MATERIALS					
Materials, total consumption	Kg/tonne	1110-1370	1140	1139	1144
Non-renewable materials	Kg/tonne	0.50-13	11	12	9.1
Printing paper not accepted by environmental labelling criteria	Kg/tonne	0-1370	74	6.8	42
Hazardous materials	Kg/tonne	(0-0.53)	1.2	0.26	0.62
TRANSPORT					
Transport to the company	Kg CO_2/tonne	-	34	14	29
Distribution of the newspaper	Kg CO_2/tonne	-	99	150	130
Business travel	Kg CO_2/tonne	-	4.2	8.9	14
EMISSIONS TO AIR (excluding emissions from transport)					
CO_2 emissions	Kg/tonne	-	39	28	30
NO_X emissions	Kg/tonne	-	0.08	0.064	0.079
SO_2 emissions	Kg/tonne	-	0.07	0.052	0.059
VOC emissions	Kg/tonne	0.17-0.45	0.69	0.34	0.26
WASTE					
Waste, total	Kg/tonne	130-420	160	160	170
Landfill waste	Kg/tonne	0-6.3	7.1	3.6	2.8
Hazardous waste (excluding electronic waste)	Kg/tonne	1.1-9.4	4.3	4.6	4.4
Electronic waste	Kg/tonne	-	0.20	0.28	0.24
FINANCIAL ASPECTS					
Cost of environmental work	EUR/tonne	-	27	9.9	7.6

[1)] Commercial printing companies (offset and flexographic technique) and Newspaper companies. Data are published in Paper II.
[2)] Newspaper companies. Data are published in Enroth 2001 and Widing and Enroth 2001.
[3)] Newspaper companies. Data are published in Paper V.
[4)] Newspaper companies. Data are published in Enroth et al. 2003.

The original model of the industry-specific indicators from 1998 was developed. This is the reason why data are missing in some cases and placed in brackets, when the definition of the indicator changed.

The time for environmental work in the companies was recalculated as costs, using the template of EUR 440/day when calculating the "Cost of environmental work" indicator.

For the suggested social indicators, 'Proportion of customers who consider environmental issues to be important' and 'Proportion of customers who consider the newspaper's monitoring of environmental issues to be satisfactory', we obtained the preliminary mean values of 80% and 24%, respectively (Enroth et al. 2003).

From the indicators based on the total weight of products, it has been seen that the range of values for different kinds of indicators varies widely among the companies studied. Based on the results in Paper V, with data from 2001 (14 Swedish companies using coldset printing technique), there was a 77% difference between the maximum and minimum values for the use of energy, which means that this area offered many of the companies great potential for both environmental improvements and financial savings. Of the total energy used by the average company in this study, about 70% was electricity and 30% was district heating. There was only an 8% difference between the maximum and minimum values as regards the use of materials (printing paper). This illustrates that the companies are consciously working to reduce their paper waste. The mean paper waste value for the entire group of companies in this study was 12% (i.e. paper waste in relation to the total amount of paper).

Our studies indicate that hazardous chemical products (0.62 kg/tonne of product, representing 19 companies in 2002) in the newspaper industry, are not used to the great extent that has been assumed earlier. In addition, our results concerning the emissions of volatile organic compounds (VOC) show that these are generally low from Swedish newspaper companies (0.26 kg/tonne of product, representing 19 companies in 2002).

In Paper V, the advantages of using complementary measurements of utility ('Total weight of product' and 'Annual turnover') and mean values from specified classes of companies when analysing data, are illustrated. As an example of this, data for the Use of Energy indicator are shown in Figure 6 for a specific class of companies participating in the study (Paper V). The class of companies shown is 'Newspaper companies with printing facilities', the typical small town newspaper company in Sweden at this time (2001). This class consisted of 7 companies out a total of 14 companies in this study. The mean value for this class (0.91 MWh/tonne of product) was shown to be higher than

the mean value representing the entire group of newspaper companies studied (0.73 MWh/tonne of product).

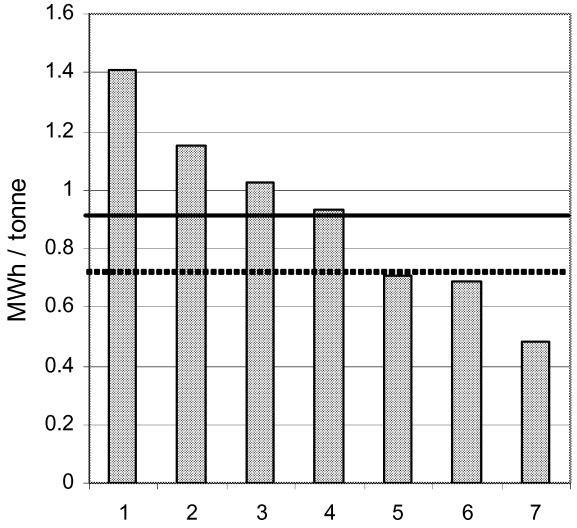

Figure 6 The Use of Energy indicator shown for 'Newspaper companies with printing facilities'. This class consisted of 7 companies out a total of 14 companies studied (Paper V). The mean value for this class (0.91 MWh/tonne of product) is shown by the line and the mean value representing the entire group of newspaper companies studied (0.73 MWh/tonne of product) is shown by the dotted line.

A summary of the study of gravure and heatset offset printing companies (Paper VI) is shown in Table 13. Data from production year 2002 were chosen.

Table 13 Mean values in 2002 for the gravure printers studied (19 companies) and heatset offset printers (9 companies). (Paper VI)

		GRAVURE	HEATSET OFFSET
Production in 2002	Tonnes/company	140,000	54,000
Paper Waste	Tonnes/tonne product	0.13 (12%)	0.21 (17%)
Use of Energy	MWh/tonne product	0.89	0.61
Consumption (loss) of VOC	Kg/tonne product	1.9	3.0
Hazardous Waste	Kg/tonne product	1.1	3.5
Share of companies with certified Environmental Management Systems (ISO 14001 and/or EMAS)	%	32	44

The mean values for the Paper Waste indicator in Table 13 (0.13 tonnes/tonne for gravure and 0.21 tonnes/tonne for heatset offset) are comparable to the data from the coldset offset printers (newspaper printers) in Sweden, i.e. 0.14 tonnes/tonne product or 12% (paper waste in relation to the total amount of paper used) based on figures in Table 12, and data from five commercial offset printers in Sweden in 2001, i.e. 0.25 tonnes/tonne product or 20% (paper waste in relation to the total amount of paper used) (Paper VI and Enroth et al. 2003). The commercial offset printers used for this comparison were comparatively small companies with small print runs.

The mean values for Use of Energy indicator in Table 13 (0.89 MWh/tonne for gravure and 0.61 MWh/tonne for heatset offset) can be compared to data from the coldset offset printers (newspaper printers) in Sweden see Table 12, i.e. 0.79 MWh/tonne product 2002, and five commercial offset printers in Sweden in 2001, i.e. 1.4 MWh/tonne product (Paper VI and Enroth et al. 2003).

Data on the Consumption (loss) of VOC indicator in Table 13 (1.9 kg/tonne for gravure and 3.0 kg/tonne for heatset offset) can be compared to data from the coldset offset printers (newspaper printers) in Sweden, viz. 0.26 kg/tonne product in 2002 see Table 12 and the mean value of 3.8 kg/tonne product which represents five commercial offset printers in Sweden in 2001 (Paper VI and Enroth et al. 2003). For coldset printers it was possible to decrease the VOC loss in a favourable manner, due to the character of the printing technique and the fact that the companies in the study were working actively on the substitution of products to reduce their use of VOC.

The mean values for the Hazardous Waste indicator in Table 13 (1.1 kg/tonne for gravure and 3.5 kg/tonne for heatset offset) can be compared to data from the coldset offset printers (newspaper printers) in Sweden, viz. 4.4 kg/tonne product in 2002 see Table 12, and the mean value of 15 kg/tonne product representing the same five commercial offset printers in Sweden in 2001, as mentioned above (Paper VI and Enroth et al. 2003).

3.2.3 Use of the industry-specific environmental indicators

The main user areas of industry-specific environmental indicators are developed and described in Paper V. They can be summarised as the following:

- To be a basis for the identification of areas of improvement and action plans, by using a benchmarking of a company's own figures, with mean values for a relevant class of companies.
- To facilitate the follow-up, the evaluation and the continual improvement of the environmental performance.

- To facilitate the internal and external communication of environmental performance.

Environmental indicators as a basis for the identification of areas of improvement and action plans

One important use of the industry-specific environmental indicator models is as a basis for the identification of areas of improvement and action plans. The aims of this are to bring about continual improvement to the environmental performance of companies and to promote more eco-efficient activities.

The indicators calculated for a specific company, together with the mean values and the range of values for the indicators representing a relevant class of companies, were used to identify areas of improvement in the specific company. For this purpose, a diagram with normalised data on all indicators in the model was used. Every company specific indicator was expressed as a percentage of the difference between the maximum and minimum values for each indicator representing the actual class of companies. From such a diagram, it is possible for the specific company to identify the indicator areas where it has an opportunity of improving. This method for identifying areas of improvement is illustrated and described in detail in Enroth et al. 2003.

Companies in the graphic arts industry that have just started their environmental work can use the industry-specific indicator models, at present, as a guideline for identifying the significant aspects of their activities.

Examples of measures implemented in the studied companies in order to obtain improvements in the environmental performance and financial savings (Paper V) could be arranged into various areas:

- Handling of waste/sorting of material for eco-cycling.
- Use of the product choice principle, i.e. exchange of hazardous chemical products.
- Exchange of technique (photography, prepress, system for cleaning, control system, etc).
- Resource management of paper and energy (e.g. energy saving measures and purchasing of declared renewable energy).
- Implementing methods and routines for environmental work (production according to the criteria of the Nordic eco-labelling [the Nordic Swan], a certified environmental management system or work with parts of an environmental management system).

