New Model of Component-based Product-Oriented Environmental Management System (C-POEMS) for Small and Medium-sized Enterprises

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Abstract

Product-oriented environmental improvement is a great challenge for SMEs. There are two main reasons for this; firstly, a contradictory situation exists because SMEs lack the knowledge and competence to adopt the mainstream principle holistic approach of environmental product policy and regulations, and, secondly, there is a growing demand to incorporate environmental management system (EMS) and product dimension via eco-design. To address these issues, this research focused on a product-oriented environmental management system (POEMS) that has been specifically developed to solve these problems. However, POEMS studies so far lack methodological development and focus more on how to incorporate EMS and eco-design rather than how to interpret the contents and improve POEMS as a standard tool.

This research aimed to develop a new model, namely, component-based POEMS (C-POEMS). The C-POEMS model is a first attempt to define a potential standardised form of POEMS in its contents and structure, and form the basis for a useable self-help format for SMEs. A C-POEMS model, comprising stages of process, categories of functional areas/units, and elements, and a diagnosis template, as a component-based application, are developed and formulated. Through primary research, the C-POEMS conceptual model was verified and applicability of a C-POEMS component to SMEs was validated.

C-POEMS made major contributions of two aspects: (1) methodological development of POEMS; (2) improvement of the format applicable for SMEs incorporating mainstream principles. Regarding methodological development of POEMS, arguments of existing POEMS methods were revealed, and the suggestions as well as analytical information in this research would provide benefit for further research in this field. The C-POEMS improved POEMS by providing clear contents and structure with predefined prior and

correlated categories of functional area/units, which are helpful for SMEs. In addition, a diagnostic approach would help SMEs recognise their own problems and focus areas. As a result, SMEs can reduce the initial time to identify a structure of product-related environmental management, and increase opportunities to focus on major targets and product aspect for environmental improvements. Because of time constraint and underdevelopment of POEMS, there remain problems, in particular, to fully integrate EMS and eco-design, and the asymmetric situation between maintaining the broad scope of POEMS and focusing upon specific areas and user demand. However, this C-POEMS model provides a foundation for the development of EMS for SME's and for ongoing development of POEMS.

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Acronyms

AIDA	Attention-Interest-Desire-Action
APEC	Asian-Pacific Economic Cooperation
BAT	Best Available Technique
BPD	Business Processes Domain
BPM	Business Process Models
CBD	Component-Based development
CBM	Centrale Bon van Meubelfabrikanten (The central association of the Dutch furniture manufacturers)
CBSM	Component-Based System Model
CCEM	Centre for Corporate Environmental Management
CEC	Commission of the European Communities
CE	Conformité Européenne
CP	Cleaner Production
C-POEMS	Component-based Product-Oriented Environmental Management System
DfE	Design for Environment
DfS	Design for Sustainability
DIY	Do-It-Yourself
DTI	The Department of Trade and Industry/ currently BERR: The Department for Business, Enterprise & Regulatory Reform
EA	Enterprise Architecture
EC	European Commission
EED	External Environment Domain
EEE	Electrical and Electronic Equipment
EMAS	Eco-Management and Audit Scheme
ENSR	European Network for SME Research
E-KPI	Environmental Key Performance Indicator
EMS	Environmental Management System
EoL	End-of-life
EPR	Extended Producer Responsibility
EU	European Union
EUC	Euro Currency
EuP	The eco-design of energy-using products
GDP	Gross Domestic Product
ICM	Integrated Chain Management

ID	Information Domain
IDSA	The Industrial Designers Society of America
IoD	The Institute of Directors
IPD	Information Processing Domain
IPP	Integrated Product Policy
ISO	International Organisation for Standardisation
IS	Information System
IT	Information Technology
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCC	Life Cycle Costing
LCM	Life Cycle Management
NGO	Non-governmental organisation
OEM	Original Equipment Manufacturer
OHS, OH&S	Occupational Health & Safety
OOAD	Object-Oriented Analysis and Design
PDCA	Plan-Do-Check-Act
PEC	Product-Oriented Environmental Care
POEM	Product-Oriented Environmental Management
POEMS	Product-Oriented Environmental Management System
PTD	Product Technology Domain
RoHS	The Restriction on the use of certain hazardous substances in electrical and electronic equipment
SCM	Supply Chain Management
SETAC	Society of Environmental Toxicology and Chemistry
TQEM	Total Quality Environmental Management
TQM	Total Quality Management
UNEP	United Nations Environment Programme
WBCSD	World Business Council for Sustainable Development
WEEE	Waste electrical and electronic equipment

Chapter 1 Introduction

This thesis aims at developing a tool that responds to the trends of recent environmental policy and regulation, and supports small and medium-sized enterprises (SMEs). First of all, background mechanisms surrounding SMEs in relation to the environment are explored in three perspectives: 1) predisposition of SMEs in environmental issue including general characteristics of SMEs and current situation of SMEs in environmental issue; 2) mainstream principles of the recent environmental product policy and legislations; 3) critical reviews of existing environmental tools with respect to organisation- and product-oriented tools. This chapter then introduces the focus of the work, develops research questions, and explains the thesis structure.

1.1 Environmental issues in SMEs' perspective

This section begins with an overview of the general characteristics of SMEs and current situation of SMEs in environmental issue. The first subject provides a review of definition of SMEs, and economical and environmental contributions of SMEs. The second part argues, in SMEs' viewpoint, about the following subjects: uptake of environmental issues, main drivers for environmental improvements, main barriers of environmental improvements, and support for environmental improvements.

1.1.1 General characteristics of SMEs

1.1.1.1 Definition of SMEs

It may be difficult to encompass small and medium-sized enterprises (SMEs) within a single definition due to the wide diversity of businesses in terms of their size as well as different patterns of their business operations. In spite of their variety, company size itself is generally represented quantitatively in employee, turnover or total balance sheet figures. Nevertheless, special characteristics of especially small companies such as their ownership identification, individual financial situation and their relationship with employees need to be considered to mark them off from larger ones. Summarising these characteristics of SMEs by Megginson *et al*. (1971, cited by Recklies, 2001) and Hauser (2000, cited by Recklies, 2001), the group of features on the right column in Table 1.1 is classified to the qualitative definition and can be compared to the quantitative attributes on the left column.

Table 1.1: A brief comparison of quantitative and qualitative definitions of SMEs

Quantitative definitions	**Qualitative definitions**
• Number of employees	• Type of management
• Turnover	• Financial situation
• Balance sheet total	• Operational area
• Cash flow	• Relative scale
	• Relationship with employees

In the type of management, a small firm often holds an 'independent ownership'[1] and management responsibility by a person or a few individuals. Capital is supplied and held

[1] European Commission (2005) defines the element of independence that an enterprise is an SME only if it is not owned by more than 25% by a large enterprise.

by a person or a few individuals, too. SME business is relatively small scale compared with the large competitors, which SMEs are often not dominant in its industry. A company's non-dominance in its industry or its relative size compared to other players is an important aspect (Recklies, 2001). "*It is often ignored that many successful SMEs are highly specialised niche players, which often dominate their special niche of the market or their special industry segment. Such criteria would necessarily require defining the scope of the industry hence include more subjective elements* (*Ibid.*)".

Table 1.2 compares various definitions of SMEs that show predominantly under 250 or 500 in employee number, and under 50 EUC (Euro Currency) in annual turnover and annual balance sheet in quantitative attributes. The qualitative definition is based on ownership and financial independence. Since establishing the first common SME definition in 1996, European Commission built a new recommendation of the definition and it entered into force in 1 January 2005. It has widely applied to policies, programmes and measures that the Commission operates for SMEs. The new definition of SMEs initially targets two audiences.

> *"The first are entrepreneurs running micro, small or medium-sized enterprises that are interested in applying for grants or loans aimed at SMEs. These entrepreneurs may also want to know if they satisfy the criteria to benefit from specific legislative provisions for SMEs. The second audience are the European, national, regional and local officials who draw up and run the various schemes, process the applications and ensure that companies satisfy the eligibility criteria for support* (European Commission, 2005)".

Table 1.2: A variety of definitions of SMEs (author's own compilation)

	No. of employees	Annual turnover (EUC)	Annual balance sheet	Ownership	Financial independence	Market share
Bolton Report+ (1971)				Owner managed	Financially independent	Small market share
Business Link (2003, UK)+	Micro: 0-9 Small: 10-49 Medium: 50-249					
DTI (1995)+	Small:0-200 Medium:201-500					
IfM Bonn (2004)‡	Small: up to 9 Medium:10-499 Large: 500 and more	Small: up to 1m Medium: 1-50 m Large: 50 m and more				
European Commission (2005)**	Micro: under 10 Small: under 50 Medium: under 250	Micro: under 2m Small: under 10m Medium: under 50m	Micro: under 2m Small: under 10m Medium: under 43m	Autonomous: completely independent/ minority partnership (each less than 25%) with other enterprises) , owner-manager	Less than 25% of the capital or voting rights	
Eurostat*	Micro: 1-19 Small: 10-99 Medium: 100-499					
US*	Micro: 1-19 Small: 20-99 Medium: 100-499					

EUC: Euro Currency

+ Sourced from Bruce and Cooper (1999), ‡ Sourced from Günterberg and Kayser (2004), * Sourced from Recklies (2001)

** Sourced from European Commission (2005): p.11, 16, 18, 19, available at:

http://ec.europa.eu/enterprise/enterprise_policy/sme_definition/sme_user_guide.pdf

The key elements of SMEs in the report (European Commission, 2005) are summarised as the staff headcount, annual turnover, and annual balance sheet. Staff headcount – which covers full-time, part-time and seasonal staff – is a crucial initial criterion for determining the category in which an SME falls. Annual turnover is determined by calculating the income that an enterprise received during the year in question from its sales and services after any rebates have been paid out (*Ibid.*). The annual balance sheet total refers to the value of a company's main assets (*Ibid.*). The report also categorises types of ownership into three groups comprising autonomous enterprise, partner enterprise and linked enterprise, which specifies the types of ownership based on some conditions such as capital and 'voting rights'[2].

Although the quantitative requirements in classifying SMEs are regarded as important determinants, they can be different depending on the scale of industry and sector, where is exampled, and the statistic information is not easily obtained from firms. Thus, it might not be possible to specify by a universal standard. However, identification of SMEs will allow for greater support for financial help or participation in specific programmes to new business applicants as well as organisations handling the policies and programmes related to SME sector.

[2] More detail is available at:
http://ec.europa.eu/enterprise/enterprise_policy/sme_definition/sme_user_guide.pdf

1.1.1.2 SMEs' contribution to economy

SMEs play a significant role in the economy. Some statistic indictors of SME contributions to the national and international economy are illustrated in Table 1.3. Firstly, small firms are generally regarded as a sizable sector in industry overall. For example, in most European countries, more than 90 per cent of businesses fall into the SME sector. The Centre for Corporate Environmental Management (CCEM) reported that around 90 per cent of European businesses in 1996 were classified as 'SMEs'[3] (CCEM, 1997, cited by Hillary, 2004). In the UK, the percentage reaches nearly all businesses as indicating 99 per cent of total businesses which is equivalent to 3.7 million. A similar proportion is seen in other European countries such as Germany and the Netherlands according to Recklies (2001) and Hoevenagel and Wolters (2000). This percentage is not only similar in Europe but all over the world and the numbers are growing (Hillary, 2000a).

Secondly, SMEs make a huge contribution to the creation of jobs. According to the survey in 2002 by DTI in the UK, SMEs account for 58 per cent of all employment in the UK and 66 per cent in the EU, which this estimated figure of new business among SMEs shows gradual increases (DTI, 2003). Even though the exact percentage of the SME portion may differ slightly depending on the regions or country, the global estimation is nonetheless much the same as that shown in European statistics. Johannson (2000) quotes some world statistics that "*the combined gross domestic product (GDP) of the world was about US$ 29 trillion, 55% of total world income was in Asia Pacific Economic Co-operation (APEC)*

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[3] Employing less than 250 people.

member countries and 45% in non-APEC member countries. The 40 million SMEs throughout APEC economies account for well over 90% of all enterprises, employing from 32% - 84% of the workforce, contributing 30% - 60% of the GDP and accounting for 35% of exports in the region. These figures are paralleled in non-APEC economies (APEC 1997, cited by Johannson 2000)".

Table 1.3: SMEs' contributions to national and international economy (author's own compilation)

	No. of SMEs	Percentage of industry	Percentage of employment	GDP	Gross investment	Turnover
APEC 1997+ (APEC countries)		90%	32%-84%	30%-60%		
CCEM 1997* (EU)		90%				
CEC 1996** (EU)		99.8%	66.3%			50% (non-agricultural market
DTI 1999* (UK)	3.7 million	99%				
DTI 2003 (UK)			58%			
Fay 2000 (UK)	3.7 million	99%	58%	38%		
Hillary 2000a		99.8% (UK) 90% (EU)				
Recklies 2001 (Germany)	3.2 million	99.3%			46%	48.8%

* Sourced from Hillary (2004)

** Sourced from Clement and Hansen (2002)

+ Sourced from Johannson (2000)

Thirdly, the source of entrepreneurship and economic growth is to be found in the innovative activities of SMEs themselves (Cawood, 1997; Johannson, 2000; Pimenova and van der Vorst, 2003). Cawood (1997) notes that small organisations are likely to start their businesses with new concepts for niche market and try to differentiate themselves from their competitors through the innovation. The author also observes that among companies receiving annual Businessweek/IDSA design awards, smaller firms are more likely to be innovative in opening a completely new path of technology or product development while larger firms tend to present products that show steady incremental improvement on existing technology and markets.

Finally, SMEs are crucial players as suppliers and customers to large companies. Hoevenagel and Wolters (2000) and Kuhndt and von Geibler (2002) emphasise the role of SMEs in the supply chain system. Especially cooperation in integrated chain management of environmental life cycle perspective is regarded as a core aspect in order for industrial ecology and overall 'eco-efficiency'[4]. Therefore, big companies, and in particular multinationals, face huge challenges in managing and supporting their suppliers as the larger ones expect to achieve improved environmental performance throughout the range of their products and components.

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[4] Eco-efficiency is the business strategy implementing the concept of sustainable development that was announced by the World Business Council on Sustainable Development (WBCSD) in 1992: '*Eco-efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity*' (WBCSD, 1996, cited by Dewulf,, Duflou and Ander, 2001)'.

1.1.1.3 SMEs' contribution to environmental impacts

It is generally accepted that SMEs largely contribute to the environmental problems although the total environmental contamination of SMEs has not been substantially quantified. In terms of the statistical estimates of the total environmental impact of SMEs, Hillary (2000a) asserts that "*national economic statistics on SMEs do not tally with data collected on emissions, waste generation and effluents from firms, so it is doubtful whether smaller firms' contribution to pollution can be calculated at all"*. With regard to this, Hillary (2000a) and Hoevenagel and Wolters (2000) agree that there is little hard data to determine the sector's contribution to pollution loads. However, the same article by Hillary (2000a) claims that "*SMEs' environmental impacts are substantial as perceived by their sheer numbers*".

Nevertheless, there are some estimates of environmental impacts from the SME sector. A number of research reports indicate that SMEs produce considerable collective impacts on the environment (ECOTEC, 2000; Environmental Agency, 2004; Hobbs 2000; Hoevenagel and Wolters, 2000; Cawood, 1997). The report of European Commission surveyed by ECOTEC (2000) claims that the environmental problem created by SMEs reaches around 50% overall. SMEs generate about 60% of commercial waste and are responsible for as much as 80% of pollution incidents in the UK (Environmental Agency, 2004). Hoevenagel and Wolters (2000) state that environmental burden by SMEs is not negligible according to the survey of the Dutch industry as shown in Table 1.4. Considering the fact that a substantial amount of SMEs are locally based (Cawood, 1997), the environmental impact of SMEs is likely to be hidden and the overall effects are far more than general perception. Hobbs (2000) claims that SMEs could cause even more pollution than larger enterprises operating in the same sector because of differences in production techniques. For example, SMEs commonly operate in some of the most problematic trades – metal finishing, leather tanning, dry-cleaning, printing and dyeing, brewing, food processing, fish farming, textile manufacture, etc. (*Ibid.*). Even though those SMEs are more often found in developing countries – labour-intensive and low-skilled activities (*Ibid.*), at a global level the cumulative impact on the environment by SMEs can parallel those of multinational corporations.