The most extensive environmental and economic savings could be done when decreasing the use of energy, paper waste and the amount of hazardous waste (Paper V).

Follow-up of environmental performance

One obvious use of the industry-specific indictors is to facilitate the follow-up, the assessment and the continual improvement of the environmental performance of individual companies and of the whole industry. The aims of this are, in accordance with the identification of areas for improvement, to decrease the environmental impact and to optimise the use of resources. The latter is often linked to considerable financial savings.

For an individual company, one of the main advantages of using indicators is to be able to follow-up its own work. This can also be valid for an industry as such but, in this case, there are many factors influencing the results that are more difficult to have control of.

The most encouraging result, so far, with regard to improvement in environmental performance from our work with the industry-specific indicators on an industry level, is the decrease in volatile organic compounds (VOC) from the Newspaper Industry in Sweden. This is illustrated in Figure 7, based on data in Table 12. The emissions of VOC to air from the newspaper companies have decreased from an average value of 0.69 kg/tonne of product in 2000 (6 companies) to an average value of 0.26 kg/tonne of product in 2002 (19 companies). The 6 companies in 2000 are represented also in the average values of 2001 and 2002.

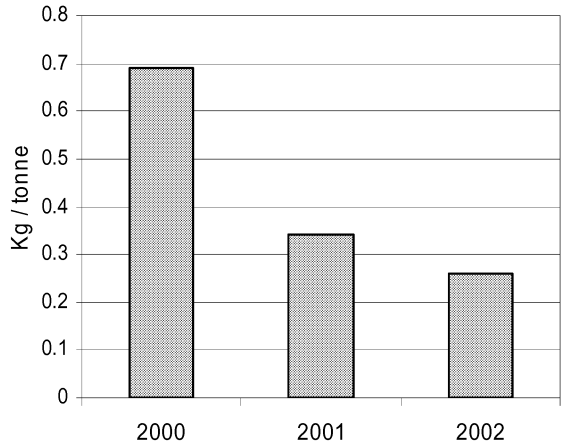

Figure 7 The emissions of volatile organic compounds (VOC) from the newspaper companies decreased from an average value of 0.69 kg/tonne of product in 2000 (6 companies) to 0.26 kg/tonne of product in 2002 (19 companies). The 2001 value is based on data from 14 companies.

Environmental indicators as a tool for the communication of environmental tasks

The use of indicators is strongly linked to the need of organisations to communicate environmental tasks both internally and externally. Internal communication is one important ingredient in the process of continual improvement in a company. The indicators provide an enhanced awareness of its own activity, which can be used in the company as described previously with identifying areas of improvement. In addition, having facts about the company in the form of indicators, the internal communication and motivation of the staff can be improved.

External communication can be facilitated with the use of indicators. In order to select the most adequate data from the model for external communication, in a common way, we investigated the type of information requested by various stakeholders from the companies (Paper V). Based on this we have recommended a selection of information from the main model shown in Table 14. In addition, we calculated some supplementary, more illustrative information for the general public, see Figure 8.

Table 14 A selection of information from the main model of industry-specific indicators for external communication of the environmental performance of a graphic arts company. The total weight of the product is recommended as a measurement of utility for external communication. The example of mean values represents 'Newspaper companies with printing facilities'. (Paper V)

ENVIRONMENTAL IMPACT	UNIT	NAME OF THE COMPANY (Own values)	MEAN VALUE FOR RELEVANT CLASS OF COMPANIES (Example)
Use of energy	MWh/tonne		0.91
Use of materials (printing paper)	Kg/tonne		1146
Hazardous materials	Kg/tonne		0.30
Transport to the company	Kg CO_2/tonne		13.4
VOC emissions	Kg/tonne		0.47
Hazardous waste (excluding electronic waste)	Kg/tonne		3.9
The proportion of renewable material in our production is xx % (example 99 %) The amount of printing paper accepted by environmental labelling criteria is yy % (example 100 %)			

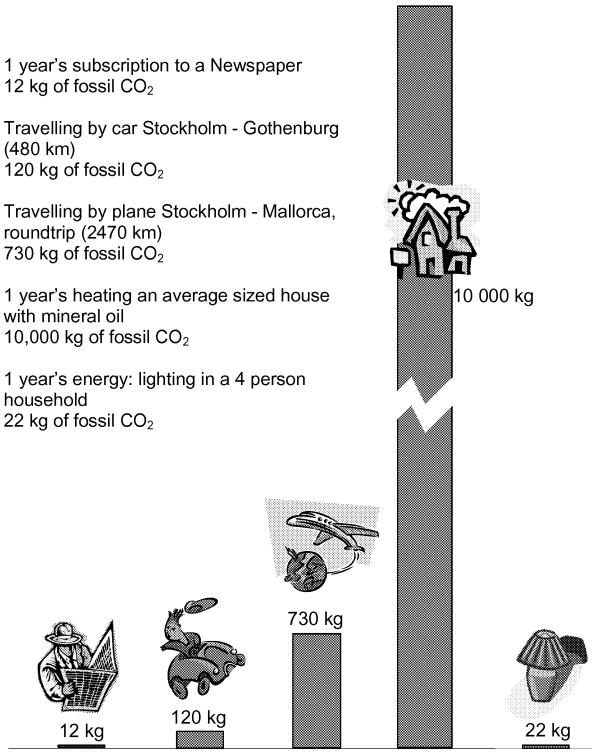

Figure 8 The environmental impact from a newspaper compared with other everyday occurrences in our lives. The comparison is based on emissions of fossil carbon dioxide to illustrate the effect on global warming. The newspaper represents a Swedish average newspaper of 110 g distributed 300 days per year.

3.3 *Design for environment (DfE) for printed products*

Our research concerning design for environment (DfE) for printed products is presented in Paper IV. The introductory questionnaire, with a response frequency of 17%, showed that there was an interest in DfE in the graphic arts industry (Paper IV, Enroth et al. 1998). The development and testing of tools yielded the most significant results of the DfE research, which can be summarised as follows:

- A described and recommended work procedure for DfE in graphic arts companies.
- Industry-specific tools for applying DfE to printed products in the form of a manual and a checklist. The checklist was designed so that it would additionally serve as a simple tool for the environmental assessment of printed products.

3.3.1 Working methods for DfE for printed products

Certain general principles (eco-strategies) are commonly used (Brezet and van Hemel 1997) as a foundation for a design for environment; see Figure 9, where they are applied to the graphic arts industry and listed. These eco-strategies can be regarded as rules of thumb for reducing the environmental impact of a product, e.g. 'Optimise functionality' and 'Reduce use of materials and energy', and should be considered at every stage of the product life cycle, where possible, as illustrated by the arrows in Figure 9.

The life cycle of printed products can be divided into various stages, e.g. 'Product design' and 'Production of consumables', etc., see Figure 9. Various players affect different stages of the product life cycle.

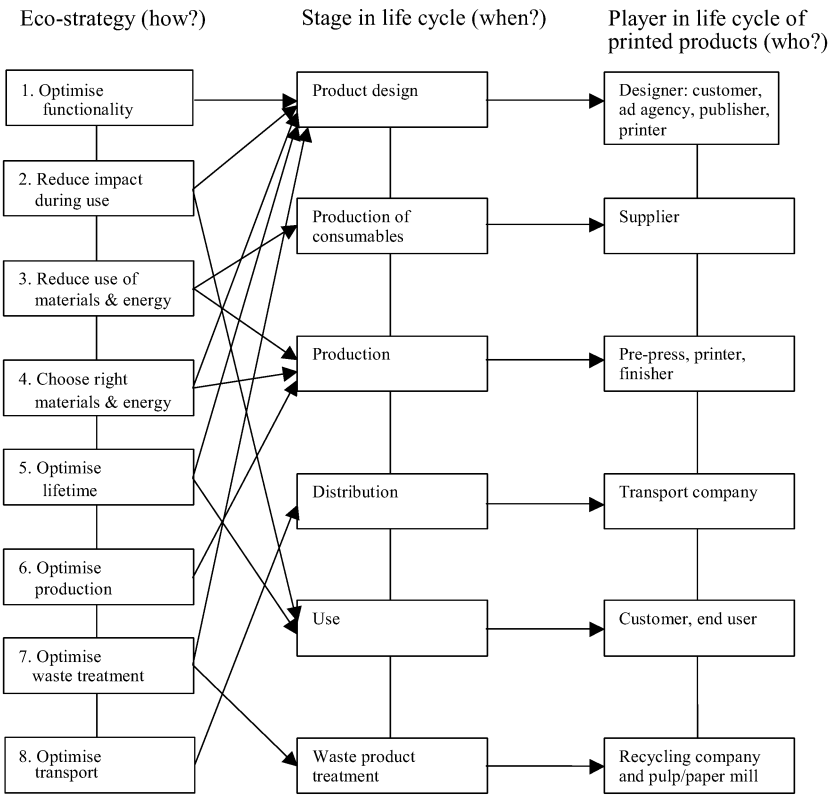

Figure 9 Eco-strategies, numbered here 1–8, for working with design for environment (DfE), adapted from Brezet and van Hemel (1997). The stages that usually make up the life cycle of printed products and the various players in the life cycle are shown in the diagram. (Paper IV)

Printed products are collaboratively developed among customers (direct customers, advertising agencies, and publishers), designers and producers (pre-press, printing houses, binders), see Figure 10. Collaboration among the players in the production chain is essential for a successful design for environment.

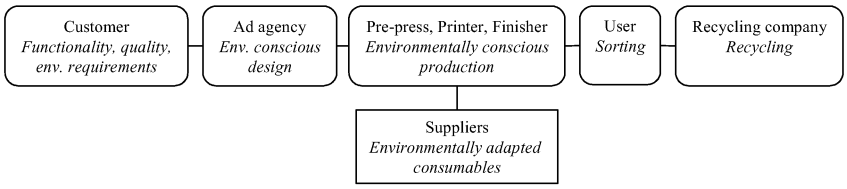

Figure 10 Design for environment in the graphic arts production chain (Paper IV).