Table 1.4: The Netherlands: The contribution of SMEs to emissions and discharges, 1995 (Hoevenagel and Wolters, 2000)

	CO_2 (kg)	CFCs (1,000kg)	NOx (kg)	SO_2 (kg)	Waste (kg)	Waste-water
Emissions (million kg)	179,535	1.085	499	147	16,799	27,894
Consumers (%)	21	4	26	3	32	55
Companies (%)	79	96	74	97	68	45
Public-sector organisations (%)	33	3	21	13	12	7
Private-sector organisations (%)	46	93	54	84	56	38
► SMEs	14	36	24	14	24	20
► Larger enterprises (%)	33	45	29	70	32	18
SMEs as total of all companies (%)	19	37	32	14	35	44

In thousands of inhabitant equivalence (1 inhabitant equivalence equals average amount of waste produced by one individual in a private household)

CO_2= carbon dioxide; CFCs= chlorofluorocarbons; NOx= nitrogen oxides; SO_2= sulphur dioxide

Source: EIM 1998

To summary, SMEs have a broad range of roles on account of significant contributions to both economic growth and environmental impacts. Despite the lack of consensus on their total environmental impacts, small firms should not be excluded from the vast environmental responsibility in the national and regional scale. In this circumstance, it needs to be explored whether SMEs either have been sufficiently involved or informed about environmental issues and, if not, why it is so.

1.1.2 Current situation of SMEs in environmental issues

This section discusses the current situation of SMEs in four major issues: SMEs' awareness and uptake of environmental issues, their main concerns as drivers, as barriers, and in environmental support.

1.1.2.1 SMEs' awareness and uptake of environmental issues

According to some research (ECOTEC, 2000; Environmental Agency, 2004; Gerrans and Hutchinson, 2000; Holt *et al*., 2000), the general awareness of environmental issues is relatively low in the SME sector. These studies take two approaches; a level of awareness of major environmental issues (e.g., legislation or special terms), and a degree of environmental performance. For example, according to some surveys (Environmental Agency, 2004; Gerrans and Hutchinson, 2000; MORI, 1998), small firms often do not recognise and name any environmental legislation. In terms of SMEs' environmental attitude or awareness, no big change of statistics is found between the relatively recent surveys and the past ones. In addition, SMEs perceive environmental impacts as insignificant in their business. A survey by Gerrans and Hutchinson (2000) indicates that more than half of the SMEs interviewed consider that they have either minimal impact or no impact at all on the environment.

The other approach is the level of environmental performance of SMEs. Even though there are different reactions to environmental issues depending on sectors or sizes – e.g., medium size or mining industry and chemical industry can be more concerned and cautious –, small companies generally lag behind larger businesses in environmental improvements. According to the survey by The Institute of Directors (IoD) in 1994, "*the smallest companies spent the least time on environmental issues, it found that 51% of respondents from companies with 20 or fewer staff spent no time at all on environmental issues, whereas only 23% of companies with 200 or more staff failed to address environmental issues at the board level* (IoD 1994, cited by Holt *et al*., 2000)".

Besides, the report of European Commission (2002) quotes the ENSR Enterprise survey in 2001 showing that only 12 per cent of SMEs support environmentally responsible activities in external activities related to social responsibilities. In the East Midlands region of the UK, only 12 per cent of the 380 firms sampled have had carried out any form of environmental review (Elliot *et al*., 1996, cited by Holt *et al*., 2000). This might mean that SMEs generally perceive environmental performance as an extra cost or burden and as obstacles to their competitiveness. Many researchers (Anglada 2000; Holt *et al*., 2000; Kuhndt and von Geibler 2002; MORI 1998; PRIME Faraday Technology Watch 2003;

Geiser and Crul 1996, cited by Wehrmeyer 1999) support this opinion that SMEs care more about short-term economic survival than their impact on the environment as they do not ask for or use environmental information or support. In relation to this, Anglada (2000) interviewed the managers involved in environmental work in Spanish small firms and none of them feel that environmentally friendly practices lead to increased earnings or competitiveness, at least not in the short term. Although public or regulation incidents may temporarily pressure the companies, the environmental concern does not seem to last in their usual business. Therefore, the environmental issue attracts little attention from management within the commercial activities.

Conclusively, these studies and surveys indicate in common that only few SMEs take the environmental account into their business. Furthermore, most companies believe that the environment is an occasional and isolated problem and they often complain about environmental issues as being too much burden imposed on industry alone rather than society in general.

1.1.2.2 Main drivers of SMEs' environmental improvement

Many researchers have attempted to understand the pressures and motivations that move SMEs towards environmentally sound business and to find solutions to meet the requirements of environmental drivers. This research has reviewed and analysed a total of

'33 studies'[5] in terms of environmental drivers (also, motivations or pressures). Firstly, the main drivers were listed from the studies, and then the each driver was individually reviewed in terms of the frequency as well as the order of importance. According to the analysis, around 11 studies rank the environmental drivers in order of importance, while the rest of the studies describe them without any order of importance. Based on the result of the frequency and priority of environmental drivers, relatively important drivers could be outlined and the main drivers were summarised as follows: pressures from legislation and government policy; consumers/customers and supply chain demands; competitiveness and marketing reasons such as company image or sales advantages; stakeholder pressures, internally (e.g., employees or shareholders) and/or externally (e.g., local authorities or NGOs); environmental or social responsibilities; economic benefits such as material- and energy-savings; business efficiency such as improvement of management skills (e.g., environmental management system (EMS) implementation); public concerns; and benefits of international standards (e.g., ISO 14001 or eco-management and audit scheme (EMAS)). The numerical comparison between important drivers is presented in the 'drivers' and '33 total' columns in Table 1.5.

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[5] Ammenberg and Sundin 2004a; Anglada 2000; Baynes, Ridder and Scheidt 2001; Biondi, Frey and Iraldo 2000; Brent and Labuschagne 2004; Curtis and Walker, 2001; Dahlström *et al*., 2003; Environmental Business Network (EBN) 2000; EnviroWise 2000; European Commission 2002; Fanshawe 2000; Five Winds International 2000; Fresner 2004; Gerrans and Hutchinson 2000; Gerstenfeld and Roberts 2000; González-Benito and González-Benito 2005; Grayson and Hodges 2004; Greenan, Humphreys and McIvor 1997; Henriques and Sadorsky 1996; Hillary 2000b; Hillary 2004; Hitchens 2001; Hobbs 2000; Holt, Anthony and Viney 2000; Munkelien and Gravlien 2004; Petts 2000; Pimenova and van der Vorst 2003; Powell 2000; Smith, Kemp and Duff 2000; Van Hemel 2001; Van Hemel and Cramer 2002; Wehrmeyer 1999; Winsemius and Guntram 2002

Table 1.5: The comparison of frequency or importance of drivers in various standards

Drivers \ Scope & measurement	18 studies focused on SMEs		15 studies in general industry		15 studies based on survey		18 studies based on literature		7 studies based on EMS		33 total	
Policy, legislation	Prior: 8 The rest: 7	***15***	Prior: 8 The rest: 8	***16***	Prior: 7 The rest: 9	***16***	Prior: 6 The rest: 9	***15***	Prior: 5 The rest: 2	***7***	Prior: 13 The rest: 17	***30***
Customers/ consumers	Prior: 2 The rest: 9	***11***	Prior: 2 The rest: 9	***11***	Prior: 1 The rest: 10	***11***	Prior: 1 The rest: 7	***8***	Prior: 2 The rest: 2	***4***	Prior: 2 The rest: 16	***18***
Supply chain	Prior:: 1 The rest: 8	***9***	Prior: 1 The rest: 8	***9***	Prior: 1 The rest: 7	***8***	Prior: 1 The rest: 4	***5***	Prior: 2 The rest: 1	***3***	Prior: 2 The rest: 11	***13***
Competitiveness	Prior: 1 The rest: 3	***4***	Prior: 1 The rest: 3	***4***	Prior: 0 The rest: 5	***5***	Prior: 1 The rest: 3	***4***	Prior: 0 The rest: 0	***0***	Prior: 1 The rest: 8	***9***
Image, marketing	Prior: 0 The rest: 5	***5***	Prior: 0 The rest: 5	***5***	Prior: 0 The rest: 5	***5***	Prior: 1 The rest: 5	***6***	Prior: 0 The rest: 2	***2***	Prior: 1 The rest: 10	***11***
Stakeholder relation	Prior: 2 The rest: 7	***9***	Prior: 2 The rest: 7	***9***	Prior: 1 The rest: 10	***11***	Prior: 3 The rest: 4	***7***	Prior: 1 The rest: 3	***4***	Prior: 4 The rest: 14	***18***
Environmental, social responsibility	Prior: 2 The rest: 3	***5***	Prior: 2 The rest: 3	***5***	Prior: 2 The rest: 4	***6***	Prior: 0 The rest: 1	***1***	Prior: 0 The rest: 1	***1***	Prior: 2 The rest: 5	***7***
Economic reason	Prior: 1 The rest: 7	***8***	Prior: 1 The rest: 7	***8***	Prior: 2 The rest: 8	***10***	Prior: 0 The rest: 7	***7***	Prior: 0 The rest: 2	***2***	Prior: 2 The rest: 15	***17***
Business efficiency	Prior: 0 The rest: 3	***3***	Prior: 0 The rest: 3	***3***	Prior: 0 The rest: 5	***5***	Prior: 0 The rest: 1	***1***	Prior: 0 The rest: 2	***2***	Prior: 0 The rest: 6	***6***
Public	Prior: 1 The rest: 3	***4***	Prior: 1 The rest: 3	***4***	Prior: 1 The rest: 4	***5***	Prior: 0 The rest: 3	***3***	Prior: 0 The rest:	***0***	Prior: 1 The rest: 7	***8***
EMS standards (e.g., EMS, EMAS)	Prior: 1 The rest: 5	***6***	Prior: 1 The rest: 5	***6***	Prior: 1 The rest: 5	***6***	Prior: 0 The rest: 5	***5***	Prior: 1 The rest: 3	***4***	Prior: 1 The rest: 10	***11***

Prior: number of studies referring to the drivers as higher priority as accounted firstly- or secondly-important drivers

The rest: number of studies referring to the drivers as less prior or without order of importance

Italic bold: total number of studies referring to the drivers according to the studies' own scopes and measurements

Secondly, this research also categorically compared the frequency and importance of the main drivers depending on what measures or scopes that the studies used, so that more reliable data of key drivers can be obtained. Hence, the 33 studies were grouped into five categories, i.e., SME-focused, general aspect (regardless of size or sector), survey-based, literature-based, and EMS-based studies. The comparison between these groups is presented in Table 1.5. Although environmental standards such as EMSs gain a relatively low attention from the studies – seven studies regard EMS implementation as an important motivation –, an EMS often plays as an initiator for strategic environmental improvement and an important indicator in measurement of corporate environmental performance. In this regard, it is reasonable to include EMS implementation in the main environmental drivers.

This study graphically converted the analysis data in Table 1.5 to Figure 1.1. In the comparison between each category of scope or measurement, most categories show a similar order of importance of the drivers. For instance, the statutory elements such as regulation or policy are without exception the most powerful motivations, and are followed by the demands of customers or consumers, and stakeholder relations. Subsequently, pressures from supply chain, economic benefits of environmental improvement, and environmental standards are also fairly important drivers. In particular, EMS is regarded as a useful instrument to manage, control, and monitor legal compliance (Biondi *et al*., 2000). Company image or marketing requirements, environmental and social responsibility, and competitiveness are also considered, although they are not markedly mentioned. Marketing reasons (e.g., environmental awareness increase sales), in particular, are hardly mentioned at all according to the survey of Spanish SMEs by Anglada (2000). Finally, public concerns and business efficiency (i.e., improvement of management skill via environmental control) are found to be of the least importance even in the EMS-based studies.

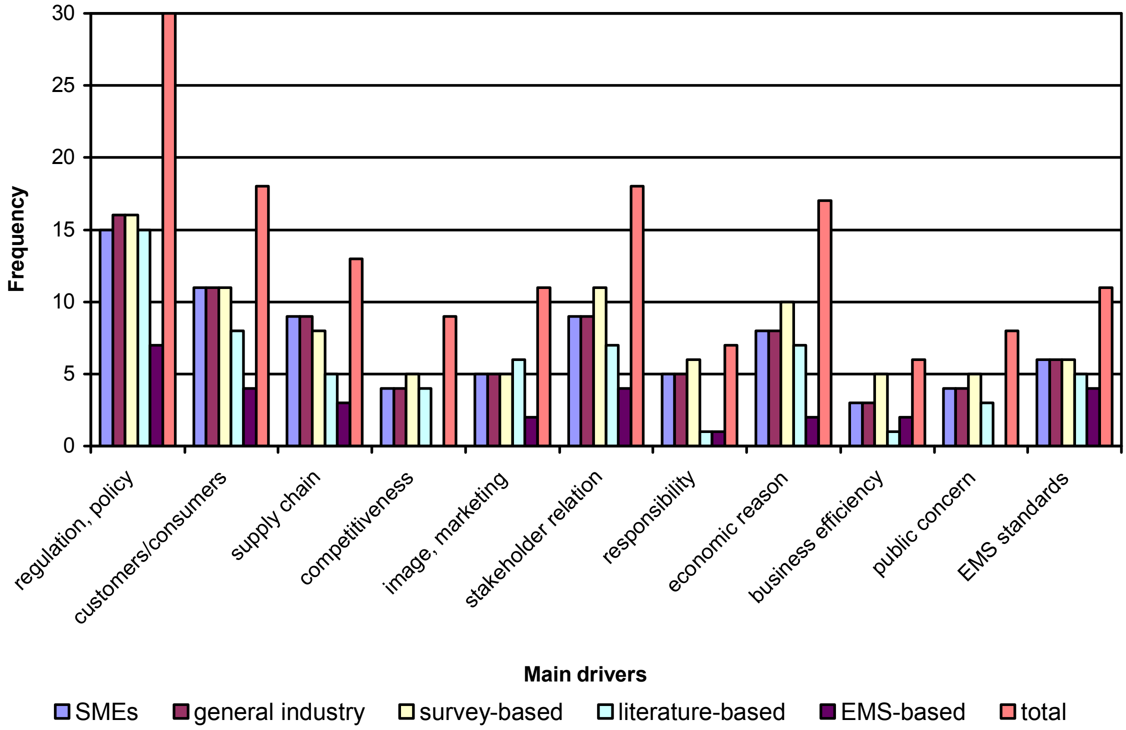

Figure 1.1: Comparison of frequency or importance of drivers in various standards

In terms of the most important drivers, environmental legislations and policy have been developed in an integrated way to control industry overall since environmental issues have been incorporated in policy, particularly within the EU. Hitchens (2001) and Hobbs (2000) assert that stricter environmental requirements affect access to markets, and stimulate demand for cleaner technologies. Considering the fact that a large majority of SMEs are suppliers for multinational companies (Biondi, 2000), environmental regulation could be a strong driving force for both big corporations and SMEs. In this regard, Hitchens (2001) explains a mechanism relating to these regulatory effects that individual enterprise in SME sector will encounter the pressures from large companies as well as importers who will require that their suppliers comply with their environmental standards and procedures. It means that SMEs face not only regulation itself but also direct and indirect pressures from all possible stakeholders affected by the laws.

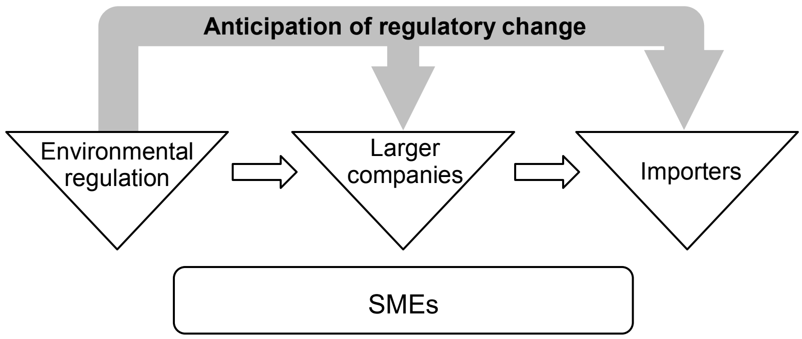

Figure 1.2: Regulatory changes and effects on SMEs

The Figure 1.1 also shows that SMEs seem to be more concerned about customers, supply chain, and stakeholders than the economic benefits at least in the environmental issue. Baynes *et al*. (2001) explain that activities beyond legal compliance often result in higher costs without showing a concrete financial benefit or an added value for the end-user. Besides, the motivations for environmental improvement depend on the possible return (Petts, 2000). Regarding this, the economic aspect could be a secondary consideration for

SMEs unless there is a specific demand for environmental improvement from regulation, customers or market.