The design for environment process for printed products can be divided into two main parts: environmentally conscious design and environmentally conscious production.

- *Environmentally Conscious Design*
  The term environmentally conscious design refers to product-specific work associated with the design of printed products, the production of originals, image production and the choice of materials, e.g. paper, ink, and printing method. Environmentally conscious design should be an ongoing process.

- *Environmentally Conscious Production*
  Environmentally conscious production refers to a plant-specific optimisation of production as a result of improved technology, the replacing of process chemicals and other process materials, use of energy, etc. Production is defined here as pre-press, printing and finishing.

The way in which design for environment (DfE), including its constituents, viz. environmentally conscious design and environmentally conscious production, relates to the production stages in the graphic arts production flow, is illustrated in Figure 11. This description is intended to link the traditional description of the graphic arts production flow with DfE. DfE is a new concept in the industry.

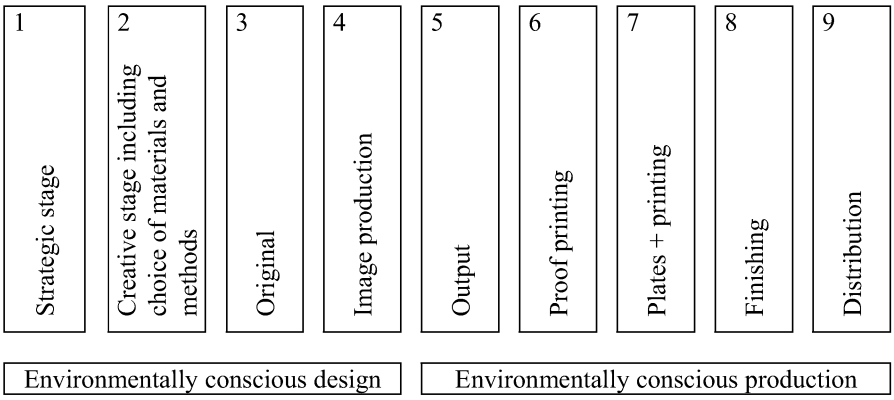

Figure 11 Links between the nine production stages of the graphic arts production flow (adapted from Johansson et al. 1998) and design for environment (DfE) for printed products, divided into its two components, i.e. environmentally conscious design and environmentally conscious production. (Paper IV)

In order to define a printed product in a way that is useful for environmental work, we need to use several parameters, which are in turn divided into sub-groups. For example, these parameters are of great importance in the work with measuring, assessing and improving product environmental performance. The most important parameters for defining a printed product are:

- Product type
- Cover
- Size of edition
- Format
- Number of pages
- Grammage of paper (body)

In this study (Paper IV), we have described and recommended a work procedure for DfE in graphic arts companies. It is described *how* eco-design strategies can be related to the different life-cycle stages of printed products and to the various players in the graphic arts production chain. The traditional description of the graphic arts production flow has been linked to DfE. Furthermore, it is clarified *when* DfE actions can be taken in the life cycle of printed products, and *who* has the opportunity of acting in the graphic arts production chain.

3.3.2 Manual and checklist for DfE for printed products

We have produced a manual for DfE, aimed at all those companies in the printed production chain wanting to improve the environmental performance of their products (Widing and Enroth 2000). The manual provides a guide to environmental improvement, as well as concrete advice on how to use current

eco-strategies in the design and production of printed products. The manual summarises environmental information about the graphic arts industry.

On the basis of this manual, we produced a checklist that gives guidance on the product design decisions that are most critical in environmental terms. The checklist is presented as an appendix to the manual and to Paper IV. It is intended for use when designing each new printed product as efficiently as possible for each order.

In addition to a product specification, the checklist contains a guide for reducing the environmental impact, when designing a paper-based printed product, with regard to the following areas:

- Production conditions
- Printing paper
- Printing ink
- Finishing
- Transport (courier)
- Transport (delivery)

The environmental aspects of energy use and electronic processing are not included in the checklist, other than indirectly (under production conditions).

It is desirable to have a simple method that permits an assessment and simulation of the types of environmental impact that result from the various alternatives in the design and production of printed products. It is similarly important to measure and monitor the way in which the environmental impact of products changes as the result of product development work. Following the experience with detailed product range inventories and life cycle inventories during the study, the project companies reported that a very simple tool is what would be necessary for carrying out environmental assessments of printed products for the ongoing task of DfE. This is the reason why we designed the checklist so that it can be used for environmental assessment and monitoring.

The various choices in the checklist (type of paper, ink, adhesive, etc.) were visually linked to various degrees of environmental impact by using ‘sad faces’ (☹). The fewer the number of ‘sad faces’ attached to an alternative, the better things are from an environmental viewpoint. For further details, see the checklist in the appendix to Paper IV. The reason why environmental impact was rated using ‘sad faces’ instead of using numbers is that it is difficult to determine with absolute certainty what environmental impact a given alternative represents. The results of the completed checklists can be compiled and used to assess and monitor the way that the environmental impact of printed products changes as a result of DfE.

4 Challenges for the graphic arts and media industry

All the graphic arts and media industries have been affected by globalisation and the radical revolution in information and communication technologies (ICT) during the past 20 years, whether through upgrading efficiency levels, the creation of new revenue opportunities or, negatively, through the elimination of traditional skills, know-how and functions. Changes in the graphic arts and media industries have been analysed and discussed by many, e.g. Abel et al. (2005), Bjurstedt (2005), EMCC (2003b), GFF (1999), GFF (2001), Hetemäki and Nilsson (2005), Lindqvist et al. (2003), Lindqvist and Siivonen (2005).

The subjects discussed in this chapter will have a large impact on how the research results presented in this thesis will or can be used. First of all, a broad use in industry is dependent on an increased awareness in society (including authorities, customers and companies) about how environmental factors influence our lives and living. How the results can be used is, among others, dependent on whether the advantages from a sustainability point of view, of the potential convergence of content and services within the ICT industry (including the graphic arts and media industry) will be utilised.

Both globalisation and the revolution of ICT are drivers of change that affect all industries. Why has the graphic arts and media industry been given special attention in this respect? To quote the European monitoring centre on change (EMCC 2003b), the challenges facing the graphic arts and media industry are both more fundamental and more complex than those facing other industries. With the shift from analogue to digital production and the arrival of IP (Internet Protocol) based communication networks, the graphic and media industries have progressed beyond the introduction of efficiencies to potential convergence of delivery, platforms of devices, content and services. The availability of broadband networks has had a major impact on the graphic arts and media industry, since content can now be delivered and distributed digitally, from the client to the media organisation, to and from their party suppliers, and ultimately, in many instances, to the end user. The potential convergence of content and services mentioned by EMCC would be called functionality sales by an environmentalist. The graphic arts and media industry is special in the sense of its customers being more and more aware of the potential of buying functions instead of just tangible products. Alongside this, as just described, the technical developments in the graphic arts industry have strengthened the potential of developing the functionality sales of information.

Additional drivers of change to globalisation and the ICT development for the graphic arts and media industry have been identified as a personalisation of offers and timescale reductions (EMCC 2003b). STFI-Packforsk has identified and reformulated the driving forces for change in the print and media value-chain as the following five, where the three first are regarded as the top-ranked driving forces; they are Globalisation, New technologies, Customer interaction, Environmental matters, and Policy and legal framework (Abel et al. 2005).

In Japanese technology forecast studies, ICT has been identified as the remaining driving force for technology and economy during the next decade. After this, it will slowly merge deeply into different applications, though it will be present all the time. New areas of technology, such as life science, environmental technology and energy, will be given more gravity, scientifically, economically and politically (Lindqvist el al. 2003), which is in line with reflections made by Hetemäki and Nilsson (2005) and our experiences too. Companies working with an environmental perspective or a wider, sustainability perspective, using, among others, the tools developed in our research might then be prepared to meet the future.

One effect of globalisation on the suppliers of equipment and consumables to the graphic arts industry is that print companies, anywhere in the world, can have access to the latest technology and, thereby, leapfrog into a leading edge position. Companies in Eastern Europe are doing this. China and India are following (EMCC 2003b). One way for graphic arts companies in the early industrialised countries to keep a competitive edge is to develop, prove and communicate that their activities are sustainable. When it comes to making processes and products more sustainable, which, to a great extent, is initially a question of company culture and management, companies in the Northern and Western Europe and some parts of North America have useful experiences.

For publishers, the developments in technology have enabled them to move away from the role of specific product providers to that of content providers and to build closer relationships with their suppliers and customers (EMCC 2003b). With the technical developments of the last decade, all the prepress work has become digital and the task of completing the pages ‘ready-to-process’ has moved to the originator. Desk-top publishing, facilitated in the early 1990s by PostScript and other reasonably priced software packages such as Adobe Photoshop, Aldus Pagemaker and Quark Xpress, moved the execution of prepress operations and the control from the printers to the publishers and the print buyers. These events have caused the previous strong bonds between printers and publishers/print buyers to disappear. In addition, the technological changes have made it possible for publishers to dramatically reduce the cost entry barrier for new titles and editions (Bjurstedt 2005). To summarise this, the strict delineation between publisher, prepress and printer activities has been

eroded, with prepress activities being largely absorbed into publisher and print activities.