Customers or consumers are also largely perceived as important drivers from the studies reviewed here. However, for SMEs, customers as business partners should be more important than end customers – i.e., what is generally meant by consumers. It is often interpreted within the supply chain system or market demands. Many studies (Biondi *et al*., 2000; EnviroWise, 2000; European Commission, 2002; Fanshawe, 2000; Gerrans and Hutchinson, 2000; Greenan *et al*., 1997; Hillary, 2000b; Hillary, 2004; Hobbs, 2000; Powell, 2000) indicate that subcontracting relationships with business customers in the supply chain often increase the chances of involving SMEs in environmentally responsible activities and thus making SMEs an strategic choice in obtaining competitive advantages against their competitors.

It is usually the case that major business customers require environmental improvements from their suppliers through EMS. For instance, large multinational companies are increasingly asking suppliers to adopt EMS in order to insure their improved environmental performance (Biondi *et al*., 2000; EnviroWise, 2000; European Commission, 2002; Gerrans and Hutchinson, 2000; Greenan *et al*., 1997; Hillary, 2000b; Powell, 2000). This relationship is regarded as one of the main factors of disseminating EMSs (Biondi *et al*., 2000). According to a survey by EnviroWise (2000), almost a quarter (23%) of responding SMEs have an accredited EMS, most often ISO 14001. Companies adopt EMS for several purposes, for example, controlling or maintaining compliance with environmental laws, satisfying customers and keeping the good relationship in the supply chain, strategic management of environmental performance, or increasing the economic benefits, etc.

Although some studies (Curtis and Walker, 2001; EnviroWise, 2000; Greenan *et al*., 1997) address the differences in environmental motivations among sectors or nations, the studies reviewed here somehow draw a consensus on the major environmental drivers, and this in turn provides meaningful understanding of the mechanisms surrounding SMEs. It seems conclusive that policy/legislation and customer/consumer demand are the most important drivers in general – customers' pressure needs to be understood within the supply chain system in SMEs. Furthermore, the first two important drivers (i.e., policy/legislation and customer/consumer demand) have a close relation to the EMS implementation that is increasingly required as a measure of sustainable business and a useful starter for environmental improvement, illustrated in Figure 1.3.

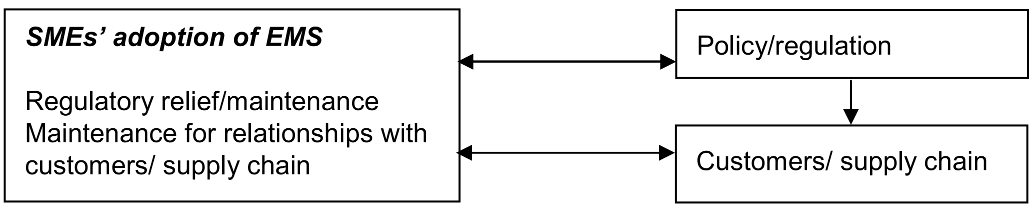

Figure 1.3: Relationship between SMEs' adoption of EMS and major environmental drivers

1.1.2.3 Main barriers of SMEs' environmental improvement

This study reviewed 'recent studies'[6] that have investigated the obstacles to SMEs in taking environmental action. The major barriers to environmental improvements in SMEs were categorised in order of frequency as shown in Table 1.6. Most of these surveys and literatures cover the following issues: what inhibits SMEs in understanding environmental issues, why they hesitate to adopt environmental innovation, and which factors influence the implementation of environmental management systems. Table 1.6 shows such major obstacles and explains the detailed issues.

Table 1.6: Barriers to environmental awareness and performance of SMEs (author's own compilation)

Barriers	Main features
Finance resources	• Lack of finance to invest, operate and maintain environmental performance (especially environmental management tools) • Economic short-sightedness (i.e., quick payback on investments)
Knowledge and information	• Difficulty in accessing information (ill-informed) • Lack of understanding of environmental problems and the potential benefits of improvements • Lack of relevant knowledge and information, for example, management information system and technology • Lack of understanding of both of general and specific environmental issues
Time	• Lack of time to carry out in-depth studies • Not sufficient time for staff to concentrate on the subject

[6] Biondi, Frey and Iraldo, 2000; ECOTEC, 2000; European Commission, 2002; Fresner, 2004; Garrette, 2000; Gerstenfeld and Roberts, 2000; Hillary, 2004; Holt, Anthony and Viney, 2000; Kuhndt and von Geibler, 2002; Pimenova and van der Vorst, 2003; Winsemius and Guntram, 2002

Perception	• Unfamiliarity with some terminology and specific environmental concepts • Underestimation of benefits from environmental improvements and of the importance of such activities • Misperception of environmental issues including costs, efforts, regulators and potential for environmental management to impact on the commercial aspects of the business • Overestimation of future burdens
Human resources	• Lack of staff having sufficient environmental knowledge and skills
System and culture	• Multi-tasking staff environment • Lack of management information system • SMEs are required to bridge a cultural gap
Support	• Insufficient information service about environmental problems and potential benefits through implementation of environmental improvements • Lack of sector-specific support and guidance • Institutional weaknesses • Environmental policy-making • Lack of support programmes in management and practices • Incentives, in particular financial, to economically stable & environmentally sustainable growth
Others	• Initiative fatigue/overload (related to lack of staff resources) • Unsuitable EMS tools for SMEs • Too complex and general management schemes for SMEs to handle • Lack of commitment from top management

It is worth first noting that most researchers except the study by Winsemius and Guntram (2002) agree that the ***financial problems*** are the critical barrier for small firms. From the survey of Spanish SMEs, Anglada (2000) concludes that majority of SMEs interviewed cannot afford costs unless there is enough time for incremental change, which often results in quitting environmental improvements or taking risks against legal or public image. SMEs tend to perceive environment-related costs as a continuous investment which, when combined with doubts about the commercial benefits, make the implementation of environmental improvement less attractive. For instance, once an SME has launched an environmental management scheme, the process is frequently found to be unexpectedly expensive and is therefore often interrupted (Hillary, 1999, cited by Kuhndt and von

Geibler, 2002; Johannson, 2000). In particular, many researchers (Biondi *et al*., 2000; European Commission, 2002; Fresner, 2004; Gerstenfeld and Roberts, 2000; Hillary, 2000b; Hillary, 2004) address these barriers with respect to implementing the standardised environmental management system (EMS) such as ISO14001 or EMAS. EMS requires larger budgets than an SME expects and has greater costs for maintaining and developing the tools even after the launch of the tools, and this in turn is regarded as a perpetual investment.

Table 1.7: The cost of certification is not always supported by market demand or seen as adding value to an SME (E2M, 1998, cited by Johannson, 2000),[7]

Cost of regulation (based on ISO 9000)					
Organisational size/sales	Initial document review	Follow-up reviews	Number of employees	Total cost per employees	Minimum total cost as a percentage of sales
Small: $ 500,000	$ 6,000	$ 2,500	1 – 49	$ 174 - $ 8,500	1.70 %
Medium: $ 5,000,000	$ 10,000	$ 5,000	50 – 100	$ 150 - $ 300	0.30 %
Large: $50,000,000	$ 18,000	$ 7,000	101 +	$ 0.21 - $ 248	0.05 %

Secondly, limited ***knowledge and information*** is a critical impediment to environmental improvement in the SME sector. Even though the knowledge and information factor is less apparent in these studies, it still must be at least as significant an element as the financial

[7] "*…the ISO support process is geared towards full adoption and favours third-party certification/registration. This brings another challenge for SMEs to the surface. While organisations can self-declare to the standard, only certification or registrations are monitored. By at large, SMEs are unlikely to certify due to cost and resource limitations – time, knowledge, skills and staff* (Johannson, 2000)".

problem inasmuch as it could be regarded as contributing to perceptions. While larger companies – especially multinationals – tend to have motivations and resources necessary to identify relevant environmental concerns and to translate them into action (Garrette, 2000), SMEs are not included in the trend of communicating environmental information with various supporting organisations. Regarding the fact that small firms are relatively ill-informed and face difficulties in accessing information about environmental issues, Garrette (O*p.cit.*) concludes that SMEs are not effective in the process of disseminating and receiving information. Figure 1.4, which describes the route of environmental information dissemination to SMEs, illustrates the gap of information access between large and small corporations.

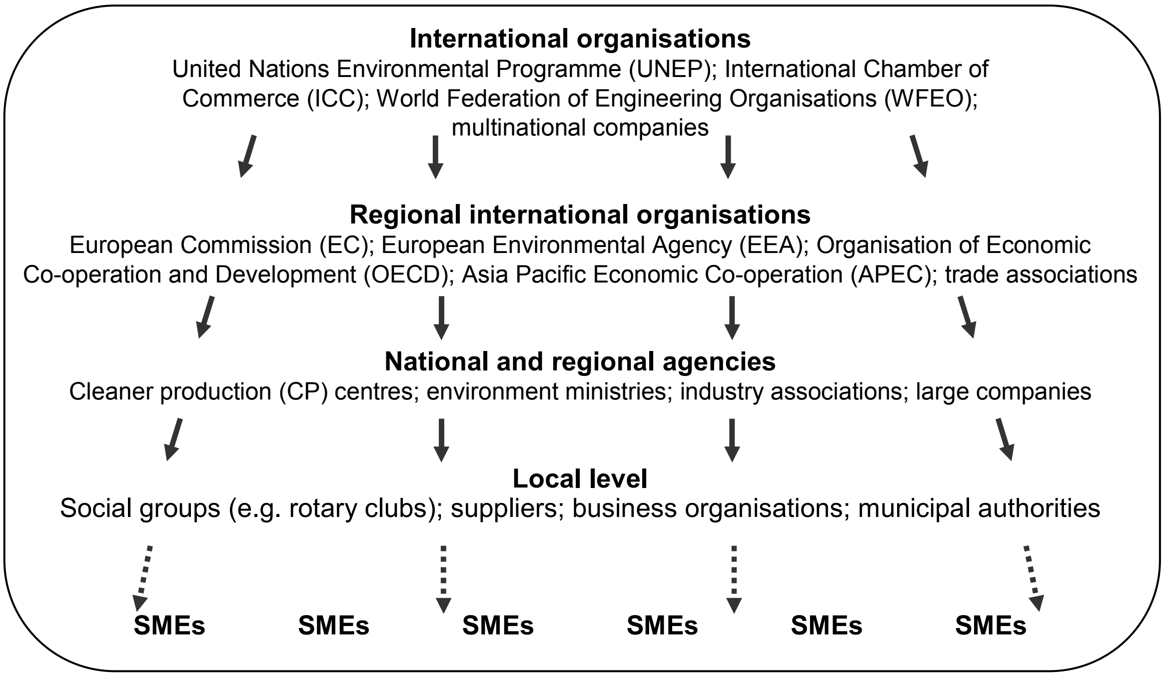

Figure 1.4: Current information pathways (UNEP TIE, 1997, cited by Garrette, 2000)

Gerstenfeld and Roberts (2000) have addressed the difficulties SMEs face in confronting an overwhelming flood of data while at the same time being unable to identify what information is actually relevant. In addition, the information systems upon which many companies rely are compliance-oriented daily-basis tasks such as technical data of emissions (Winsemius and Guntram, 2002). Therefore, it is difficult to support a long-term strategic environmental management and environmental improvement in life-cycle perspective. Thus, general as well as specific knowledge for a sector or a firm in both management information and technology need to be provided. Also, the availability of streamlined information needs to be matched to SME requirements.

Thirdly, ***time*** is considered to be one of the key difficulties for SMEs in making and managing the time devoted to environmental improvement. According to Pimenova and van der Vorst (2003), 55 per cent of surveyed companies, and in particular micro-enterprises, reported time as a crucial impediment. Many small companies cannot afford to make special efforts towards long term plans especially when it comes to environmental management. For instance, if significant management resources are required for EMS implementation, it is reasoned that this detracts from other parts of the business and thus environmental management receives little or no attention in most SMEs (Gerstenfeld and Roberts, O*p.cit.*). In reality, SMEs, which are likely to manage daily affairs and spend the greatest part of their time dealing with issues and incidents in an ad hoc and reactive manner, tend to focus on survival and maintaining competitiveness unless environmental issues are a bottom line pressure (Line and Vogt, 1996, cited by Gerstenfeld and Roberts, 2000.).

In fourth, lack of ***human resources*** is a good excuse to delay or curtail implementation and mainly caused by issues of size. The greatest barriers impeding EMS implementation and that most frequently cited in the studies (Hillary, 2004) particularly involve shortcomings in human rather than financial resources. For example, small sized companies find it difficult to implement and maintain EMS with a limited number of employees, who are themselves likely to already serve in multiple functions (*Ibid.*). Thus, these companies are hardly able to appoint a person to deal solely environmental issues. Exacerbating this is what seems to be a serious lack of expertise in the general workforce in actually implementing environmental management (Gerstenfeld and Roberts, O*p.cit.*). According to the survey by Anglada (2000), the response of mangers in SMEs shows that the current state of their environmental management is such that there is nobody in particular in charge. This reflects the fact that small firms unlikely have organisational structure or system, and tend to make informal and incompetent performance.

Perception is also regarded as a barrier indicating the lack of knowledge of the costs, practical aspects, relevant regulations, and potential benefits of improvement in environmental management (Gerstenfeld and Roberts, 2000; ECOTEC, 2000). For example, many leaders in organisations tend to overestimate required environmental expenditures (Winsemius and Guntram, 2002.), or, more to the point, they underestimate or miscalculate the positive effects including commercial gains over the longer term from the investment (Gerstenfeld and Roberts, 2000; Winsemius and Guntram, 2002). According to many researchers[8], this negative perception might be strongly related to the dearth of information and confidence. Winsemius and Guntram (O*p.cit.*) argue that many senior managers and technicians are far less confident about the implementation of an integrated environmental improvement as opposed to what they are easily satisfied with their company's ability to comply with existing regulations. Therefore, business strategies do not adequately incorporate environmental developments (Lober, 1998; Winsemius and Guntram, 2002), so that new business opportunities arising from such developments are hardly exploited (Winsemius and Guntram, O*p.cit.*).

The fifth aspect is that due to the nature of small organisations, they may be unable to support ***systematic and cultural*** innovation. Most environmental improvement programmes such as EMS and cleaner production (CP) require structural innovations in an organisation internally and externally. For example, 'cleaner production'[9] is essential in the identification of best practices, mostly based on a systematic description of the flows of mass and energy within a company through an evaluation of the efficiency of the use of materials, water and energy regardless any methodology to implement the concept (Fresner,

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[8] ECOTEC, 2000; European Commission, 2002; Fresner, 2004; Gerstenfeld and Roberts, 2000; Hillary, 2004; van Hemel and Cramer, 2002

[9] Definition by UNEP: "*Cleaner Production is the continuous application of an integrated, preventive strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment* (Fresner, 2004)".

2004). Collier (1995) indicates that introducing EMSs is not straightforward at all because environmental risks and concerns can cover nearly all aspects of a company's operations. Hillary (2004) argues that both initiatives (EMAS and ISO 14001) can be well adopted when fulfilling the need for an organisation to implement a number of management system stages to formalise the organisations policies, procedures and practices that control environmental aspects. However, even experienced companies in environment-related operational measures can fail to have the infrastructural muscle required for an integrated response (Winsemius and Guntram, O*p.cit.*). In conclusion, the advancement of organisational systems enabled to adequately deal with environmental performance is a key issue for continuous environmental improvement.

Finally, there are ***more barriers*** as shown in Table 1.6. In particular, many studies highlight the problems of EMS implementation in SMEs. The details are discussed in the Chapter 1.3. To conclude, the many barriers identified from studies could be reduced to a common or general description, but in practice, these barriers are just as diverse as SMEs themselves. While one particular problem faced by one company may not necessarily pose any difficulty to another company, and this type of barrier may not affect entire areas of the sector, too. However, by identifying problems, whether they are unanimously experienced throughout a sector or not, any solutions are more likely to be of merit to a majority of that sector (Gerstenfeld. and Roberts, 2000).

1.1.2.4 SME support for environmental improvement

SME support for environmental improvements aims to increase awareness of and appropriate business responses to environmental issues required in the sector. To be successful, guidance and support in various respects of environmental approach in business have to be implemented effectively and efficiently. In this regard, there are many possible supports mechanisms such as financial support and incentives, information and knowledge, tool and technology guidance, environment-related business support (e.g., telephone-helpline, face-to-face and/or visit), networking (to encourage cooperation, engagement and partnership), free or charged consultancy, education and training, and provision of various contacts (e.g., conference, industry seminar, workshop, etc.). These environmental supports are led by a variety of initiatives in national and international levels.

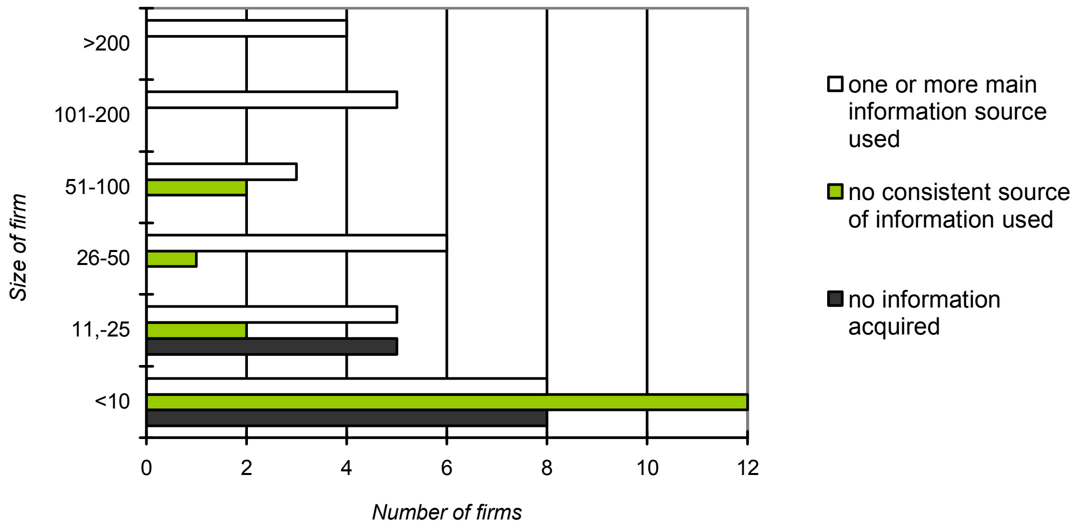
Among those environmental supports, provision of environmental information is regarded as the primary form of environmental support (European Commission, 2002; Pimenova and van der Vorst, 2003). The survey by Pimenova and van der Vorst (O*p.cit.*) shows, for example, that 70 per cent of environmental support initiatives in the UK have a form of information and advice, followed by financial support (30%), technology (20%) and training (20%). Especially, information dissemination related to environmental management for SMEs is central for the success of every environmental programme on the national or international level (Gerstenfeld and Roberts, 2000). Hence, environmental management has been rapidly growing with respect to the requirements of various stakeholders asking for environment-related information for applications as diverse as legal compliance, green purchasing, marketing, product and process development, financing, training, etc. In order to establish an environmental information service system, the exchange of experiences related to EMS, and easy access to environmentally relevant data are key factors in the move towards more sustainable companies (Lentz, 2001).

Despite various support initiatives for SMEs, the vast majority of SMEs still remain uninformed (Fanshawe, 2000; Holt, Anthony, and Viney, 2000; Van Hemel, 2001) and progress has been disappointing (ECOTEC, 2000; European Foundation, 2000). Many SMEs do not fully understand the impact of regulatory tools and other key environmental issues (Fanshawe, 2000; Gerstenfeld and Roberts, 2000). For instance, accredited EMSs (e.g., ISO 14001, EMAS) have been implemented in only a few SMEs in Europe. Some other environmental schemes such as eco-efficiency schemes, eco-design or sustainable manufacturing concepts show an even lower rate of adoption. Moreover, smaller companies tend to make use of less environmental information as seen in Figure 1.5.

In order to develop the argument, this chapter reviewed '25 studies'[10] and summarised the key points of those discussions. These studies reach some points of agreement with regard

[10] Anglada, 2000; Biondi, Frey and Iraldo, 2000; Boster and Lundström, 2005; Brezet and Rocha, 2001; Clement and Hansen, 2002; Curtis and Walker, 2001; ECOTEC, 2000; EIGT/ DTI, 2004; EnviroWise, 2000; European Commission, 2002; European Commission 2006; European Foundation, 2000; Fanshawe, 2000; Gerstenfeld and Roberts, 2000; Greenan, Humphreys and McIvor, 1997; Hobbs, 2000; Hoevenagel and Wolters, 2000; Holt, Anthony and Viney, 2000; Lentz, 2001; Madsen and Ulhøi, 2001; Pimenova and van der Vorst, 2003; Schischke, 2005; Smith, Kemp and Duff, 2000; Van Hemel, 2001; Welstead, Aitchison and Savage, 2006

to a current condition of the contents and provision of environmental information, problems of supporting tools, and SME attitudes in using these tools and information.



Source: Anthony and Shane 1994

Figure 1.5: The relationship between size of firm (number of employees) and the level of use of environmental information in 66 SMEs in Enfield, Essex and Hertfordshire (Holt, Anthony and Viney, 2000)

Problems in environmental information support

According to the survey of Fanshawe (2000), SMEs feel that there is insufficient information available to help them, and this perception is compounded by inconsistent and confusing messages of different requirements from various stakeholders including the government and regulators, environmental help organisations and trade associations, and the insurance and banking industries. In reality, however, there is an almost overwhelming amount of information available about almost every environmental subject. In spite of this, though, because much of the information does not seem to correspond with what SMEs expect, and because of a lack of any single definitive source of information, this abundance of information adds further to the confusion of the SME managers (European Commission, 2006; Fanshawe, 2000; Gerstenfeld and Roberts, 2000; Holt, Anthony and Viney, 2000; Welstead, Aitchison, and Savage, 2006). The reason for this phenomenon can be explained in several points including the paradoxical situation of the contents and provision of environmental information, a lack of diagnostic information or programmes, and a lack of expert support.

(1) A paradoxical situation of the contents and provision of environmental information (need of general and specific information for SMEs):

Holt, Anthony and Viney (O*p.cit.*) argue the reason of low awareness of environmental issue in SME sector, which is due to information obtain. The authors point out a lack of management information systems in SMEs, too much concentration on information-gathering by few people, and lower levels of resources availability for information gathering (James *et al*., 1998, cited by Holt, Anthony and Viney, *Op.cit.*).

> *"SMEs are in a paradoxical situation: to a certain extent they face a dearth of information for their specific requirements, yet they also face an information overload. In recent years a plethora of handbooks, guides and workbooks have been developed to assist businesses in environmental improvement. A recent US handbook, specifically targeted at SMEs, intended to aid the*

> *development of an environmental management system, is 150 pages long (Cooney and Stapleton, 1997, cited by Holt, Anthony and Viney, 2000). This guidebook, and many of its UK counterparts, may be too long and too generic for an average SME manager to seek out easily the core useful recommendations and assimilate them quickly into business practice* (Holt, Anthony and Viney, *Op.cit.*)".

Besides this, the demand for environmental information on specific issues such as sustainable design is not always same among various countries and companies, which prove to be a difficulty in providing generalised information to industry. According to the survey of eco-design adaptation (Curtis and Walker, 2001), some nations and enterprises that already achieved a certain level of environmental improvements have a widespread awareness of environmental issues in both market and industry. Therefore, they look for a further innovation believing that competitiveness and payback through more investment and implementation on environment will be achieved. It leads them to want to move towards relatively more proactive activities such as sustainable design than to continue supporting some points such as cleaning site or managing legislation-compliance.

It gives an important insight in providing information to SMEs, for what they want is not only a pile of environmental information but also some guidance on how to use and where to apply the information. However, generic information is still required by many SMEs due to the fact that majority of SMEs are new to the sustainable business and thus continue to lag behind when compared to larger sectors. For this reason, general as well as specific information support should be offered to SMEs. Therefore, it allows a SME to draw up an overview surrounding it based on the general information, find further specific one, and then create its own environmental management system.

(2) Lack of diagnostic information and programme:

As both environmental support services and demands are considerably diverse, SMEs may feel it difficult to find the right service to solve inefficient business processes that are hard to identify but certainly environment-related problems (Hoevenagel and Wolters, 2000). Hoevenagel and Wolters (*Op.cit.*) believe that environmental support services have somehow failed to meet the demand because a wide range of environmental information fails to diagnose environmental problems, which may relate to difficulties that SMEs face in filtering existing information and the resulting time and resource shortfalls. It could also be strongly related to the paradoxical situation of environmental contents and provision. When a small firm conducts environmental initiative, a starting point can be identified through diagnostic approach. Understanding both situations of SMEs' nature of business and newness in environmental issues, diagnostic information or programme may be critical for increasing environmental performance in SMEs.

(3) Need for expert support:

Another significant problem is that small businesses do not have access to the expertise to introduce complex management systems without expert assistance (Welford and Gouldson, 1993, cited by Gerstenfeld and Roberts, 2000). For example, Hoevenagel and Wolters (O*p.cit.*) criticise in particular how government policy approach in the Netherlands is not effective for the SME sector. The authors claim that the government tends to use generic environmental policies that often focus on large and heterogeneous groups while taking more moderate routes such as subsidies or information campaigns for SMEs. Thus, this attitude has generated the gap between information support and real demand of SME sector. For instance, SMEs often end up repeatedly asking same questions in order to get specific answers, which is time-consuming and expensive (van Wijngaarden, 1995, cited by Gerstenfeld and Roberts, *Op.cit.*). In addition, SMEs have a fear of contacting with organisations particularly regulators, because of possible disadvantages such as prosecution (Holt, Anthony and Viney, *Op.cit.*).

Although sector- or company-specific information support is ideal, it could be very costly (Hoevenagel and Wolters, *Op.cit.*). Regarding this, many studies (EnviroWise, 2000; European Foundation, 2000; Hoevenagel and Wolters, 2000; Holt, Anthony and Viney, 2000; Lentz, 2001) suggest that intermediate organisations (e.g., public or private consultancies) can play an important role in providing specific advice and support. Business consultancies have the strength of being close to their SME clients, serving as sounding boards, and being allies rather than adversaries (Chalmers quoted in Elliot *et al.*, 1996, cited by Holt, Anthony and Viney, *Op.cit.*). Robinson (1996, cited by Gerstenfeld and Roberts, *Op.cit.*) confirms that most SMEs in the UK need a sufficient external assistance, be it in the form of consultants, software, checklists, or official advice, to develop their environmental management system.

Problems in environmental tools for SMEs

Methods and tools are also a significant concern for both support organisations and industry, and are strongly related to environmental information. According to some studies (Brezet and Rocha, 2001; Gerstenfeld and Roberts, 2000; Greenan, Humphreys and McIvor, 1997), an environmental management system provides an adequate structure to help a firm acknowledge its own environmental problems and set up a proper strategy and plan. In establishing a corporate environmental policy or plan, the gathering of relevant environmental information is an inevitable first step followed by setting up an appropriate framework for the environmental management system. EMS programmes (e.g., ISO 14001, EMAS) are strategic tools for the implementation of environmental improvements. It may benefit SMEs at an initial stage of environmental business to outline any relevant environmental information that a company needs. Indeed, a systematic approach improves the opportunities for continuous improvements of environmental performance. There are significant arguments that have been developed in improving environmental supporting tools. Further in-depth discussions are presented in Chapter 1.3.

SMEs' attitudes in using environmental information and tools

Certain forms of information support are counted to be costly and ineffective. For example, mass-produced publication may be excessive when it does not meet the actual demands of real users (Welstead, Aitchison, and Savage, 2006). Thus, efforts must be made to find a balance between cost and benefit in information supply (*Ibid.*). In order to increase the optimisation of environmental support, users' attitudes and preference for support format need to be reflected within any type of environmental support. Following section summarises that SMEs show certain predispositions in using environmental information and/or tools.

(1) Pragmatic attitude of SMEs:

As a result of the number barriers to environmental work, SMEs often end up applying one-off activities that are hardly internalised within their system. It is easily found that, for instance, when a series of workshops of eco-design campaign was being held, most SMEs replied that they were very busy tackling urgent environmental legislations such as 'WEEE and RoHS'[11] (Schischke, 2005). These workshops were undertaken by 21 host countries with 1,202 participants in the electronic and electrical sector, more than half from SMEs. During the 28 workshops with the campaign, a consensual viewpoint of SMEs was drawn up stating that "*SMEs tend to favour a very 'pragmatic approach' (if any): focusing on single 'green' aspects (material reduction or power supply or redesigned packaging or similar), instead of a systematic approach considering the whole product life cycle* (*Ibid.*)". This is a significant notion that explains the reason for the poor responsiveness in utilising environmental information and tools. It indicates that SMEs are unlikely to deal with, at

[11] WEEE: (Directive on) waste of electrical and electronic equipment; RoHS: (Directive on) the restriction on the use of certain hazardous substances in electrical and electronic equipment. For more information, see Chapter 1.2

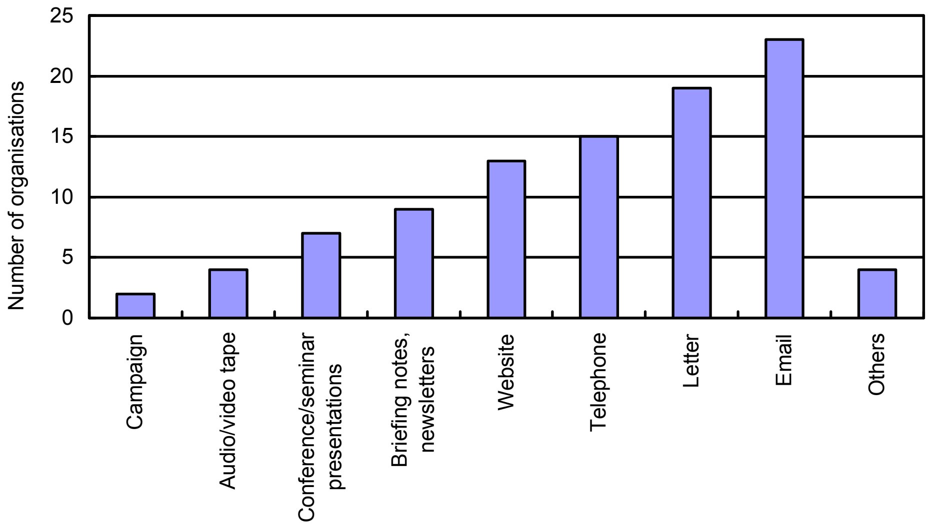
once, various environment-related issues in life cycle perspective. Inasmuch as product-related environmental information is increasingly important for any attempts in environmental management of production units and products, and also for making solid purchasing decisions (Erlandsson, 2006; European Commission, 2006), environmental information and tools to support SMEs must take account of overcoming this attitude.

Table 1.8: SMEs' preferred format of environmental information (author's own compilation)

Types of information	MORI (1998)	Pimenova and Van der Vorst (2003)	Smith, Kemp and Duff (2000)
Printed format: Checklists/DIY guide	80%	70%	83%
Printed format: Newsletters (or updates on new technology)	-	40%	73%
Internet	40%	40%	44%
Telephone	-	-	78%
Video	-	-	47%
advice from regulators	-	-	74%
on-site advice from local consultants/advisors	-	-	61%
local seminars/workshops	-	-	52%
national conferences	-	-	15

(2) Preferred support type of SMEs:

Publics are more familiar with traditional methods of dissemination such as newsletters, community centres, libraries and the telephone rather than new technologies (Welstead, Aitchison, and Savage, 2006). SME industry seems to have similar preferences according to some studies (EnviroWise, 2000; Madsen and Ulhøi, 2001; Smith, Kemp and Duff, 2000). When small firms were asked about the types of support they favour in a survey (Pimenova and van der Vorst, 2003), they showed a clear preference for printed information such as checklists and Do-It-Yourself (DIY) guides (70%) followed by newsletters and Internet information, both receiving 40% support. Similar statistics are shown in MORI study conducted in 1998 (cited by Pimenova and van der Vorst, *Op.cit.*) and the study by Smith, Kemp and Duff (*Op.cit.*).



(Information providers' survey n=25)

Figure 1.6: What media are used to disseminate environmental information? (Welstead, Aitchison, and Savage, 2006)

Although majority of SMEs are still comfortable with the conventional ways, the Internet cannot be disregarded with respect to the growing population using it, its superior accessibility, and high performance owing to continuous technological development. The pattern of information acquisition preferred by SMEs is collectively high in electronic routes such as email, telephone or website as illustrated in Figure 1.6.

In summary, there is, first, a paradoxical situation, i.e., overabundance of environmental information corresponding with a lack of an effective system for filtering that information, lack of expertise support, and the tendency of existing environmental information to fail to diagnose environmental problems as well as specific information for SMEs' needs. Second, SMEs fail to utilise EMS despite its potential benefits, which relates to unsuitability of the tools for SMEs. Third, SMEs have a pragmatic attitude in that they prefer to deal with a single issue rather than taking a life cycle approach, and they consequently prefer a document-type DIY or checklist self-help guide in environmental support formats. To conclude, it is recommended that a combined form of information and tool support would be effective through combination of generic and specific information with diagnostic programmes or filtering systems, self-help DIY/checklist tools and expert advice, and document-based information and on-line support.