In future, the content will be simultaneously created for different media and all the content (assets) will be in digital format. All the different media platforms and information carriers set different requirements for the content visualisation and layout, but cost efficiency will require a rationalised content production. The multi-purposing of content and multimedia workflow is important for all future players in the graphic and media industry. When it comes to printed products, there will be a demand for shorter print runs and targeted, customised printed products. (Lindqvist et al. 2003)

The effect of the structural changes in the graphic arts industry on skills characteristics and requirements are discussed by e.g. Bjurstedt (2005), EMCC (2003b) and Politis (2003). The graphic arts sector, the printing sub-sector in particular, is going from low-tech, intensive labour to high-tech, low labour. The rapid pace of change implies that life-long learning will be the norm in the graphic arts industry, since the need for training increases more frequently. Skills are now being recognised as a key factor in productivity, 'hands-on', vocational training is a favoured method for employees to acquire the necessary skills. ICT has removed the delineation between job roles, leading to more multi-skilling and increased flexibility in skills. Publishers have seen an increase in the use of outsourcing and freelancers.

The printing industry has experienced an image problem, which makes it unattractive to young people and women in particular (EMCC 2003b). This has also been identified in companies taking part in our research, see Paper VII, where the low popularity factor of the printing industry was identified as a prioritised, social threat. By seeing the future printing industry as a part of the entire ICT industry, these problems ought to be solved in the future.

The relationship between the development, diffusion and use of information and communication technologies (ICTs) and environment, or the broader goal of sustainability, is not yet well understood. Based on recent literature, Berkhout and Hertin (2004) have described the most important linkages between ICTs and impacts on the environment, providing a qualitative assessment of the risks and opportunities stemming from the information revolution. Berkhout and Hertin identify three main types of effects, viz direct impacts, indirect impact and structural/behavioural impacts. They argue that the diffusion and use of ICTs are leading to both positive and negative environmental impacts and give examples. However, because the effects of ICTs on economic activity are pervasive, their impacts on the environment are difficult to trace and measure (ibid.).

As examples of indirect effects related to ICTs on production processes, products and distribution systems, print and e-business, are discussed by

Berkhout and Hertin (2004). As discussed earlier, paper-based information products are under competitive pressure from cheaper and more easily retrieved and updated sources of information on the Internet. Several studies have been made trying to predict the impacts of electronic media on printed media and the use of paper (e.g. BCG 1999, GFF 1999, Hetemäki and Andersson 2005 and Kipphan 2001). The Boston Consulting Group (BCG 1999) predicted that the substitution of printed matter with on-screen information would, in the future, outweigh the contrary trend, i.e. the greater use of office papers as a result of the broader diffusion into office and home of digital printers. Many studies indicate that printed matter is still increasing, although not to the same great extent as information products in general (e.g. Intergraf 2004, Kipphan 2001, Lindqvist 2005). The trends are different for different types of paper and in different parts of the world, which is described by Hetemäki and Nilsson (2005). The historical relationship between economic growth and growth in the demand for paper seems to have broken down (e.g. in North America and the Nordic countries). This is most evident in the case of newsprint, but indications, albeit less strong, are also present for office paper grades. Magazine papers still seem to be following the historical pattern more closely (Hetemäki and Nilsson 2005). However, just as the use of computers did not lead to a 'paperless office', an incomplete substitution of old structures by new digital systems could result in additional environmental burdens. Similarly, the behaviour of e-shoppers is likely to contain surprises with many choosing to do some of their shopping online while going to the stores to buy other goods at the same time (Berkhout and Hertin 2004).

As an example of the structural/behavioural impacts of ICT, rebound effects are being discussed (Berkhout and Hertin 2004). Many ICT applications allow a better management of things such as time, money, labour and transport infrastructure, thus providing scope for, and creating new demands. The rebound effects are real threats to incremental efficiency gains. In many cases, ICT provide new opportunities to access and consume material and non-material goods and services. One concrete example of re-materialisation is document access through the web, allowing for a printed paper copy within a minute. The environmental performance of a paper copy from a (home) office printer, printed on relatively a high quality office paper grade, is likely to be lower than a paper copy from an efficient, well controlled, industrial print production process (Johansson 2002a, Hischier and Reichart 2001, and Widing et al. 2000b).

In the long term, the net environmental effect of the ICT revolution will depend on the balance between "de-materialising" effects and the counter "re-materialising" influences of economic growth (Berkhout and Hertin 2004). ICTs do not necessarily lead to a more environmentally-sound future, but they offer new opportunities to develop more sustainable solutions. As in many other industrial-environmental domains, the role of policy and regulation will be crucial if these opportunities are to be captured (ibid.). For the graphic arts

industry, this was indicated in the aforementioned foresight study by STFI-Packforsk (Abel et al. 2005).

The research presented in this thesis can be helpful, when starting to take environmental and sustainability aspects into consideration at the same time as future information product service systems are being optimised, according to the functionality/purpose of the information, actual target group, cost characteristics and quality of the information carrier in each typical case.

5 Discussion and conclusions

5.1 Discussion

5.1.1 About methods

In the research presented in this thesis we have used a number of different methods and data gathering techniques. Some aspects of these are discussed below.

The techniques for data gathering used in our EMS study (Paper I) were questionnaires and semi-structured interviews. It is important to be aware that questionnaires and semi-structured interviews (as opposed to in-depth interviews) often reflect preconceived ideas (Wallén 1996). In our EMS study (Paper I), we tried to avoid this by giving the companies fairly large leg-room during the interviews and do the documentation in consultation with each company. It is also important to bear in mind that the answers are dependent on the kind of person in a company answering questionnaires or being interviewed. In the EMS study (Paper I), we principally interviewed the environmental officers or environmental co-ordinators of the companies, which could have given too positive a result.

When qualitative data are categorised or assigned to different categories, it may be difficult to delimit and classify a particular phenomenon to the right category. It is possible to do some statistical analysis based on data, in the form of values for the number of cases. In the EMS study (Paper I), the statistical data analysis, based first and foremost on categorised qualitative interview data, could, due to these difficulties, be questioned from the aspect of generalizability (external validity). To some extent, we handled this question by using different kinds of data gathering techniques (questionnaires and semi-structured interviews) in the study. This could be referred to as a 'between-method' triangulation. As mentioned before, this type of triangulation can be used to examine the degree of external validity in qualitative research (Jick 1979).

Regarding the surveys, in the form of questionnaires, that were used for evaluating certified environmental management systems (EMSs) (Paper I) and initiating the Design for Environment (DfE) study, investigating the interest for DfE (Paper IV), it would have been interesting to carry out dropout analyses, e.g. surveying non-respondents, which was not done. In the EMS study (Paper I), we got a 49% response to the questionnaire. The number of responses from companies in the varying classes studied, broadly reflected the number of certified companies in each class. Therefore, we made the assumption that the answers were representative for the entire group (Paper I). With regard to the

response we got in the DfE study (17% response frequency) (Paper IV and Enroth et al. 1998), it was the environmentally conscious companies that answered. Most of the answers were gained from printers but different types of companies in the graphic arts production chain were represented. In addition, companies of different sizes were well represented among the responding companies.

A reflection concerning the indicator data presented in this thesis, resulting from the different multi-company studies (Paper II, Paper III, Paper V and Paper VI) is that data from 10-20 companies for each of the main groups of companies represented (viz. companies using coldset offset, heatset offset and gravure printing) do not give a fully statistical base to assign figures to the recommended industry-specific indicator models. However, the coldset offset group adequately represents the newspaper industry in Sweden (Paper V) and the gravure printing group adequately represents the publication gravure printing in Europe (Paper VI). Because some of the multi-company indicator studies only cover a few individual cases (Paper II and Paper III), the question of external validity might be of concern in these studies. Nevertheless, the main purpose of these introductory indicator studies was not to gather data from many companies but mainly to study how industry-specific indicators, reflecting common significant aspects, could be defined and related to a reasonable inventory process and calculated to provide indicators for a typical company in the graphic arts industry. The later multi-company studies (Paper V and Paper VI) had the added task of gathering enough data to develop the prerequisites for benchmarking.

Our work with indicators has much in common with the participatory processes as described by e.g. Fraser et al. (2005). Furthermore, we used such processes e.g. for identifying sustainability aspects in our study with strategies (Paper VII). Although we have not so far used community involvement in our research, the methods of involving different kinds of stakeholders will be a prerequisite in the future for developing tools aiming at sustainable development.

Participative observation that has been used as one technique for the gathering of data in some of the studies presented in this thesis (Paper IV and Paper VII) has, as its strong point, the fact that it covers events in real time and in context. In addition to this, the technique can be insightful for observing interpersonal behaviour and motives. Some of the criticism that can be raised against all types of observation is that the event may have proceeded on a different course, due to the mere fact that it is being observed. Furthermore, when it comes to participative observation, the data could be biased due to an investigator's manipulation of the events (Yin 2003). This is also a criticism of action research but, at the same time, it is the strong point of this method, since it offers an outstanding access and nearness to the data (Gummesson 2004).

Since the researchers in some of the studies presented in this thesis, when developing general work procedures and tools for applying DfE (Paper IV) and sustainability strategies in graphic arts companies (Paper VII), took an active role in the project groups at the studied companies, it could be referred to as action research (Gummesson 2004). Action research applies to processes or phenomena that would not occur if researchers did not initiate or influence a course of events (Wallén 1996).

In Paper VII we used a modified SWOT analysis. The use of the SWOT method for strategic planning has been criticised over the years, see e.g. Dyson (2004) and Hill and Westbrook (1997). Some of the criticism is that the resulting, often long lists of SWOT factors with general descriptions are not prioritised and that there is insufficient verification of the factors. The most worrying general characteristic of SWOT analysis identified by Hill and Westbrook (1997) was that few subsequently use the outputs in the later stages of the strategy process. Even if Dyson (2004) refers to SWOT analysis as somewhat outdated in literature, he argues that the framework has stood the test of time and can readily incorporate ideas from newer approaches, such as scenario development and resource and competency-based planning. The advantage of SWOT analysis is that it attempts to connect external and internal factors for stimulating new strategies (Dyson 2004) which we have practiced and developed in our research with sustainability strategies. In our strategy study (Paper VII), criticism of the SWOT method can be met, since we used the results of the SWOT analysis as a basis for the later stages in the strategy process. The prioritised external factors strongly influenced the outcome of the SWOT analysis and became the basis for the latter stages of the strategy process.

Since we have used two cases in our strategy study (Paper VII), where we predicted similar results, this can be referred to as a literal replication logic, which strengthens the external validity of the study (Yin 2003). The similar results that had been predicted were based on the fact that both companies in the study intend moving towards sustainable development.

5.1.2 About the results

Environmental management and strategy

Our evaluation of certified environmental systems (EMS) (Paper I) was one of the earliest studies after the introduction of the EMS standards (EMAS 1995 and the ISO 14001 1996). It was based on the assumption that it is possible to create the right conditions for developing and streamlining environmental management work by applying experience gained from practical work so far. Compiling and disseminating experience provides companies with the right conditions for optimising their efforts, whether they have already made relatively good progress with their environmental work or whether they have yet to begin.

One of the restricting factors in our EMS study is that there are almost ten times the number of environmentally certified companies in Sweden (3,500 companies in January 2006) as when the survey began (www.isoguiden.com). Strictly speaking therefore, the conclusion applies only to the 360 companies that were environmentally certified in the autumn of 1998. Furthermore, since this was an early study of certified EMS, most of the systems included in the study had only recently been implemented.

This early study showed that only 20% of the companies were working with the products and that the companies all too seldom had targets related to the environmental impacts derived from their products. In addition, it emerged from the interviews that approximately half of the companies had made some essential mistake in their identification of or their environmental assessment of environmental aspects. This showed that there was room for improvements as regards which environmental aspects the companies chose to work with. Nevertheless, the study indicated at the same time that most of the companies have environmental targets in the majority of areas that could be regarded as important. More recent evaluations of certified EMSs have come to the conclusion that a focus on products, product development and indirect environmental aspects is still lacking (Ammenberg 2003, Axelsson et al. 2003).

Ever since the introduction of the EMS standards the effects of certified EMSs have been evaluated. The important question as to whether a certified EMS leads to an improved environmental performance has been discussed by many, e.g. Ammenberg and Hjelm (2002), Axelsson et al. (2003), Berkhout et al. (2001) and Zobel (2005).

Our EMS study indicates the potential of certified EMSs to contribute to a better environmental performance, by examining the certified companies' results of the environmental target work regarding emission or resource reduction. On average, nearly 70% of the physical targets were achieved. The study however showed that half of all environmental targets would have been realised, even if the environmental work had not been certified and there was a frustration among companies about the environmental management work not having achieved more environmental improvements. We might then question whether certification is justified from an environmental view point, considering all the extra costs and bureaucracy involved. What might have been achieved if these resources had, instead, been channelled towards making environmental improvements? What argued in favour of certification was that almost all the interviewed companies emphasised that it had lead to better order and systemisation. Although the bureaucracy was frustrating, it was considered necessary. The reason for this could be that a structured work provides opportunities for developing the work with continual improvements, even after the most obvious ones have been made. Similar to the results of our EMS study,

interviews made in a later evaluation (Axelsson et al. 2003), indicated that certified EMSs have the potential of leading to a better environmental performance, but this has not yet been possible to substantiate quantitatively. Some of the recent published EMS evaluation studies reviewed in Zobel (2005) indicate quantitative environmental improvements e.g. Fresner and Engelhart (2004), while others do not e.g. Zutshi and Sohal (2004). Based on a meta-study of 46 studies from 33 countries worldwide there is no general causal linkage found between EMS implementation and improved environmental performance (Zobel 2005). This result is the same as concluded in Ammenberg and Hjelm (2002), Axelsson et al. (2003) and Berkhout et al. (2001).

During the 1980s and 1990s, numerous case studies were generated to illustrate cleaner production, pollution prevention or other similar concepts. The most common types of changes that are demonstrated by such case studies are things such as changes to the type, quality or quantity of resources used, improved maintenance or "housekeeping", equipment modification or substitution, changes to processes and, more recently, changes to products and services (Stone 2000). With the exception of the observed changes to products and services, these results are similar to what we found in our evaluation concerning environmental improvements made from early certified EMSs.

The matter of only one person being questioned in a specific company to gain a company judgement can be raised in our EMS study. It would be interesting to analyse the difference in judgement depending on which position the person questioned have. In our EMS study, people with similar positions (environmental manger or a corresponding position) in the different companies answered the questionnaire and were interviewed. Similar criticism was raised at the Environmental Self-assessment Program (ESAP) tool and it focused on the subjective nature of the questionnaires used for data gathering (Eagan 1997). Some respondents in the evaluation process of ESAP believed that one individual cannot possible possess a broad enough knowledge to do the assessments being asked for (in this case, concerning all the ICC principles). The fact that our study used only one respondent might potentially create grounds for bias. However, other research suggests no major concerns, and careful targeting of a knowledgeable respondent can assist in overcoming potential problems with common method variance (Vachon and Klassen 2005).

In addition, it would have been interesting for us to investigate a control group from non certified companies as well. In this case, a control group could lead to a number of problems, when it comes to estimating or measuring environmental performance. The more an organisation knows about its performance, the worse it seems to be in relation to others, as indicated by Stone (2000) with experiences from such a control group, and by our own research (Enroth et al. 2003 and Paper VI). This is further discussed in this section.

The drivers for the Swedish companies to implement an early certified EMS were mainly a competitive advantage and the demands from owners and customers, as revealed in the background documents to Paper I (Zackrisson et al. 2000). To some extent, the evaluation of the early certified companies in Sweden can be seen as evaluating the pioneer companies in the environmental field. Their reasons for implementing EMS might have been different than the reasons for the companies that did it later. In later studies, mainly describing the situation in Sweden, customer requirements, engagement and potential savings of financial and physical resources were identified as the main drivers (Axelsson et al. 2003).

According to the European monitoring centre on change (EMCC 2003b), Corporate Social Responsibility (CSR) does not have a high profile in the graphic arts and media industry, although they mention some exemptions, such as the EU Solvents Emissions Directive 1999/13/EC, which has been a major driver in reducing the use of volatile organic compounds (VOCs) in the printing industry. EMCC claims that the very nature of the industry, which is dominated by a small number of very large players, with the remainder being very small organisations of 20 employees or less, is a reason why the majority of companies are not in a position to fully embrace CSR (other than by legal obligation). EMCC however states that existing and forthcoming EU directives will require greater adherence to CSR principles for the graphic arts and media industry in future. The general meaning in Sweden (GFF 1999) and the experience gained from our research is different concerning the CSR profile in the graphic arts industry. When it comes to developing environmental sustainability in the graphic arts industry in Sweden and some other countries, especially in Northern and Western Europe, the profile is high in many foresighted companies. This is due mainly to customer demands.

The drivers for companies' environmental work in some parts of the world have been studied by others. Referring to Vachon and Klassen (2005), governments impose legislation and standards that set the lower boundary of customer expectations regarding environmental compliance in North America. Among customer expectations, increasing attention is now being devoted to the social responsibility of companies, with a particular focus on fair and legal use of natural resources. From recent studies of the UK refrigeration and baking industries (Drake et al. 2004), results from interviews however revealed that legislation maintains it's pre-eminence as a motivation for change. Companies remain driven by the commercial, rather than the environmental, imperative. The demand for environmental products and processes, necessary for win-win situations (good for the environment and good for business), has yet to materialize (ibid.).

It has been suggested that, in order for environmental issues to be addressed seriously by industry, they must be shown to be economical, i.e. cost reducing in

both the short and long term and 'quick and simple to incorporate' (Argument et al. 1998). The theoretical benefits for the industry arising from environmentally conscious product development, including gaining a long term competitive advantage from their products and reinforcing the 'responsible, caring' image of the company, are in most cases not sufficient, which is also described by van Hemel and Cramer (2002) and in our DfE research (Enroth and Widing 2000). The competitive advantage based on a sustainability approach, such as that described by Hart (1995) and Welford (1998), for example, may not quite be realised yet.

There is a critical view of concepts for sustainability management arguing that they are inefficient, since they try to solve too many problems at the same time. Often, general data has been used, which does not offer a solution to the individual problem that has to be tackled by a certain actor or firm (Seuring 2004). By the use of tools, tailor made and adapted to specific trades of industry using specific data, e.g. using the industry specific indicators and eco-design methods described in this thesis, the possibility of actually realising sustainable actions and products might be increased.

A vital issue in the integration and acceptance of all types of environmental management in organisations is senior management commitment, which is a statement made time after time, e.g. in Argument et al. (1998), Axelsson et al. (2003), as well as something that was experienced in our research.

Supply chain collaboration is one of the pro-active management approaches for sustainability. Many graphic art companies need to work on their development of supply chain collaboration. This approach is very important, when the main environmental aspects of a product can be identified as parts of the product life-cycle, on which the company itself has no direct impact. The supply chain collaboration approach has been used in the research presented in this thesis, when developing corporate strategies, when developing indicators for part of a supply chain (gravure and offset printers) and in our Design for environment (DfE) research. Related studies have been described in Humphreys et al. (2003) and Vachon and Klassen (2005), for example, see earlier in Section 1.1.2.

The shared visions, on which the strategies in our studies (Paper VII) are built, can be criticised for being too brief. In our studies this was due to the fact that companies have difficulties in making a more long-term planning in real-life conditions. It can be claimed that a vision should capture a perspective long enough, so that the organisation sets an ultimate aim that is independent of current trends and current downstream problems. This has been discussed in literature for strategic sustainable development (e.g. Robèrt 2000, Robèrt et al. 2002 and MacDonald 2005) and in future studies, discussing and using backcasting (e.g. Börjeson et al. 2005, Carlsson-Kanyama et al. 2003, Höjer and

Mattsson 2000). The very long perspective is advantageous but difficult to apply in practice.