1.1.3 Summary

So far, environmental issues surrounding SMEs have been explored in various aspects including the nature of SME business itself, the current situation of their environmental awareness and performance, the main barriers and drivers in environmental improvement, and their access to environmental information and tool support for SMEs. Several issues were found to overlap and repeat. However, the key discussions in terms of overview in SMEs' situation in environmental issues can be summarised in Table 1.9.

Table 1.9: Summary of environmental issues surrounding SMEs and recommendations for environmental information and tool support

<table>
<tr><th colspan="2">Main discussions in environmental issues surrounding SMEs</th></tr>
<tr><td colspan="2">1. SMEs' characteristics and situation</td></tr>
<tr><td>Business nature:
Diverse business and size</td><td>• Lack of resources (time, finance and human)
• Lack of structural and systematic management
• Lack of competence and capability
• Lack of information and knowledge (especially in environmental management system)
• Low awareness and uptake of environmental improvement
• Ad hoc approach</td></tr>
<tr><td>Drivers</td><td>• Policy and regulation pressures
• Business customer pressures
• Supply chain pressures
• Environmental standards</td></tr>
<tr><td>Barriers:
strongly influenced by the SMEs' characteristics</td><td>• Lack of resources (time, finance and human)
• Lack of knowledge and information
• Lack of competence
• Lack of cultural and systematic innovation caused by lack of structural management</td></tr>
<tr><td colspan="2">2. SMEs' attitudes, needs and preference in environmental support
• Pragmatic attitudes and preference in using environmental information and tools
• Need of generic and specific information support
• Preference for self-help checklist and DIY guides
• Preference for documents and on-line format (e.g. Internet and email)
• Need of expert advice and support</td></tr>
<tr><td colspan="2">3. Support in environmental information and tools</td></tr>
</table>

Information support system	• Paradoxical situation of contents and provision of environmental information (overabundance but lack of filtering systems for specific information • Lack of diagnostic information or programme (identifying environment-related problems)
Tools	• EMS is an important tool to establish strategic and systematic environmental management and continuous improvement • EMS is not suitable for SMEs
Recommendations for environmental information and tool support	
• Increase and clarification of environmental motivation for individual SME or the sector • Flexible approach for SMEs to use according to the business and size as well as the level of environmental performance • Need of structured and strategic approach • Need of diagnostic information or tools • Combination of generic and specific information • Combination of self-help DIY/checklist information or tools and expert advice • Combination of document-based information or tools and on-line format	

1.2 Recent trend in environmental policy and regulations

Previously, the main drivers of environmental performance of SMEs were identified as policy and regulation. These elements are important determinants directing industry by where to and how to drive environmental innovation. The background related to the development of environmental policies and regulation would help understand the recent mainstream issues leading a control system over industry.

1.2.1 Importance of product aspect in environmental issues

Last decades, environmental regulators have paid a huge attention to environmental aspect of products. Firstly, overall quantity of products in modern society is now threatening to overwhelm society altogether. For instance, industry and households each contribute about 25 per cent of greenhouse gas emissions in EU countries (Ernst & Young, 2000). Thus, rapidly growing consumption and rising volumes of waste drive the environmental approach focused on products (Ammenberg and Sundin, 2004a; Ernst & Young, 2000; European Commission, 2001a). As a result, there is a strong need that reducing environmental impact resulted from increased quantities of products must be dealt within policy level (European Commission, 2003a).

Secondly, products are closely linked to the most significant flows of environmental impacts such as materials and energy (Ammenberg and Sundin, 2004a; Ammenberg and Sundin, 2004b; Li and Geiser, 2005). Especially electrical and electronic products create most resource consumption and pollution production during their use. Those products that use energy and other resources during their operation, such as hot water systems, heaters, cooking equipment, fridges, lights, air conditioners, and washing and drying machines, collectively use 95 per cent of the energy in an average house (ACA, 1992, cited by Lewis and Gertsakis, 2001). Besides, products have a direct contract to consumers (Ernst & Young, 2000). Thus, environmental aspects of products can be placed in the core of the context of environmental consumption.

Finally, products lie at the nodes on the web of production, consumption and disposal as they carry out all possible aspects surrounding environmental impacts (Li and Geiser, *Op.cit.*). As products are becoming more complex and the components are traded globally, it is even more difficult to track and measure the environmental impacts produced by products and their components as well as from related phases of their life cycle (European Commission, 2003a). Therefore, it is widely recognised that products are the starting point to manage environmental improvements in both consumption and production (Charter and Belmane, 1999; DIW Berlin, 2002; Ernst & Young, 2000; Li and Geiser, 2005).

1.2.2 Evolution of environmental product policy

Despite the success of traditional environmental policy focusing on production process, overall improvements of eco-efficiency has not been fundamentally improved and the problems tended to move to another phases of product life cycle or to end up polluting the nature (Ernst & Young, 2000; Rubik and Frankl, 2005). Hence, following critiques about the traditional environmental policy approach were raised.

Firstly, the environmental impacts are created along entire life cycle of a product rather than at a particular stage of its life time such as single production or disposal stage. As opposed to this, most attention of traditional environmental policies was paid to environmental media (namely, end-of-pipe technologies and middle-of-pipe solutions such as waste minimisation, cleaner production and pollution prevention in site) (Charter *et al*., 2001; Rubik and Frankl, 2005). Moreover, a cleaner manufacturing process does not necessarily guarantee that products themselves are clean (Li and Geiser, 2005). As a result, the conventional policy approach is limited in addressing environmental problems without ‘sub-optimisation’[12] and exploring potential opportunities to reduce environmental impacts. The scopes of areas for improvements are largely different between production-focused environmental policies and product-oriented ones (see Figure 1.7). Consequently, the non-green products tend to have less potential to collectively improve environmental performance of industry and the effects of improving processes can be easily diminished.

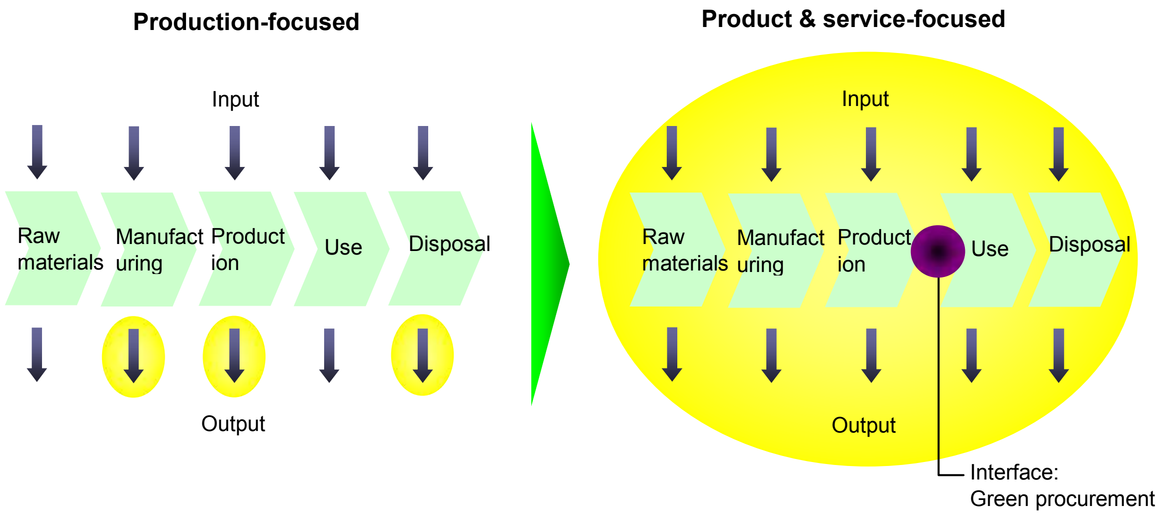


Figure 1.7: Comparison of production-focused and product- and service-focused environmental policy (Korean Ministry of Environment, 2003)

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[12] There is no official definition found in terms of ‘sub-optimisation’ in environmental context. However, the following concept would be generally accepted to explain the term. “*Sub-optimisation refers to the situation were optimisation in one part of the product life cycle causes even larger environmental burdens in another part, whereby the total environmental burdens in the life cycle increases. This is of course undesirable and should be avoided by looking on a product from a holistic point of view. Example: The production department introduces a new material, which makes it possible to reduce energy consumption for cabinet processing by 10%. However, the new material cannot be recycled when the cabinet is disposed off. The new material therefore creates a new waste disposal problem in another life cycle phase* (IPU/DTC, 2005)”.

Secondly, the traditional environmental policies clearly lack in integration with other policies or policy instruments. Ernst & Young (2000) points out that the previous environmental policies concentrated on measurable environmental impacts. Hence, those policies tend to respond to more identified environmental risk even in the precautionary principles as policy actions seem to be drawn by an assessment of environmental risk (*Ibid.*). Moreover, as the process-oriented environmental policies were based on a 'simple' governance model (Rubik and Frankl, 2005) and developed categorically without careful analysis of possible interaction with other sector policies on different environmental problems (Ernst & Young, O*p.cit.*), potential environmental problems or opportunities to improve are hardly exploited. This attitude hardly influenced different actors in product chains to establish their own innovation-driven environmental strategy and foster continuous improvements.

Thirdly, process and site-focused environmental policy did not comprehend the effectiveness through an earlier involvement of environmental considerations within product development. A products once marketed likely have less potential to improve its environmental performance, which is inclined to reduce the effects of improving processes too (Li and Geiser, 2005). It also means less opportunity to involve various individuals and organisations in the product chain for improvements. It is certainly not the efficient way towards the overall eco-efficiency.

Fourthly, the structural changes in the economy from materials and energy-intensive industrial economies towards more service-intensive economies create a need for an advanced approach of policy making towards being less reliant on traditional point-source control, and being more flexible and responsive (Ernst & Young, O*p.cit.*). Moreover, the recent trend of business environment (e.g., innovation-driven) encourages companies to produce a variety of products and services such as many different versions of products as well as new products under the shorter cycle of innovation (European Commission, 2003a). However, process and standard-oriented approach of policy instruments stipulate a static technical objective that does not stimulate innovation (Rubik and Frankl, 2005). In addition, previous environmental policies failed the economic efficiency principles, for example; end-of-pipe technologies are expensive and are liable to become progressively more costly with each additional unit to reduce emissions (*Ibid.*). Therefore, environmental policy must consider not only the environmental side being increasingly complicated and unjustifiable but also the economic side being revolved around continuous growth of product quantity.

Finally, the complexity and global trade of products mean that products now involve a greater variety of actors throughout their life cycle, which product policy needs to be capable of addressing many different actors (European Commission, 2003a). Considering the condition that products could come from unknown places through the line of being assembled, marketed and used in various places under the different sets of societal values, environmental policies should contribute to improving information flows along the supply chain (*Ibid.*). This situation requires more general paradigm shift from a 'command-and-control' approach to a 'push-pull' approach that needs active engagement and shared responsibility among several different actors (Ernst & Young, 2000; European Commission, 2003a). Manufacturers are, for instance, in a position to influence products' environmental characteristics because they affect the product development process and have to deal with many different stakeholders regarding that they are connected to most activities of product's life cycle (De Bakker, 2002). Eventually, those critiques above requiring a paradigm shift of the environmental policy contributed to the change of environmental policy orientation towards products.

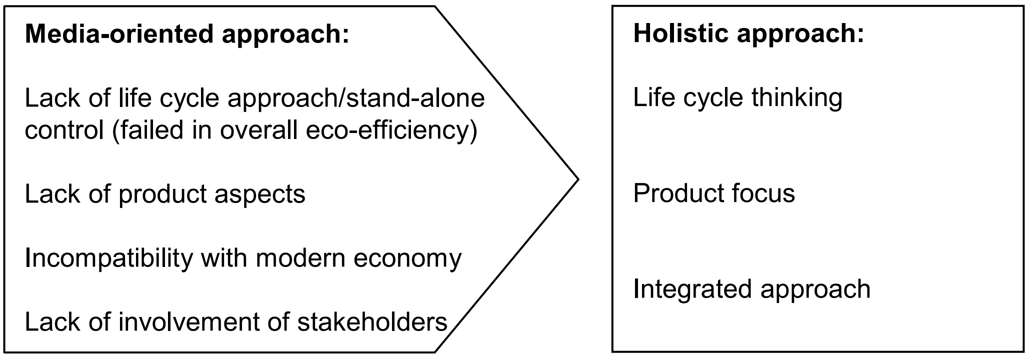

Figure 1.8: Evolution of environmental policy approaches

1.2.3 Integrated product policy (IPP)

Around 1980s, some product-related environmental policies were introduced mainly in Europe. However, the major critique on traditional environmental product policies was on the gap of individual function in the policy mechanisms. Lack of communication and integration between policy instruments in national and international level did not contribute to collective and effective control of environmental problems and improvements with synergy effect within the policy framework. For example, eco-labelling schemes have been introduced in different countries with different measures and information channels. It may have been successful within some leading countries and influenced environmental consumption through consumer education (Charter and Belmane, 1999). However, eco-labels, as environmental product information schemes in a general term, did not seem to work in some European countries and other markets such as UK, France and Belgium, and they, hence, often cause a confusion for customers because of the diversity of eco-labelling schemes in the marketplace (*Ibid.*).

In this respect, coordination and integration between environmental product policy instruments as well as the consistent interpretation in different regions are crucial repeatedly raised by 'many studies'[13]. Therefore, cooperation and integration of environmental product policies and policy instruments are widely recognised as leading principles, which also stress partnership along the life cycle in finding the most cost effective manner to implement environmental objectives (Schmidt, 2000).

Based on the lessons from the predecessors, integrated product policy (IPP) has been developed within the initiative of EU level. The conclusive reason of introducing IPP is, first, of the fact that traditional policy approaches failed to address the link between environmental impacts and products as well as their use. Second, the previous

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[13] Charter and Belmane, 1999; Charter, Young, Kielkiewicz-Young and Belmane, 2001; Ernst & Young, 2000; European Commission, 1998; European Commission, 2001a; European Commission, 2003a; Rubik, 2003; Rubik and Frankl, 2005; Schmidt, 2000

environmental product policies across Europe appeared to be a fragmented picture due to the lack of coordination and consistency in their elements and measures. Therefore, a holistic and integrated approach between similar policy tools is now significant to be general concepts in implementation of IPP. These features of IPP will direct mainstream principles that influence and shape industrial ecology in the future.

1.2.3.1 Definition and aims of IPP

The first report that conceptualised IPP defines it as "*public policy that explicitly aims to modify and improve the environmental performance of product systems* (Ernst & Young/ SPRU, 1998)". Another definition by Federal Ministry for the Environmental, Nature Conservation and Nuclear Safety (BMU, Germany, 1999, cited by Charter and Belmane, 1999) describes that "*public policy aims at or is suitable for continuous improvement in the environmental performance of products and services within a life cycle context.*"

The product-focus[14] is the main concept of both EU IPP and German product-oriented environmental polices. The first report of EU IPP (Ernst & Young/SPRU, 1998) articulates that environmental policies must be explicitly concerned with resource efficiency or

[14] Even though IPP expresses that potential opportunity of inclusion of 'services' with a condition that "*insofar as IPP approach can be applied to improve the environmental impact of services, this should not be excluded although services are not the primary focus of IPP* (European Commission, 2001a)", inclusion of service area within IPP may be problematic in elaboration of IPP because a high complexity of its area makes difficulties in the definition and scope of IPP and requires a long time-frame to formulate IPP strategies for services (Charter, Young, Kielkiewicz-Young and Belmane, 2001). Therefore, IPP or other policy instruments seems to focus on tangible goods for a while.

environmental impacts of products, which should be integrated across more than a single stage of products' life cycle. Integrated approach of IPP is clearly differentiated from the posture of the traditional environmental product policies. The integration issue is described in depth in later report updated in 2000 by Ernst & Young on the purpose of clarifying and developing the arguments of the future development of IPP. According to the report (Ernst & Young, 2000), the principle of integration in implementing IPP is interpreted in three dimensions: horizontal integration, vertical integration, and policy integration.

In the context of horizontal and vertical integration, a total life cycle approach of products so called 'cradle to grave' is significant that environmental considerations should reach all relevant stages from raw material extraction and manufacture to final disposal and recycling of the products and components. In order to achieve this, involvement of many different actors such as product developers, marketing people, retailers and consumers in the product chain is essential, so that improvements of individual phases of the product chain is encouraged. Shared responsibilities for environmental impacts are the biggest challenge for IPP to be successful.