In research with strategies, we have tried to bring the sustainability concept into practice. For initiatives of conceptual sustainability strategy work, refer to Hart (1992), Hart (1995), Robèrt (2000), Robèrt et al. (2002) and Welford (1998), for example. In Paper VII, our research was related to these conceptual works. There are also initiatives that aim at bringing the sustainability concept into practice in companies; some examples are given in Cerin (2005), MacDonald (2005) Roome and Bergin (2000), and Waage et al. (2005). Many indicator initiatives can be mentioned here. The most used ones in the wood fibre based supply chain companies are the Global Reporting Initiative (GRI 2002) and CEPI (CEPI 2005). Important for our future work, in particular, are the experiences described by Roome and Bergin (2000), delineating the chain of events that lead to a failure in implementing a sustainable strategy in a company. Roome and Bergin (2000) emphasize the importance of developing and maintaining a corporate-wide definition of sustainable development that is fully integrated with all business processes and activities. In the studied example, a shared vision was missing and the strategy never became established as a key element of the corporation (ibid.).

Environmental indicators

Our studies of indicators (Paper II, Paper III, Paper V and Paper VI) have focused on one of the types of indicators defined by ISO 14031, viz. operational performance indicators (OPIs). This means mainly that indicators, which provide information about company operations, are included. Factors such as the level of training and education, the involvement of management, and environmental conditions in the surroundings, are not taken into account. One could argue that the Cost of Environmental Work indicator is a management performance indicator (MPI).

The use of indicators always assumes a defined method for inventorying and calculation, if a comparison is to be made among different years in one company or among different companies. If the developed main model of industry-specific indicators is used, a method for inventorying and the manner of calculation are also defined (Widing et al. 1999, Widing and Enroth 2001).

Historically, many organisations tracked environmental performance with intensity ratios (GRI 2002). This means that indicators have been formulated to express intensity (fewer throughputs for a given service) with a measurement for environmental impact as the numerator and a measurement for utility as the denominator. A declining intensity ratio reflects a positive performance improvement. Other indicators, e.g. the WBCSD suggested indicators (WBCSD 2000) express efficiency (more services from a given throughput) with a measurement of utility as the numerator. The choice of indicator type

depends on the actual perspective; ecological or economic (Spangenberg 2002). We have chosen an ecological perspective for the developed industry-specific indicators, since they express intensity.

For our industry-specific indicator model, a recommended measurement for the utility of companies represents the physical production, the 'Total weight of products'. Another recommended measurement for utility in the model is a financial measure, the 'Annual turnover'. (Paper II, Paper III and Paper V.) As a basis for this recommendation, a number of alternative measurements of utility were tested (Paper II). For companies in the graphic arts industry, 'Information value' would be desirable as a measurement of utility and the value of a company, but it has not yet been possible to measure this parameter on a practical level.

It is possible to use measurements representing the weight of products, for example, as long as the products are physical and not different types of services. It is however important that the total amount of the production is what is actually required. In this type of measurement, there is no indication as to whether or not there is an overproduction not being utilised. Financial measurements can be helpful, since they also contain a valuation of the activities and products in companies, meaning that what the printer produces is exactly what the customer orders and will pay for. The disadvantages of financial measurements are that factors, such as interest rates and the price of shares etc., have an influence on turnover and added value. Since these types of measurements of utility complement each other, we have recommended one measurement of each type for the main model of industry-specific indicators. For an interpretation of data, it is beneficial if both types of measurements are represented. The product-related 'Total weight of products' is useful, when analysing the efficiency of resource use, for example. The financial 'Annual turnover' describes differences in the market situation more effectively.

For the recommended selection of indicators for external communication (Paper V) and in Paper VI, we have chosen to relate environmental data to only one type of measurement for utility, i.e. the 'Total weight of products'.

Our indicators arise, with some exceptions, from a gate-to-gate inventory. When this is the case, it is important to remember that aspects that arise outside the site, e.g. extraction of raw materials, production of additives, transport and waste management, can cause significant impacts on the environment. However, the possibilities for an organisation to influence or control aspects outside the site can be limited (depending on its role in the actual supply chain). One advantage with gate-to-gate indicators is that, in principle, it is possible to add them along a supply chain.

Regarding data quality, the data collected and reported in this thesis on the industry-specific environmental indicators are reviewed by the researchers before they are stored in the databases and used for benchmarking purposes. The review process is based on the definitions and the instructions for inventorying of the indicators. Due to our industry-specific knowledge, the nearness to and the familiarity with data, as well as the close dialogue with the participating companies, we have the possibility to secure a high quality of data. This procedure can be compared to collecting data from publicly available information in e.g. the MEPI project (Berkhout et al. 2001 and, Berkhout and Hertin 2001).

A key to the practical use of industry-specific indicators is data availability, representing a company's own different production years and data representing an adequate group of companies to benchmark against, while referring to the number of companies and the types of activities.

This thesis presents data from quite a large number of Swedish newspaper companies (Paper V, Enroth et al. 2003). With data from approximately 20 companies, the values for the entire group could be used as guides and, to some extent, reference values. It is worth noting that the values represent a group of environmentally aware newspaper companies. These companies represent 10% of the approximately 200 newspaper companies in Sweden that were affiliated to the Swedish Newspaper Publishers Association in 2002, when Paper V was compiled. These companies' common representation of the coldset print capacity in Sweden is estimated as being as high as 52%, based on the share of newsprint use.

Paper VI presents data for significant environmental aspects in quite a large number of printing companies in different parts of Europe and in the United States, i.e. 19 gravure printers and 9 heatset offset printers in 2002. The gravure printers studied represent a considerable portion of the printing capacity, not only in Europe but worldwide. The production in the gravure printers that were studied in Europe in 2002 corresponded to 32% of the gravure print capacity in Europe. Production in the offset printers studied in Europe corresponded to approximately 2% of the offset print capacity of Europe.

The range of values among different studied companies from around Europe and the United States is wide for all the studied indicators (Paper VI). There are probably many explanations to this. From the developments between 2000 and 2002, we can see a tendency for the data to converge among the companies, which is probably a result of starting to use the same definitions for indicators and of using a similar method for measuring and calculating.

As a consequence of this learning process for all the parties involved, the mean values for the different indicators have had a tendency to increase, which is a

phenomenon that we have also seen in our indicator research with the newspaper industry (Enroth et al. 2003). In the study involving companies from different parts of the world (Paper VI), we had difficulties in understanding all the actual explanations to the reporting of some of the lowest reported values.

The differences between gravure and offset printers in the Paper Waste indicator (Paper VI), with a higher average value for offset printers, can be explained by the fact that offset printers generally print smaller editions, when compared to gravure printers. A similar situation was seen in our studies of the newspaper industry, where values from newspaper companies were compared to values from comparatively small commercial printers (Paper V and Enroth et al. 2003).

When it comes to the Use of Energy indicator, the wide range of values reported in Paper VI can, to some extent, be explained by different traditions and the practice of handling energy data in the companies. The Use of Energy indicator in our indicator models is comparable to 'Site Energy', as defined by the Energy Information Administration, which is 'the amount of energy delivered to an end user that is not adjusted to account for the energy lost in the generation, transmission and the distribution of the energy' (Energy Information Administration 2004). This type of definition is discussed by Lammers (1999) and described as the 'Total end use of energy'. Our reason for using this definition was that we wanted it to be practical for the companies to quantify the indicator, which is the main advantage with this definition. Using this definition, the most common case for gravure printers and offset printers describes the amount of natural gas purchased, to be used in the toluene recovery process and the heatset process, plus the amount of grid electricity purchased. The disadvantage of this definition is that the potentially different energy situations in the companies, e.g. purchasing different proportions of primary and secondary energy, influence the level of the indicator value. Note that the Emissions to air indicators in our main industry-specific indicator model (Paper V) include emissions from production (fuel distribution and generation but not transmission and distribution to user) of the purchased electricity and district heating.

Some researchers suggest that consumers and business managers seem to prefer one single indictor when making decisions and that fewer indicators send clearer messages. However, a smaller number of indicators cannot ever fully describe the complex reality of environmental problems. Energy indicators that address the use of primary energy in a life-cycle perspective for a product, for example, are common options in environmental evaluations. Energy use as a single indicator or, in a set of just a few indicators, is often used in environmental management and applied research. However, the environmental relevance of the few selected indicators, e.g. energy use, is seldom questioned, as discussed by Svensson et al. (2005). The relationship between environmental relevance and energy indicators might seem obvious but it has not been thoroughly discussed in what way this is obvious. Svensson et al. (2005) elucidate and critically

discuss the use of energy indicators. The actual energy system (energy supply, its conversion and its use in society) is a crucial issue for the environmental relevance of an energy indicator. The description of an indicator needs to be transparent to the receiver, i.e. to address the validity of the results and to highlight what is excluded. It is important to note that all categorising, weighing and giving priority to different impact categories is dependent on values and is a political, not a scientific act. So while the energy indicator may seem to reflect some of the most debated environmental pressures of today, this can change in the future, when other political agendas arise (Svensson et al. 2005). However, the current strong connection between the use of energy, often based on a large portion of fossil resources, and the impact on climate change motivates our attention to the Use of Energy indicator in the developed indicator models.

Our indicator studies involved companies having different prerequisites, such as different legislation, different printing capacities, different experiences with environmental work and different experiences of quantifying the environmental impact from printed products. Generally, data from companies in different parts of Europe and the United States (Paper VI) on volatile organic compounds (including toluene) and hazardous waste, for example, are uncertain due to the different legislation in the various countries and due to the different handling procedures in specific companies. This is indicated by a wide scattering of the values. When it comes to data for the industry-specific model of indicators from Swedish newspaper companies (Paper V), business travelling and electronic waste are uncertain so far, for a variety of reasons. Newspaper distribution figures should also be treated with care. This indicator is very important, from an environmental aspect, but should be used mainly for internal communication and actions.