Policy integration aimed at promoting complement among relevant policies and avoiding duplication and contradictions between them. A lack of integration between similar policies and regulation is related to traditional environmental policy approach that used to develop individual policy instruments such as acidification strategy, climate change policy, urban air quality strategy, etc. that correspond to environmental categories (e.g., air, water, land, etc.) and multiple sub-categories (Ernst & Young, 2000). As the categories are increasing, complexity and difficulty to manage environmental policy context also have grown (*Ibid.*). Interaction with other sectoral policies and problems caused by unintended trade-offs between different goals of different polices and the regulations needed to be reconsidered (*Ibid.*). Policy integration in IPP attempted to solve these problems.

1.2.3.2 Main principles of IPP

Throughout ongoing discussions on IPP development, European Commission has drawn up basic principles which described in the report by European Commission (2003a). The leading principles of IPP are life cycle approach, market orientation, stakeholder involvement, continuous improvement, and integrated approach. Life cycle thinking is the fundamental principle that makes IPP distinct from the traditional environmental policies. Also, the integrated approach with other legal instruments gave a powerful position to IPP compared to the previous environmental product policies.

Life cycle thinking means that environmental impacts of a product shall be collectively reduced along its entire life cycle and shifting environment burdens from a stage to other media in the life cycle shall be avoided. Life cycle concept encourages firms to measure and improve environmental impacts at the point in the life cycle where they are likely to be most effective in reducing environmental impacts and saving costs for business and society (*Ibid.*). In this context, identifying environmental impacts of entire product chain and providing the information to others are the crucial steps.

Market-based approach entails a balance between environmental and economic aspects. Environmental issues are likely subjected to a periphery in reality, especially to small businesses. Integrating the commercial aspect into environmental activities through incentives or rewards may facilitate the market to move towards more sustainable manner. Hence, IPP promotes the supply and demand of greener products, which will reward those companies that are more innovative, forward-thinking and committed (European Commission, 2003a). Innovation can often be made to decrease a product's environmental impact across its life cycle, whether in design, manufacture, use or disposal, taking into account the parameters set by the market (*Ibid.*). In response to this, IPP aims for a **continuous improvement** in this context (rather than setting a precise threshold to be attained) which leads companies to be able to set their own pace and focus on the most cost efficient improvements (*Ibid.*).

Environmental improvements in life cycle perspective cannot be achieved without **involvement of all stakeholders** in related areas. Stakeholder involvement in IPP intends to encourage those who have a close contact with the product (e.g. industry, consumers and government) to act on their sphere of influence and to encourage cooperation between different stakeholders (*Ibid.*). The feedback from consumers about purchase, use and disposal of greener products can be circulated in industry so that they can look at how to better integrate environmental aspect in the design of products (*Ibid.*). Therefore, cooperation and communication between various actors in product chain is the fundamental for the stakeholder involvement.

Integrated approach among relevant policy instruments as well as various phases of product chain is significant because there is a variety of products available and different stakeholders involved (European Commission, 2003a). Policy instruments range from voluntary initiatives to regulations and from the local to the international scale (*Ibid.*). "*Within IPP, the tendency is clearly to work with voluntary approaches, although mandatory measures might also be required. The determining factor is the effectiveness of the tool to achieve the desired result with regard to sustainable development* (*Ibid.*)". Concerning the effectiveness in improving product-related environmental problems, the focus on early stage of product development needs to be considered.

1.2.3.3 Product-oriented environmental legislations

Many different products and actors in product chains would not be covered within a single policy measure. Hence, IPP attempted a full integration throughout existing policy instruments – both voluntary and mandatory – that can be used to achieve the IPP objective. In this respect, IPP established a structure that facilitates consistency and integration across environmental product policies and relevant regulations. The environmental policy and regulatory framework of EU are expected to lead corporate environmental improvement fundamentally. The following sections introduce the most recent legislations within the policy frame of IPP. The legislations under the policy shift in emphasis away from controlling impacts of processes to controlling impact of products are as follows (Clements, 2004; European Commission, 2003a):

- Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)

- Directive 2002/95/EC on the restriction on the use of certain hazardous substances in electrical and electronic equipment (RoHS)
- Directive 2005/32/EC on the eco-design of energy-using products (EuP)

WEEE Directive

Although the numbers of wastes from electrical and electronic goods are found to be slightly different depending on studies (Danish EPA, 2000; European Commission, 2000; Goosey, 2004; IPTS, 2000; Lee and Røine, 2004), overall conclusion of WEEE impacts on the environment is seriously problematic. In addition, the fast growing volume of WEEE contains a variety of toxic materials especially lead, mercury, cadmium, hexavalant chromium and certain brominated flame retardants. These materials have a high potential to contaminate land and water when they are landfilled. WEEE directive aims to contribute to the protection of the human health and the environment as required by Article 174 of the Treaty, which is to be achieved by means of a wide range of measures including the measure on the design as well as and separate collection, treatment and recovery of WEEE (European Commission, 2000; European Union, 2003b). The preventive measures aims at phasing out hazardous substances from electrical and electronic equipments (EEE), increasing opportunity to recycle and/or reuse valuable materials (e.g., iron, copper, glass, ceramic and plastics; major constituents of EEE), and promoting to reuse and integrate recycled components and materials in new equipments (European Union, 2003b; IPTS, 2000).

WEEE directive applies the principle of producer responsibility to industry. It means that manufacturers are required to recycle and recover their products which having been marketed after August 13 2005; otherwise they have to potentially pay a fee of two percent of their revenue (Wilson, 2005). In order to reduce waste and to facilitate the recovery of WEEE, subsequent activities are necessary, for example, assessment of environmental impact of products, improvement of the design of products, and waste management of products that requires appropriate systems to deal with return and collection of used EEE, and financial support for private households to return the used EEE free of charge.

According to European Commission (2000), Goosey (2004) and IPTS (2000), the benefits of implementing WEEE directive can be summarised as: environmental impact will be significantly decreased; production costs can be saved by using secondary materials rather than virgin; disposal costs can also be saved through reusing and recycling higher levels of WEEE; the costs for reuse and recycling will be lowered in the future through better design of new equipments due to the feedback mechanism of producer responsibility and through additional instruments such as eco-design guidelines; external costs, including the future generation, caused by landfill of WEEE and resource depletion would be diverted to economic cycle in a form of possible use of the resources contained in WEEE; and early adopters can have a competitive edge as, in general view, the global competitiveness of the EEE sector will depend in the long-term on its ability to minimise waste and the environmental impacts of products in the life cycle.

RoHS Directive

Despite the effect of WEEE directive, some dangerous parts of WEEE will still remain in the current disposal paths. Hence, there is a need to reduce the presence of some hazardous substances in the environment once and for all and thus decrease the risk to people dealing with the process of recycling or recovering WEEE (Clements, 2004; European Union, 2003a; Goosey, 2004; IPTS, 2000). In this regard, directive on the restriction on the use of certain hazardous substances in EEE (RoHS) introduced a substitution requirement for those substances posing the main environmental problems during their disposal and recycling (Goosey, *Op.cit.*). According to the official document of the European Union (2003a), RoHS directive enacted after 1 July 2006.

Under the implementation of the RoHS directive, manufacturers have to get rid of any substances defined by the directive from the production and products by the date. Companies failed to meet the compliance with the prohibition on the hazardous substances in RoHS regulation could result in a fine not exceeding the statutory maximum (currently £5,000) on summary conviction or an unlimited fine conviction on indictment (DTI, 2004). It means that consistent breach or disregard of the both directives (WEEE and RoHS) will cause companies and other legal persons facing criminal charges such as 'fines'[15] or a prison sentence for up to two years (Holland, 2003). Also those failing to submit compliance documentation at the request of the enforcement authority may be liable to a fine up to level five on the standard scale (DTI, *Op.cit.*).

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[15] For more information of penalties of WEEE/RoHS: http://www.goodbyechain.com/pdf/weeerohsfines.pdf

The substances banned in RoHS regulation are mercury, lead, cadmium, hexavalent chromium and two classes of flame retardant, the polybrominated byphenyls (PBBs) and two polybrominated diphenylethers (PBDEs) (penta-PBDE and octa-PBDE) (European Union, 2003a; Goosey, 2004). Another flame retardant, deca-PBDE, also covered by the directive, may gain a potential derogation from a restriction, depending on the outcome of an EU risk assessment (Goosey, *Op.cit.*). In response to RoHS directive, materials declarations for suppliers are being developed by industry so far in a variety of formats (Clements, 2004). Many leading manufacturers started to prepare RoHS implementation (Sommer, 2006; Goosey, 2004), by, for instance, publishing such data and demanding product material declarations to their suppliers.

EuP Directive

Due to the broader awareness of the importance of products and product related requirements in environmental improvements, European Commission has proposed a framework directive to promote the eco-design of energy-using products (EuP). In line with the directives of WEEE and RoHS, the approach of IPP can be achieved by proactive environmental activities such as manufacturers to design products with environmental considerations along their entire life cycle. The official journal of the EU on EuP directive (European Union, 2005) clearly articulates this issue that the eco-design of products is a crucial factor in the Community strategy on IPP. This directive represents a merger of two earlier initiatives, namely, the impact on the Environment of Electrical and Electronic Equipment (EEE) Directive and the Energy Efficiency Requirements (EER) Directive

(Goosey, 2004). European Commission (2003b) defined the objective of the EuP directive that creates a comprehensive and coherent legislative framework by addressing eco-design requirements with the aim at:

- *ensuring the free movement of energy-using products within the EU,*
- *improving the overall environmental performance of these products and thereby protect the environment,*
- *contributing to the security of energy supply and enhance the competitiveness of the EU economy,*
- *preserving the interests of both industry and consumers*.

However, the proposal was introduced without direct requirements for specific products or legal obligations for all energy-using products. But, it does define conditions and criteria for setting through subsequent 'implementing measures and requirements' regarding environmentally relevant product characteristics (European Commission, 2003b; European Union, 2005). The legal obligations for manufacturers will only arise once the EU enacts separate 'implementing measures' for specific targeted products (European Commission, 2003b; Goosey, 2004).

The scope of the directive is covered as follows: "*Energy-using product or EuP means a product which, once placed on the market and/or put into service, is dependent on energy input (electricity, fossil fuels and renewable energy sources) to work as intended, or a product for the generation, transfer and measurement of such energy, including parts* *dependent on energy input…* (European Union, 2005)”. However, this directive shall not apply to means of transport for persons or goods (*Ibid.*). Also the directive shall not be affected by other Community legislations such as waste management legislation and chemical legislation (*Ibid.*). Although the proposal does not clarify which product groups will be targeted, it states eco-design requirements that will be applied only to product groups with significant volumes of sales which represent a considerable environmental impacts and clear potential for improvements through product design (European Union, 2005; Goosey, 2004).

According to the European Union (2005), when introducing ‘implementing measures’ of EuP directive, manufacturers will be required to conduct relevant documentation for making a possible ‘assessment of the conformity’ of the directive. It was also indicated that the conformity assessment procedures can be achieved through either ‘internal design control’ or ‘(environmental) management system’, which let a manufacturer choose. In terms of ‘internal design control’, before the implementing measures of EuP directive is placed, ‘CE mark’[16] and declaration of conformity such as eco-labelling by the manufacturer or its authorised representative will be applied in order to demonstrate compliance with the relevant implementing measures (European Commission, 2007; European Union, 2005; Goosey, 2004).

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[16] CE mark is an abbreviation of Conformité Européenne, and is a mandatory conformity mark that certifies that a product, placed on the single market in the European Economic Area (EEA), has met EU health, safety, and environmental requirements. For more information, see: http://ec.europa.eu/enterprise/newapproach/legislation/guide/index.htm

Table 1.10: EU legislation summary: EuP, WEEE, RoHS (Schischke, Hagelüken and Steffenhagen, 2005)

EuP	WEEE	RoHS
	Targets	
Optimising the whole product life cycle Consideration of environmental effects in the life cycle phases	Improvement end-of-life management for electronics Implementing extended producer responsibility	Restrictions of hazardous substances from electrical and electronics equipment (lead, mercury, cadmium, chromium-VI, PBB, PBDE)
	Scope/ product groups	
In general: ● products which represent a significant volume of sales and trade, involve a significant environmental impact, and present a significant potential for improvement Product groups under discussion for implementing measures: ● Heating and water heating equipment ● Electric motor systems ● Lighting in both the domestic and tertiary sectors ● Domestic appliances ● Office equipment ● Consumer electronics ● HVAC (heating ventilating air conditioning) systems	● Large and small household appliances ● IT and telecommunications equipment ● Consumer equipment ● Lighting equipment ● Electrical and electronic tools (with the exception of large-scale stationary industrial tools) ● Toys, leisure and sports equipment ● Medical devices ● Monitoring and control instruments ● Automatic dispensers	● Large and small household appliances ● IT and telecommunications equipment ● Consumer equipment ● Lighting equipment ● Electrical and electronic tools (with the exception of large-scale stationary industrial tools) ● Toys, leisure and sports equipment ● Automatic dispensers (Currently exempted: medical devices, monitoring and control instruments; see WEEE)
	Status and deadlines	
Framework directive adopted in principle by Council and European Parliament in April 2005 For single product groups specific directive will be adopted, based on the EuP Voluntary agreements by industry may be considered as alternatives, under certain conditions	Directive 2002/96/EC of 27 January 2003 Published in Official Journal February 13, 2003 EU member states transpose WEEE by August 13, 2005 (April 2005: deadline will be missed by most EU members) Take-back logistics to be established by August, 2005 (postponed in some countries) Recycling quotas to be met by end of 2006	Directive 2002/95/EC of January 27, 2003 Commission Decision 2004/249/EC of March 11, 2004 EU member states transpose WEEE by August 13 2005 (April 2005: deadline will be missed by most EU members) Restrictions come into effect July 1, 2006 Review of exemptions undertaken by European Commission

EuP	WEEE	RoHS
Setting up an eco-profile of the product may be required by the implementing measures Design control or appropriate environmental management system in place CE marking requires EuP conformity Generic ('improvement') and specific ('limit values/thresholds') requirements to be defined in follow-up directives (implementing measures)	'Distributor' or 'producer; are obliged to follow the requirements, not of direct relevancy for (component) suppliers Separate Collection ≥ 4kg per inhabitant and year from households (per country) Specific recovery/ recycling/ reuse quotas per product category Producers finance recycling Producers have to offer an appropriate take-back solution for B2B customers Producers are obliged to submit to recyclers all relevant information for proper recycling	Restrictions of RoHS-6 substances in all products within the scope put on the market after June 30, 2006 (certain exemptions applicable)
	Eco-design relevancy	
EuP implements IPP Product design has to be improved considering the whole product life cycle	Product design should not hinder dismantling, recovery, and reuse (priority on reuse and recycling of WEEE, their components and materials) Products should be designed for easy disassembly of critical components (PCBs, batteries, brominated flame retardants containing plastics,…) Producer has to pay for recycling, thus, recyclability is an economic issue	Product material content has to be known as least regarding RoHS-6 substances Supply chain communication needed regarding legal compliance Reduction/elimination of hazardous substances

Regarding 'environmental management system', it is allowed to adopt voluntary instruments such as the Eco-Management and Audit Scheme (EMAS), which the design function is included within the scope of that registration (European Union, 2005). The documentation of implementing measures for conformity assessment shall include general description of the products and their use, ecological profile in accordance to the implementing measures, eco-design requirements, possibly management system encompassing the environmental product performance policy, etc., which all measures are considered with life cycle dimension (*Ibid.*). In this respect, manufacturers should implement environmental measures and improve their products and relevant areas through adopting eco-design principles and methods (*Ibid.*). Also, the EuP directive implies and encourages a potential integration of eco-design within environmental management systems.

1.2.4 Summary

There are important principles and issues across the product-related environmental product policy and regulation approach. Firstly, *integrated approach* and *life cycle thinking* are the key principles. Companies should consider and be able to make an effort to achieve various environmental requirements throughout the life cycle of products. It is because the orientation of environmental legislations pursues overall eco-efficiency throughout entire life cycle of products and most phases in product chains will be influenced by those regulatory measures. Secondly, the new environmental product policy (IPP) and the legal instruments (WEEE, RoHS, and EuP) are oriented to the balance of environmental and economic challenge through *innovation-driven way* and it encourages *continuous improvement* of environmental improvements. Therefore, overall eco-efficiency can be achieved both in production and consumption side, which, thirdly, require *cooperation and communication* between various actors requiring their involvement for environmental improvements in product chains.

However, it is still questionable that to what extent SMEs can improve environmental performance in this manner. Therefore, the following section will discuss environmental tools in the perspective of SMEs as well as the mainstream principles of the environmental product policy and regulations.

1.3 Review of environmental tools

This section explores the tools in two way; organisation-oriented method representing EMS and product-oriented method, namely, eco-design. Also benefits and critiques of the tools are reviewed with respect to the mainstream principles of the environmental product policy and regulations, and SME viewpoints.

1.3.1 Organisation-oriented method: EMS

Since the concept of environmental management systems (EMSs) was introduced and widely disseminated during 1990s, the application of standardised EMSs (i.e., EMAS and ISO 14001) within industry has been significantly increased (Ammenberg and Sundin, 2004a; Brezet and Rocha, 2001). Brezet and Rocha (*Op.cit.*) provide a figure that "*in October 1995 only 15 companies were registered under EMAS; in April 2000 that number had risen to over 3,300. Regarding ISO 14001 (which is applicable to all type of organisations and not only to industrial sites), that were over 15,000 companies certified at that same time*".

1.3.1.1 Objectives and strategies of EMS

EMS aims to improve corporate environmental performance by detecting and removing environmentally weak points, derived from either internal motivations or external pressures (Freimann and Walther, 2001). ISO 14001 (2004) defines EMS as, "e*nvironmental management system is the part of the overall management system that includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy*". The fundamental objective of EMS is to control and reduce environmental impacts resulted from an organisation's activities including products or services. EMS can also serve as an indicator ensuring conformity to stakeholders' expectation of the organisation.

The report of global eco-efficiency by Five Winds International (2000) summarises the four principles as the foundation of any EMSs, consisting of purpose, commitment, capability and learning. *Purpose* means that an organisation should establish clear goals and objectives, and condense them into its environmental policy that leads all relevant activities to perform in a consist manner. *Commitment* among the people in the organisation is crucial, which to represent its environmental values and internalise them into organisational activities so that necessary actions can be taken place. *Organisational capability* includes human and financial resources, knowledge, and skills that facilitate and achieve the final goal of the environmental policy. The whole experience of EMS is a *learning process* and ongoing improvement of organisational management, so that the environmental objectives can be fulfilled more effectively and continuously. For this, monitoring and evaluation of management and performance are required. The main clauses of ISO 14001 encompass these principles within its procedure, and provide a structural guidance with sub-clauses.

1.3.1.2 Potential benefits of EMS

Many studies[17] claims benefits from EMS adoption that can be categorised into several aspects. Firstly, many companies including SMEs perceive that competence and knowledge are increased by the systematisation and documentation of EMS processes. EMS provides relevant information including environmental policies and regulations. This is often related to the recognition that EMSs have a role as a regulatory relief owing to continuously monitoring compliance.

Secondly, many researchers (Brezet and Rocha, 2001; Collier, 1995; Gerstenfeld and Roberts, 2000; Greenan *et al*., 1997) agree that an environmental management system provides an adequate structure that helps a firm recognise its own environmental problems, and set up proper strategies and plans. Collier (1995) emphasises that an appropriate management system is essential in the long-term task to eliminate environmental risks. This strategic and structured process of EMSs also helps a firm advance management skills (e.g., risk management, better trained employees, etc.) and communication. In order to

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[17] Biondi *et al*., 2000; Dahlstrom *et al*., 2003; European Commission, 2001b; Five Winds International, 2000; Freimann and Walther, 2001; Greenan *et al*., 1997; Hillary, 2004; Johannson, 2000; UNC/ELI, 2003

achieve environmental policies and plans, it is inevitable to gather environment-related information in the first step, and to substantially establish an appropriate framework of the environmental management system.

Thirdly, Greenan *et al*. (1997) found that EMS would be important for monitoring and measuring a firm's environmental performance in management and operation especially for SMEs who are often required to implement EMS by their customers. Acquiring standardised EMSs under these pressures become a competitive advantage or threats for small firms that fail to meet the requirements and likely lose business. Greenan *et al*. (*Op.cit.*) also insist that "*environmental issues should be regarded within an extended quality management that enhances organisational performance because quality and business performance are inextricably linked*". In this respect, Madsen and Ulhøi (2001) describe that "*international guidelines and recommendations for sustainable business practices stress that companies must formulate an environmental policy with systematic approach*". Through an EMS implementation, not only better environmental performance but also economic benefits can be achieved through maintaining a competitive position in the market as well as keeping good relationship with customers and stakeholders.

1.3.1.3 Critiques on EMS

Despite the success and contribution of EMS to environmental improvements in industry, the level of adoption in SME sector is very sceptical according to some studies (European Commission, 2002; Greenan *et al*., 1997; Johannson, 2000; Pimenova and van der Vorst, 2003). Johannson (2000) quotes the results from two surveys indicating that less than one per cent of Canadian SMEs recognise standardised EMSs such as ISO 14001. Similar responses are found in other cases: more than 90 per cent of SMEs have not registered in any type of EMS in the MORI survey (Pimenova and van der Vorst, 2003); only 18 per cent of SMEs are among the EMAS registrations in the EU (European Commission, 2002). A Spanish survey confirms the relationship between company size and EMS implementation in Figure 1.9.

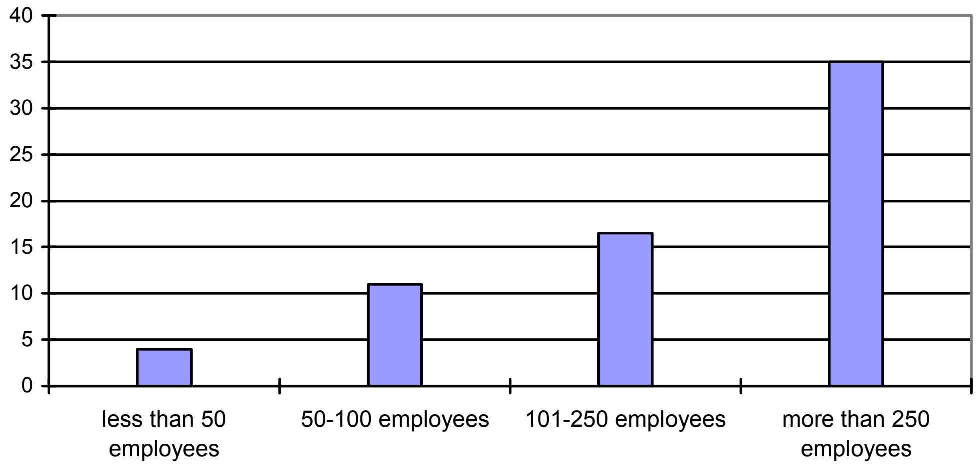

Figure 1.9: Percentage of Spanish SMEs with an environmental management system, by enterprise size (European Commission, 2002)

Critical viewpoints have been raised by many researchers and practitioners. In this study, discussions are presented in two ways – SMEs' perspective and the context of the mainstream principles of the environmental product policy and regulations – from the debates of 'these studies'[18].

Shortcomings of EMS in SME perspective

Regarding a low adoption of EMS in SMEs, these studies (Hillary, 2004; Holt *et al*., 2000; Johannson, 2002; Gerstenfeld and Roberts, 2000; Pimenova and van der Vorst, 2003) assert that the standards are not suitable for SMEs as they were developed by and oriented to large size of organisations. Johannson (2002) provides a reasonable explanation that SMEs do not usually participate in the ISO forum (TC207) according to some researchers in Canada, which the situation of other countries is similar. Hence, the important decision is made by government and big companies without proper consideration for SME sector.

Gerstenfeld and Roberts (2000) summarises the reasons of the contradictory situation between SME tendency and conditions for implementing an EMS: "*firstly, a common concern is that the standards are strategic approach to management while SMEs generally do not approach management strategically; secondly, the standards are generic whereas SMEs are specific; and thirdly, the standards are market-based instruments that rely on market-based pressures which presently are not felt extensively by SMEs*". Thus, EMS is rather effectively applicable to large and those organisations with existing strategic

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[18] Almgren and Hjelm 2003; Ammenberg and Sundin 2004a; Ammenberg and Sundin 2004b; Biondi, Frey and Iraldo 2000; Brezet and Rocha 2001; Charter *et al*., 2001; Ernst & Young 2000; Freimann and Walther 2001; Gerstenfeld and Roberts 2000; González-Benito and González-Benito 2005; Greenan *et al*., 1997; Hillary 2004; Holt *et al*. 2000; Johannson 2000; Rocha and Brezet 1999; Schmidt *et al*., 2001; UNEP 2004

management structure than to small firms. Consequently, unless there is immediate market rewards, this situation remains as a fundamental problem for SMEs when implementing the standards. Some studies mention high costs for implementing as well as auditing EMS, which are far beyond than SMEs expect and afford (Almgren and Hjelm, 2003; Freimann and Walther, 2001; Hillary, 2004; Johannson, 2000). Freimann and Walther (2001) raise the payback issue in economic effects that smaller firms likely have much longer payback periods.

In addition, environmental management tools have overemphasised standardised EMS and certification, even though there is no guarantee a significant improvement, at the expense of eco-efficiency, eco-design, integrated approaches, and fundamentally more sustainable manufacturing (European Commission, 2002). END report (1995, cited by Gerstenfeld and Roberts, 2000) describes that "*SMEs generally see the standards as bureaucratic, confusing and esoteric and frequently feel like the victims of environmental red tape*".

Shortcomings of EMS in the context of the mainstream principles

According to the studies[19], the most important critique is that the traditional standards overlook product aspects within their framework. One of the reasons is that EMSs more focus on (production) process-oriented and sites-specific treatments rather than whole life cycle of a product. Rocha (2003, cited by UNEP, 2004) describes that "*although*

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[19] Almgren and Hjelm, 2003; Ammenberg and Sundin, 2004a; Ammenberg and Sundin, 2004b; Brezet and Rocha, 2001; Ernst & Young, 2000; Freimann and Walther, 2001

conceptually the standards encompass life cycle thinking, since at the core of an environmental management systems in line with the standards are the environmental aspects of 'activities, products and services', practice shows that the ISO 14001 certified systems are in general applied to those activities under the organisation's direct influence, mostly manufacturing processes in industry". This is because the tools have been predominantly developed for technical measures and still on additive (end-of-pipe) technologies (Freimann and Walther, 2001). This approach is clearly opposed to the mainstream principles of the environmental product policy and legislations.

In addition, more companies are becoming interested in organisational activities of product-oriented ecology and implementing environmental product care system (Brezet and Rocha, 2001). However, a lack of resources on the approach incorporating product aspects might negatively influence on the support to encompassing environmental issues within the product design as well as long-term EMS strategies of a company. Thus, it causes a problem that a little linkage between EMS and eco-design is likely to hamper proactive and preventative performances. To conclude, it is still questionable to what extend traditional EMSs can integrate and support product aspects in environmental improvements.

1.3.2 Product-oriented method: Eco-design

Environmentally friendly product design and development has become important than ever. Main reason of this trend is that the planning phase of product development is decisive in achieving more or less 80 per cent of costs and environmental effects of product and product chain (Tischner *et al*., 2000). For example, as seen in Figure 1.10, product attributes such as cost, energy use and mass are fixed in the early stage of product development (i.e., R&D and design phase) whereas most of the actual costs are incurred in the manufacturing or production phase (Five Winds International, 2000). Therefore, eco-design became regarded as leverage to an ultimate change towards environmentally sound products and product chain.

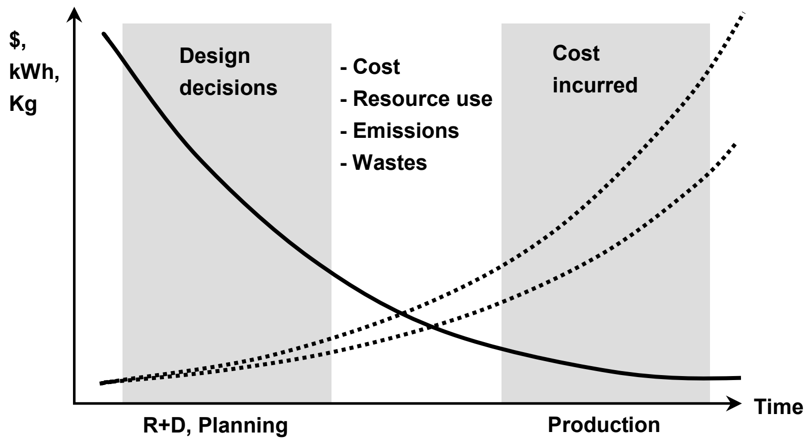

Figure 1.10: How design decisions affect cost and environmental aspects of a product (Five Winds International, 2000)

There are various motivations for enterprises to take account of eco-design in their business. Although these studies[20] show different drivers for eco-design according to different regions, industries and company size, there is certain consensus for adopting eco-design concept mainly as legislation compliance, market competition, stakeholder relationship specifically business customers' demands to SMEs, economic benefits, and product innovation.

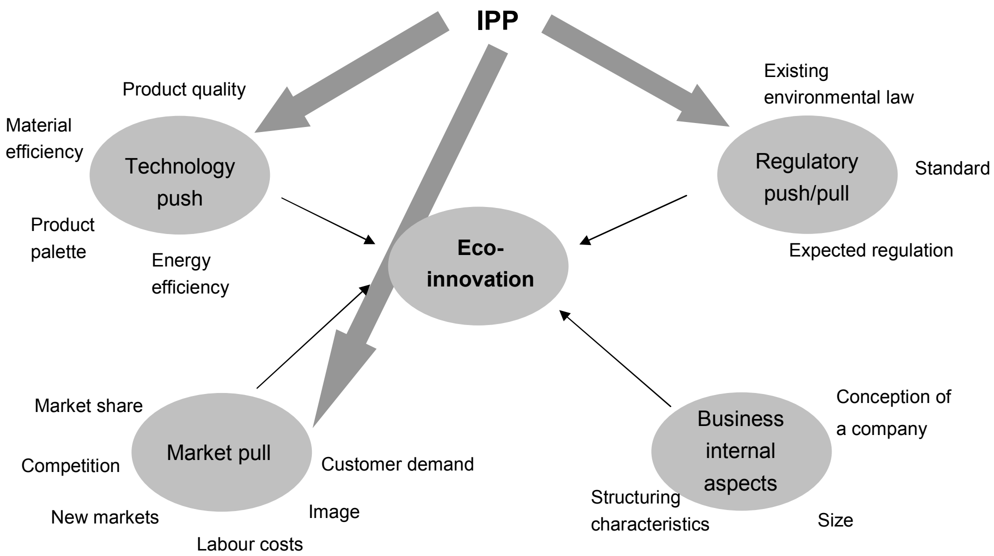

Figure 1.11: Determinants of product innovations (Source: Cleff/Rennings 1999 and own supplementations by Rubik, 2003).

[20] Curtis and Walker, 2001; Deprez, 2006; Jansen and Vercalsteren, 2001; Five Winds International, 2000; Mathieux *et al*., 2003; McAloone *et al*., 2002; O'Connor and Hawkes, 2003; Quella, 2001; Tischner and Charter, 2001; Vercalsteren, 2000; Woolman and Veshagh, 2006

1.3.2.1 Objectives and strategies of eco-design

Since eco-design concept has been adopted in business practice last decades, different terminologies have been used, for example, green design, design for environment (DfE), eco-design, sustainable design, environmentally friendly/sound design, etc. Among them, 'DfE or eco-design is more generally accepted worldwide'[21]. According to the literatures[22], a common definition of eco-design has a wider understanding that generally means environmentally conscious product design and development, which is based on the life cycle perspective of a particular product and integrated approach with business, culture and capabilities of the organisation. The EuP directive also defines eco-design as "*the integration of environmental aspects into product design with the aim of improving the environmental performance of the EuP throughout its whole life cycle which eco-design requirements based on the ecological profile of the directive should cover the all interlinked stages of an EuP from raw material acquisition, manufacturing, packaging, transport and distribution, installation and maintenance, use, and end-of-life* (European Commission, 2003b; European Union, 2005; Goosey, 2004)".

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[21] No official terminologies are found in reference to environmentally conscious design concept. This thesis uses eco-design or design for environment (DfE) based on the international organisations such as UNEP and European Commission. More information is available at:
http://www.unep.org/, http://glossary.eea.europa.eu/EEAGlossary/E/eco-design,
http://ec.europa.eu/enterprise/eco_design/index_en.htm

[22] Brezet and van Hemel, 1997; Five Winds International, 2000; Fry, 1994; Lewis and Gertsakis, 2001; Santos-Reyes and Lawlor-Wright, 2001; Tischner, 2001; Tischner and Charter, 2001; Tischner *et al.*,2000; Victor, 1995

A common principle of eco-design is '***life cycle thinking***' indicating that eco-design searches for potential environmental improvement through entire life cycle of a product. '***Integrated approach***' implies in some ways. First, eco-design not only focuses on just environmental aspect but also requires a balance with classical design that is business-oriented. Eco-design appreciates the traditional design values such as functionality, quality, profitability, productivity, technical feasibility, etc. Second, eco-design embedded in business nature means that it should be compatible with existing corporate culture while enhancing economic value by reducing environmental damages. The term 'eco-design' directly expresses that *Ecology* and *Economy* must be joined inseparably by means of good design in eco-design procedures (Núñez *et al*., 2006; Tischner *et al*., 2000).