In line with general recommendations for business ethics, our studies with indicators showed that great care should be taken if indicators are used for comparison among companies. For such a comparison to be relevant, it ought to be made among companies with similar activities. The procedure that we recommended for newspaper companies was that they use benchmarking against mean values that are derived from a group of similar companies, viz. companies with similar activities and working under similar conditions. This should be of value for companies and in line with the codes of business ethics.

The main industry-specific indicator model provides an opportunity for communicating the environmental performance of a graphic arts company in a general way. A trustworthy communication of the environmental performance of an individual company or an industry, using industry-specific indicators developed by an independent organisation, can contribute to strengthening the environmental image of the industry. At present, the assumed target groups for the information are mainly customers and professional purchasers. Professional purchasers often ask for a lot of information that is sometimes collected in

extended questionnaires. If the graphic arts company, as a supplier, already has a prepared set of indicators which are environmentally relevant for its activities, it will make the work more efficient for all parties.

As with a study in New Zealand (Stone 2000), indicating that the more an organisation knows about its performance, the worse it seems to be in relation to others, at least for a certain time period, we have had the same experiences in our indicator studies. It is difficult to get reliable figures on environmental performance from companies with a scant knowledge of their performance, which is a phenomenon reported by Stone (2000) and indicated in our studies (Enroth et al. 2003 and Paper VI). In addition, this phenomenon was illustrated in work by Agrawal on all US oil companies, presented by Baumann (2004) where the environmental performance of companies that communicate more environmental information to the public than is required by the US EPA, is consistently lower than the environmental performance of companies that do not communicate information. This is still a large problem for studies aimed at evaluating the environmental efficiency of different concepts of environmental management. The combination of data availability and the nearness to data in our research can be used to overcome this problem for the future evaluation of different concepts of environmental management, legislation, etc., related to the studied companies in our research.

The Porter hypothesis (Porter and van der Linde 1995) suggests that environmental policy improves the environment and productivity. This hypothesis has often been criticised and a number of researchers have tried to determine whether good environmental performance leads to good financial performance, but the evidence so far is mixed (Clark 2005). Positive examples have been reported from large companies with early eco-design processes that gained increased brand awareness and valuable publicity through 'concept demonstrator' products, e.g Husqvarna, Philips and Electrolux. As an example, the 1998 Electrolux environmental report showed that green range refrigeration products accounted for 16% of sales but 24% of gross margins (Simon et al. 2000). Based on the data we gathered from newspaper companies, using the industry-specific indicators presented in Paper V, we have estimated the maximum financial savings, if a company is making progress from 'the worst in class' value to 'the best in class' value for the Use of energy, Paper Waste and the amount of Hazardous Waste indicators. This indicates that 0.5% to 5% of the annual turnover can be saved. The highest figure refers to estimations for the sub-class, 'Newspaper printing companies' (Enroth et al. 2003).

A literature survey (Paper III) indicated that industry-specific indicators for the graphic arts industry, developed in joint projects, are uncommon and have only been used to a limited degree. Initiatives were found in the MEPI study (Berkhout et al. 2001 and, Berkhout and Hertin 2001), Cadra (1998), Cook (1997) and GA (1999). The survey also showed that industry-specific

indicators for all dimensions of sustainability, especially for the social dimension, were not well developed or used. This was not only valid for the graphic arts industry. The MEPI follow-on project, Sustainability performance benchmarking, Perform (www.sustainability-performance.org) has since then included indicators for all sustainability aspects. The benchmarking service is no longer operational but there is a lot of data available at the web-site. When comparing the Perform data regarding environmental indicators, these are in the same range as the environmental indicator data reported in this thesis. We have only made a limited number of suggestions for financial and social indicators in our concept, because there were problems with finding indicators with general definitions in these areas at this time. In addition, when it comes to financial and social indicators, these are more difficult to interpret than the environmental indicators, where lower emissions of fossil carbon dioxide are interpreted as good, to give an example. Regarding social aspects, customer relationships are important for companies. For newspaper companies, the ability to inform, educate and generate opinion in favour of sustainability issues can be of interest, but this has to be balanced with the 'code of honour' for there to be objectivity.

There are many links among the Measuring Environmental Performance of Industry (MEPI) project (Berkhout et al. 2001 and Berkhout and Hertin 2001) including the study described by Olsthoorn et al. 2001, and our work with indicators, when it comes to work procedures and defined indicators. The study by Krajnc and Glavič (2005), developing the use of indicators in methods for sustainability assessment, is also close related to the work procedures in our present and future indicator research.

In line with the industry-specific indicator research, as described in this thesis, the need for specific indicator models with a set of indicators adjusted and tailor-made to different types of industry were discussed in recent studies. Some examples are given in Maxime et al. (2005) for the Canadian food and beverage industry, in Rao et al. (2005) for small and medium enterprises (SME) in the Philippines, in Tam et al. (2006) for the construction industry in Hong Kong and in Thomassen and de Boer (2005) for dairy production systems in Western Europe.

To reach the overall objectives for society, according to governmental commitments for sustainable development, there is need for a 'bottom-up' perspective. Based on industry-specific indicators, specific trades of industry have a possibility of developing general environmental and sustainability objectives for the industry. This could make environmental work more proactive in the whole industry, and might make it easier for small companies that have difficulties in making extensive environmental inquiries on their own.

Design for environment (DfE)
The development of DfE tools in this thesis was limited to a consideration of printed products. Developments in the industry and the growing desire and demand among customers for complementary media products mean, nevertheless, that electronic media are of interest too. Whatever the industry, DfE often reveals major potential in entirely new product concepts (e.g. Brezet and van Hemel 1997), which makes different types of media attractive for different purposes and target audiences. Efforts were made to examine these wide-ranging issues in the framework of another project (Widing et al. 2000). It should be mentioned that a further limitation to the present study is that DfE efforts focused on reducing the environmental impact of products, rather than improving the benefits of products.

Experience from our and related research shows that general guidelines for DfE must be tailored to a type of industry or products, in order to be used effectively (e.g. Behrendt et al. 1997, Dahlström 1999, Enroth and Widing 2000). This is so because DfE tools require a large amount of specific environmental information about the types of products, as well as a good knowledge of current production conditions. For the purposes of our study, it was additionally important to find ways for small companies with limited resources to use DfE. Furthermore, the design process in the graphic arts industry can be described as ongoing and is very rapid, which have imposed special demands on the industry-specific working methods and tools.

In the case of printed products, product development often involves a continuous process of improvement. Each new order effectively results in a new variant of the product. Development work therefore takes place on an ongoing basis among the customer/advertising agency and the printing houses. Collaborating with customers is the most effective way of improving environmental performance in the industry, since the customer usually decides not only the purpose and communication target of the product, but also its appearance.

The numbers of products that are produced by a graphic arts company are far too large per unit time to permit quantification of the flow of resources and materials during ongoing DfE work. A project that studied environmental indicators in Danish graphic arts companies (GA 1999) reached the same conclusion. The companies themselves prefer tools that are quick and simple to use in their ongoing DfE work (Enroth and Widing 2000). In order to encourage the widespread use of DfE, it is important to develop tools that are simple to apply but which still give valuable assistance. The term ‘simple tools’ refers primarily to tools that are easy to use. This requirement is achievable. On the other hand, there is no credible way of simplifying the background information to provide a simplified tool. The design of simple tools must therefore be based on environmental information obtained from sources, such as previously conducted Life-Cycle Assessments or environmental reviews.

Product development is a creative process that must not be limited by guidelines that are too strict. Thus, the sometimes rigid procedures suggested and described in previous mentioned conceptual literature on DfE should be considered as a general framework for environmental modelling and decision making during the product development process.

The research presented in this thesis, resulting in tools, such as a manual for DfE applied to the graphic arts industry and a method for formulating and realising environmental and sustainability strategies in companies, mainly matches the preferences of researchers, involved in the study by Argument et al. (1998). In the Argument et al. study, industry requirements were matched with academic research in the area of design for environment. Argument et al. (1998) identified gaps between research and industrial requirements for DfE, which is similar to the experiences in our DfE studies. However, by tailoring the DfE tools and guidelines to a specific type of industry and their products and by a practical approach, this gap might be bridged within a reasonable time, presupposed that customer demands are evolved.

For the graphic arts companies, as for many companies that produce goods or supply services, the greatest environmental impact and, therefore, the most important significant environmental aspect is often due to the products themselves. Therefore industry-specific tools for DfE could be of great future interest.

It was the general opinion of the participating companies in our study that an essential requirement for the development of DfE work in companies is that it should be seen as offering a strong competitive edge (Enroth and Widing 2000). The DfE tools developed have the potential of strengthening the collaboration with customers, which, in turn, can contribute to a strengthened competitive edge. In line with this, van Hemel and Cramer (2002) concluded from their studies in companies that an eco-design improvement option only stands a chance if it is supported by stimuli other than the expected environmental benefit alone.

In a similar way to Maxwell and van der Vorst (2003), we developed our methods for DfE in close co-operation with industry and practitioners. The work procedure described in the Irish initiative is reminiscent of our research. The example of a checklist for sustainable product and/or service development (SPSD), as described by Maxwell and van der Vorst, is very interesting and correlates to our further work with developing sustainability indicators for wood fibre based products.

5.2 Conclusions and future industry-specific research needs

5.2.1 Environmental management and sustainability strategies

Conclusions

The most significant results of the research on environmental management and sustainability strategies presented in this thesis can be summarised as follows:

- An evaluation of early certified environmental management systems (EMSs) in Sweden.

Among other things, this evaluation showed that:

- The identified significant environmental aspects corresponded well with the areas within which companies had established environmental targets. In addition, the study indicated that most of the companies had environmental targets in the majority of areas that were regarded as important.
- On average, nearly 70% of the physical targets of the certified companies, regarding emission or resource reduction, were achieved. On the other hand, half the environmental objectives and targets would also have been achieved without EMS.
- Companies using environmental indicators to follow up environmental objectives and targets seemed to attain a better environmental performance than others.
- Half of the environmental objectives and targets produced payback within one year, through cost savings or increased revenues.
- The greatest cost savings were made due to reduced expenses for energy, waste treatment and raw materials.

By the time of this evaluation (1999), the following four areas were identified as priorities in making EMSs more efficient:

- Clarify the identification process and assessment of environmental aspects.
- Improve the follow-up of environmental work.
- Link EMSs to product design and put more focus on the products (goods and services) from a life cycle perspective.
- Streamline and co-ordinate different management systems.

Out of the four identified areas that needed to be developed, we continued the research presented in this thesis by mainly developing two of the areas for the graphic arts industry: environmental indicators and design for environment (DfE).

- An established and successfully tested working method for formulating and realising corporate sustainability strategies in the graphic arts industry.

  This result was built up by the following :
  - The working method was proved useful in real life and enabled two case studied companies to formulate a strategy, based on a shared vision in extended management groups within a reasonable timeframe.
  - The previously suggested connection between the capabilities in establishing a shared vision and the ability to accumulate the resources necessary for sustainable development was illustrated.
  - The study demonstrated the value of some of the previously suggested prerequisites for successful sustainability work, such as strong management, continuous commitment and support from top management and a systems (life cycle) perspective.
  - Description of some concrete practical results in detail, which contributes to the process of bringing the thoughts of conceptual sustainability into practice in industrial applications.

  The developed working method consists of six stages. It is inspired by the Plan-Do-Check-Act (PDCA) method in ISO 14001 and the SWOT methodology. These methods were combined, modified and put into practice. A modified SWOT analysis, focusing on the external factors (opportunities and threats in society) is used in the first stage, the business intelligence process. The following stages are: identification of significant aspects, the formulation of vision and long term objectives, the formulation of short term targets, implementation as well as monitoring.

  The established working method is a general one and applicable to different types of industries and organisations. However, in order to identify the significant aspects and focus the strategy work on the relevant actions, the strategy has to be based on industry and company specific sustainability knowledge. By using the working method, it could be possible to support companies in their efforts to strive for sustainable production and to develop more sustainable products.

Deliberate, strategic environmental work in companies is often started and carried out within the framework of a certified environmental management system (EMS), although there are other types of environmental management that are used in the graphic arts industry.

Future industry-specific research needs
Future industry-specific sustainability management and strategy development research of interest includes, amongst others:

- Investigating the possible relationships among the environmental performance of companies and different kinds of environmental management, conditions in the companies, different types of production and products, size, etc. This includes investigating the effects of the developed strategies on sustainability performance.
- Developing the work procedures of supply chain collaboration and organising the supply chain for the graphic arts industry.

5.2.2 Environmental indicators

Conclusions
The most significant results of the research on environmental indicators presented in this thesis can be summarised as follows:

- Industry-specific environmental indicator models for the graphic arts industry with defined methods for standardised inventorying and calculations. These models are compatible with each other and have been tested, used and approved of by the industry itself.

  The main model consists of 17 environmental measurements that are related to two different measurements for utility, viz. 'Total weight of products' and 'Annual turnover'. In addition, the main model includes some financial and social measurements. This model has mainly been used in the Swedish newspaper industry.

  A selection of the indicators from the main model (5 of the recommended environmental indicators from the main model and information on the existence of certified EMS) were chosen for measuring the environmental performance of gravure and heatset offset printers. This selection is useful for print buyers collaborating with their suppliers, for example.

- Collected and compiled data for the developed indicator models. Data have been collected from quite a large number of companies (10-20 companies for each of the printing techniques covered, i.e. coldset offset, heatset offset and gravure) over a period of several years. For example, the production of the studied gravure printers in Europe in 2002 represented more than 30% of the total gravure printing in Europe that year.

  The indicator data presented in this thesis can be used as a guide for printers and buyers of printed products, who are striving for making continual improvements with the aim being more environmentally adapted printed products. In addition, to some extent the compiled data can be used as

reference values for the environmental performance of graphic arts companies.

- The use of the industry-specific indicator models was developed and illustrated.

  A method using industry-specific environmental indicators, as a basis for the identification of areas of improvement and action plans, was developed and tested.

  The follow-up and promoting of an improvement in environmental performance, by means of environmental indicators, were illustrated.

  An industry-specific tool for the communication of environmental tasks were developed and illustrated. Based on the type of information requested from the companies by various stakeholders, a selection of indicators from the main model, related to the 'Total weight of products', were suggested for external communication.

The industry-specific indicator models developed fulfil some basic requirements; they describe the significant aspects, are based on scientific knowledge and are well defined. It is possible to carry out an inventory process with reasonable resources, since clear inventory instructions and clear system boundaries are available. They are easy to communicate with a common tool and, most likely, they are easy to understand.

The areas of use of the industry-specific indicators for a company as well as the industry, as such, can be summarised as an enhanced awareness of the situation, possibilities to achieve improvement in environmental performance and financial savings and an improved internal and external communication of environmental tasks. Altogether, this could help companies in their efforts to strive for a sustainable production and to develop more environmentally adapted printed information products.

Future industry-specific research needs

A future industry-specific indicator research of interest comprises, among others:

- Reviewing and updating of the industry-specific indicator models on a regular basis, in order to adjust them to comply with changes in legislation and emission factors related to the production of energy and various means of transport, for example.
- Developing industry-specific sustainability indicators for the graphic arts industry, which take into account companies providing printed and electronic information products and product service systems (PSS) for information products.

- Collecting data from more companies, in order to gain even more representative data and be able to fine-tune adequate groups of companies for benchmarking with regard to such things as type of activities, used printing techniques and size of the company.
- Developing general sustainability objectives for the graphic arts industry, in order to promote an improvement of its sustainability performance.

5.2.3 Design for environment (DfE)

Conclusions

The most significant results of our industry-specific research on design for environment (DfE) can be summarised as follows:

- A described and recommended work procedure for DfE in graphic arts companies including industry-specific tools for applying DfE to printed products, in the form of a manual and a checklist. The checklist was designed so that it can serve as a simple tool for the environmental assessment of printed products. The tools were tested by graphic arts companies.

The manual offers an introduction to DfE and suggestions for the work procedure, when designing and producing printed products. Furthermore, the manual gives environmental information about important aspects of the design, production and the recycling of printed products. The checklist gives advice on the most critical decisions, when designing and producing printed products, from an environmental point of view.

Future industry-specific research needs

Amongst others, a future industry-specific DfE research of interest includes:

- Reviewing and updating on a regular basis of the information and advice given in the tools that have been developed. This is necessary because opinions about relative environmental impact are changing, as new knowledge is acquired and new consumables and technical solutions are launched.
- Relating DfE for printed products to DfE for electronic information products, which are developing rapidly and becoming increasingly widely used.
- Developing ways of inventorying and quantifying the “benefit” of various types of information products.
- Linking DfE to business development and functionality sales.
- Developing the DfE tools to tools for sustainable product development (SPD). These tools need to take into account printed as well as electronic information products and product service systems (PSS) for information products. In addition, they have to bring into consideration all the Triple Bottom Line (TBL) elements.

5.2.4 Final remarks

Sustainable development will not just happen on its own, but needs the action of many complementary as well as competing approaches to conceptualise and put it into operation so that it can be implemented.

Information products have the potential of playing an active role in the development of a sustainable society, since information, knowledge and inspiration can be prerequisites for creating commitment and involvement in such things as democratic processes.

Foresighted graphic arts and media companies can take advantage of the ICT revolution for developing and creating new revenue opportunities, in the form of new product service systems, where tangible products (goods) and services are combined for creating added value. At the same time, the changed and extended customer demands for information products (tangible and intangible) have to be balanced, in order to develop sustainable activities and products in the graphic and media industry in future. One of the challenges for the industry is to optimise the use of different types of information products (e.g. printed products and electronic products) with regard to functionality/purpose, target group, costs, quality and sustainability performance. In short, the right type of information product must be used for the right purpose.

By using the developed industry-specific work procedures and tools, it could be possible to improve the efficiency of environmental and sustainability efforts in the graphic arts value chain and the environmental performance of printed products.

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7 The author's contribution to the papers

Paper I
Environmental Management Systems – Paper tiger or powerful tool, by Maria Enroth and Mats Zackrisson. I carried out the research behind the report, together with Mats Zackrisson and Angelica Widing. I collaborated with Mats Zackrisson when writing the paper, although I was the one responsible for writing and presenting the paper.

Paper II
Environmental indicators in the graphic arts industry, by Maria Enroth and Angelica Widing. I carried out the research behind the report together with Angelica Widing and colleagues at another research institute. I was responsible for writing and presenting the paper.

Paper III
Promoting sustainability using business specific indicators, by Maria Enroth. I carried out the literature survey. The multi-company studies behind the research were carried out in collaboration with Angelica Widing. The paper was written by me.

Paper IV
Tools for Design for Environment (DfE) - Applications in the Printing Industry, by Maria Enroth and Angelica Widing. I carried out the research behind the report together with Angelica Widing. I was responsible for writing the research report, while Angelica was responsible for writing a handbook. I was responsible for writing and presenting the paper. I initiated and led this study.

Paper V
Environmental indicators in the newspaper industry, by Maria Enroth, Martin Johansson and Åsa Moberg. I carried out the research behind the report, together with Martin Johansson and Åsa Moberg. I was responsible for writing the research report and the paper, which was presented by me. I initiated and led this study.

Paper VI
Environmental data on gravure and offset printing, by Maria Enroth and Martin Johansson. I carried out the research behind the reports together with Martin Johansson. I was responsible for the research and for writing and presenting the paper.

Paper VII
How to formulate and realise a corporate sustainability strategy, by Maria Enroth. The research behind the reports was carried out by me in collaboration with Martin Johansson and, to some extent, with Bosse Lundgren. The paper was written and presented by me.