Eco-design activities are ideally and potentially across all stages of a product's life cycle. This approach requires '***relevant actors to be involved***' along the product life cycle. O'Connor and Hawkes (2003) define these people as 'product stakeholders' who are affected by, and influence many facets of a product's life cycle including its environmental impacts. The product stakeholders scattered in the product chain are manufacturers, users, distributors, service technicians and end-of-life asset managers (e.g. disposal experts) (McAloone *et al*., 2002; O'Connor and Hawkes, 2003). To avoid misinterpretation and lack of introduction of environmental information and strategies between stages of life cycle, cooperation among internal external stakeholders is essential. For example, internal actors (e.g., product managers, purchasing and environmental experts, marketing people and designers) can facilitate establishing a company's database to provide internal environmental policy, regulations, standards, lists of hazardous substances and design guidelines (Mathieux *et al*., 2003). Meanwhile, users as external stakeholder might use the product's environmental information to avoid wrong way of using the products, and can feedback inappropriate design to the company (Wimmer, Züst and Lee, 2004). Therefore, eco-design can play as a hub of cooperation, which will be a challenge to get all stakeholders involved in environmental product development and encourage them to do their best for their job in environmentally sound way.

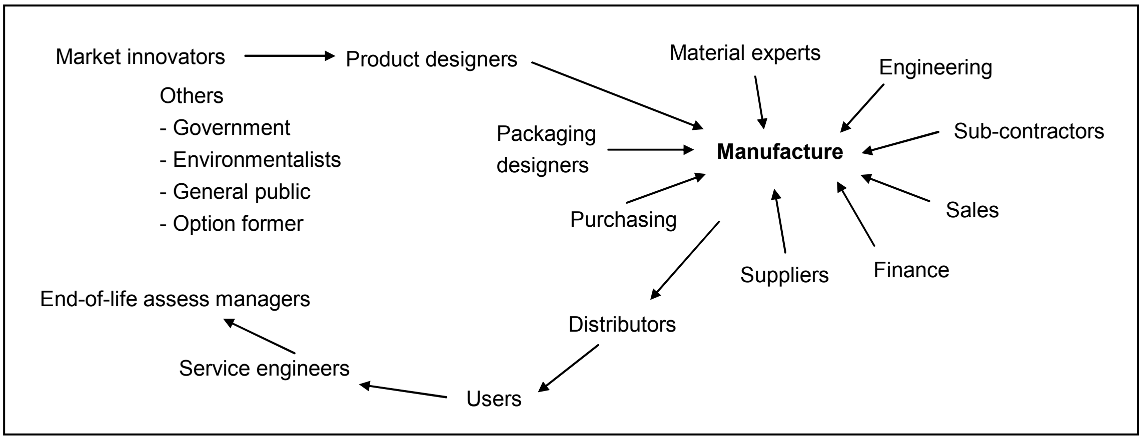

Figure 1.12: Product stakeholders (O'Connor and Hawkes, 2003)

Lastly, '***continuous improvement***' is an important aspect in eco-design. Eco-design is a learning process, so called, heuristic principle (Mathieux *et al*., 2003; Wimmer, Züst and Lee, 2004). An extended scope of eco-design could reach a further innovation of whole business system rather than a product or more extensively a product system innovation. Wimmer, Züst and Lee (*Op.cit.*) summarise this principle in three dimensions; considering time-related changes, thinking in alternatives and options, and working from an overall to a detailed view.

1.3.2.2 Potential benefits of eco-design

Eco-design begins to gain more attention by business community despite its relatively less recognition in commercial context compared to other environmental issues such as waste and emission management. There are no sufficient experiences of eco-design in practice and research, and not many industrial responses. Therefore, it is hard to draw a conclusion of advantages or shortcomings of eco-design in various aspects. Nevertheless, there are some arguments of potential benefits as well as evidences of shortcomings of eco-design, which give an insight for further development of the tool.

Product focus

Eco-design only exists within the ‘product’ substance as the concept of general ‘design’ was created for the reason that products are invented and innovated with better values. Therefore, product focus is the inherent principle of eco-design which being supplemented by extended environmental considerations from general design attributes. Even traditional design must consider the various aspects to increase every economical efficiency and productivity in its own activities, which are regarded as part of sustainability benefits. Therefore, eco-design already contains these values in the principles in line with environmental aspects.

Life cycle thinking

The characteristics of life cycle and integrated approach are also embedded within the concept of eco-design. Effective and successful implementation of an eco-design project requires analyses of the life cycle of a product, and searches for possible opportunities to improve environmental and economical performance of the product. The detailed contents of product life cycle in eco-design concept is described in the IPP principles, namely 'cradle-to-grave' or entire life cycle of a product. Therefore, the eco-design project should implement environmental profiling of the target product, and, based on this data, establish objectives, strategies and a procedure along with other considerations and activities in production, sales and marketing, distribution, use, and disposal.

Legislation compliance

Most frequently mentioned benefit is that eco-design is a proactive approach towards legal compliance (Schischke *et al*., 2005). Recent legislations (WEEE, RoHS and EuP) are expected to have large influence to industry in particular EEE sector. In this circumstance, manufacturers started looking for a framework systematically dealing with these issues in the early stage. Eco-design can play an important role as an eye-opener that possibly provides guidance.

Increased relationship with stakeholders

Industrial consumers are further important driver for eco-design, especially the global players affected by the environmental product policy and legislations, in turn, that have a huge influence on their suppliers (Charter and Belmane, 1999; EIGT/DTI, 2004; Schischke *et al*., 2005; Tischner *et al*., 2000; Wimmer and Züst, 2001). Because the supply chain can represent up to 95 per cent of a product's manufacturing costs (EIGT/DTI, 2004), effective control of supply chain system can be the main issue for large firms. Companies especially electronic sector are no longer manufacturers, but 'systems integrators' as significant environmental impacts resulted from their supply chains (Charter and Belmane, 1999). Therefore, being a 'green supplier' can be a decisive argument to be chosen at all as a supplier (Schischke *et al*., 2005). With this prospect, eco-design could contribute as a core tool to the management of product as well as supply chain relationship.

Other benefits

In eco-design concept, the economic gain from sound production and less use of materials is not only a benefit but also a potential income from overall improvement in supply chain system, which can be substantial when the eco-design principles are fully embedded. For instance, manufacturers producing printed circuit board may save about 20-40% of total manufacturing costs if they could reduce material and energy assumption during production (*Ibid.*). The effects are also demonstrated in reduced internal logistics such as assembly and disassembly processes of products, decreased handling costs of hazardous substances and less packaging, using cheaper recycled materials, and so on.

Eco-design can provide new opportunities for value creation, for example, many products still contain valuable, durable components at the end of their life (Tischner *et al*., 2000).

The eco-design principle, ‘continuous improvement’, motivates companies keeping products up-to-date and increasing their efficiency (Schischke *et al*., 2005). Moreover, customers would be much satisfied with more reliable and of better quality which is added value by eco-design (*Ibid.*). There is also an opportunity of a new market that opens to environmentally competitive products in a particular business market. For instance, companies now frequently consider the environmental profile of a supplier when selecting major OEMs (Original equipment manufacturers) (*Ibid.*).

1.3.2.3 Critiques on eco-design

With all due respect of the benefits that eco-design is intended, this tool has not been widely implemented in industry particularly SME sector according to these studies (CfSD 1996 and CfSD 1999, cited by Charter and Belmane, 1999; Jansen and Vercalsteren, 2001; Mathieux *et al*., 2003; Schischke, 2005; Vercalsteren, 2000). The attitude in the majority of SMEs to eco-design is even negative (Jansen and Vercalsteren, 2001). Most of the studies agree that eco-design methods have limitations to apply due to the following reasons.

Lack of strategic and management approach

Eco-design is not a management issue that SMEs would consider it as strategic goals of environmental product policy (Schischke, 2005). Thus, eco-design is unlikely applied strategically, as many authors[23] emphasise the need of a systematic approach integrated

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[23] Ammenberg and Sundin, 2004a; Brezet and Rocha, 2001; Charter, 2001; Charter and Belmane, 1999; Quella, 2001; Rocha and Brezet, 1999; Santos-Reyes and Lawlor-Wright, 2001; Schischke, 2005; Tischner, 2001

with organisational (environmental) management when implementing an eco-design project. SMEs tend to return to 'business as usual' after completing an eco-design project (Ammenberg and Sundin, 2004a). So, many eco-design projects and initiatives end up one-off case, and most emergent eco-design tools often focus on a single issue of the product life cycle (Brezet and Rocha, 2001; Santos-Reyes, Lawlor-Wright, 2001; Schischke, 2005). It implies that the eco-design principle of continuous improvement, as it claims, is missing in reality. The experience of ad hoc eco-design projects can be hardly internalised into the company's business routine. Therefore, a lack of strategic and management approach of eco-design needs to be overcome.

Difficulties in environmental implementation of SMEs

Although one of the key characteristics of eco-design is the integrated approach by cooperation, communication and involvement of all relevant actors in product chains, it is barely realised in practice. According to Woolman and Veshagh (2006), SMEs believe that the major task of environmental improvements such as identifying environmental impacts in product development is responsible for the design area. This is a narrower approach than dealing with entire life cycle of a product across departments. This may be due to the insufficient capability of small firms which is most frequently pointed out in eco-design implementation. Eco-design objectives and strategies encompass a wide range of areas that companies have to tackle a lot of issues relating to products and thus this holistic approach certainly requires a great amount of effort. On the contrary, a survey of British Design

Council (Curtis and Walker, 2001) states that more than 80 per cent of UK companies want a specific approach rather than holistic.

According to the studies[24], the implementation of eco-design in day-to-day business is very limited or rarely happened in small firms. SMEs are critical on eco-design because they regard it as very theoretical and not useful in practice (Jansen and Vercalsteren, 2001). They perceive that implementation of eco-design into daily product development activity is the most difficult to conduct because of time and cost pressures, and the increasing complexity of products easily disinterests companies (McAloone *et al*., 2002). From the two surveys of SMEs' attitudes or perception on eco-design (Schischke, 2005; Woolman and Veshagh, 2006), the majority of companies either more care about impending issues such as economic incentives, or show a negative view on eco-design owing to the perception of high cost or lack of customer demand. Thus, it may not be possible to expect that profound objectives and potential benefits of eco-design can be achieved in SMEs.

1.3.3 Summary

There are some overlaps of benefits between EMS and eco-design, such as legal compliance, cost savings, etc. However, there is also a clear contradiction of benefits and shortcomings between the two tools. For instance, EMS has a strength at strategic and management support where eco-design is relatively venerable. Life cycle approach and

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[24] Charter and Belmane, 1999; Jansen and Vercalsteren, 2001; McAloone *et al*., 2002; Mathieux *et al*., 2003; Schischke, 2005; Vercalsteren, 2000; Veshagh and Li, 2006; Woolman and Veshagh, 2006

product focus are the key concepts in eco-design whereas EMS lacks in incorporation of them within its process and practice. Therefore, many researchers[25] suggest that EMS and eco-design need to be integrated.

In SMEs' point of view, both tools have a lack of consideration for small businesses. In EMS, generic, strategic and long-term approaches are not achievable by SMEs. Eco-design has a broad scope of life cycle and integrated approach that may not be realised in SME sector. Especially, life cycle approach requires a company to must consider and coordinate a variety of environmental activities occurred in product chains, while SMEs are likely to focus on a single issue and carry on a one-off project.

1.4 Problem statement and key research questions

This chapter has argued the background mechanisms of environmental issues surrounding SMEs in three aspects; 1) the predisposition of SMEs in environmental issues, 2) the mainstream principles of the environmental product policy and legislations, and 3) the existing environmental tools with respect to SMEs and the mainstream principles. A conflicting situation exists between the mainstream principles and SME situation, as well as between the existing tools and the needs of SMEs, described in Figure 1.13.

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[25] Ammenberg and Sundin, 2004a; Ammenberg and Sundin, 2004b; Carey and Laszewski, 2002; Charter and Belmane, 1999; Charter *et al*., 2001; Fiksel, 2001; Schischke *et al*., 2005; Madsen and Ulhøi, 2001; Tischner *et al*., 2000

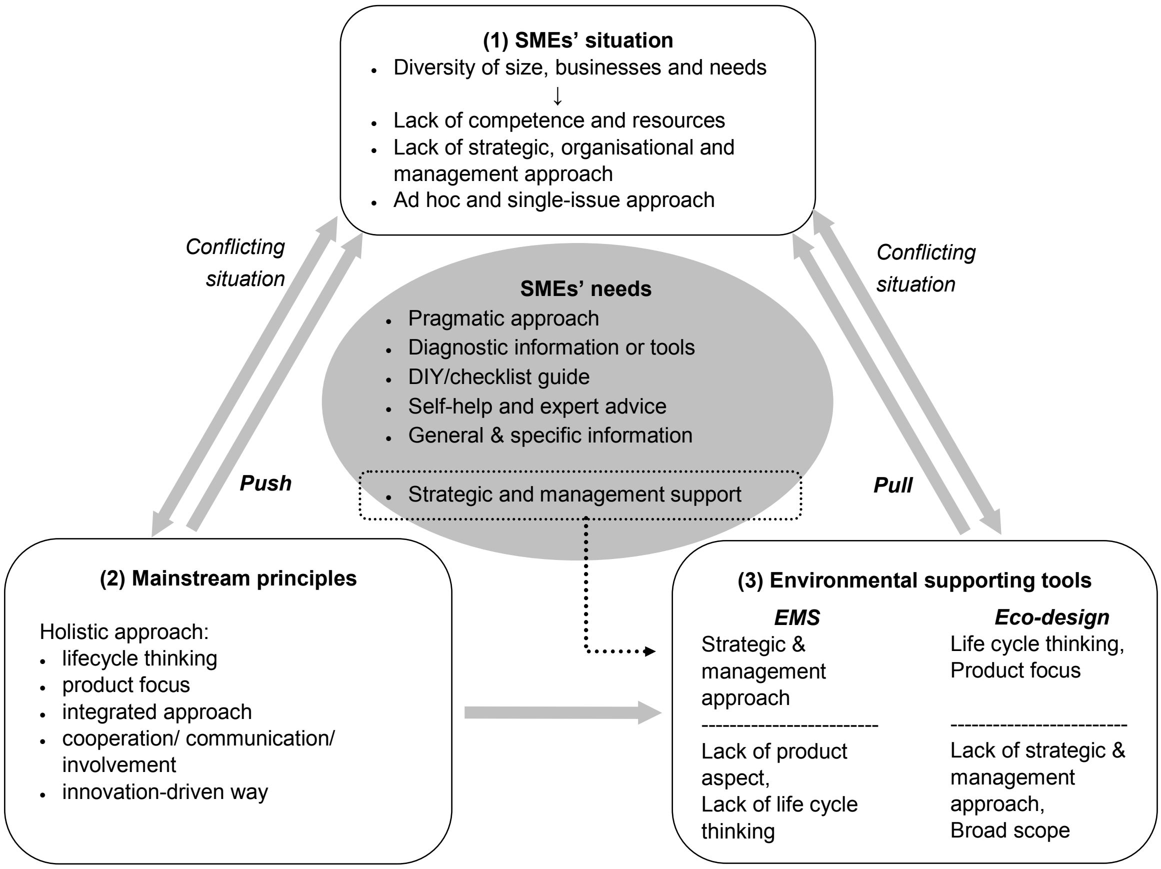

Figure 1.13: Background mechanisms of key environmental issues surrounding SMEs

The relationship of box (1) and (2) in Figure 1.13 indicates that there is a contradictory situation between the mainstream principles and their realisation in SME sector. Although SMEs may want to achieve an ambitious goal covering entire life cycle of a product, they are often trapped in a specific and short-term basis approach of environmental works.

In the relationship of box (1) and (3), both EMS and eco-design have their own inherent shortcomings as well as limitations to be implemented in SMEs. Regarding this, firstly, there is a strong insistence that EMS and eco-design need to be integrated in order to achieve the product-oriented environmental management strategically. Secondly, both tools should be modifiable and adoptable by SMEs through providing generic and specific guide, strategic and management support to product dimension, diagnostic approach identifying focus areas of individual SMEs, and applicable format for SMEs such as DIY/Checklist.

In the relationship of box (2) and (3), the mainstream principles will have influenced on EMS and eco-design towards that they are incorporated and complemented. However, there is a substantial room for further development of the tools. At present, integration between EMS and eco-design is entirely up to an individual company performing both aspects of product and organisational environmental management. Considering the fact that SMEs are generally incompetent and incapable of strategic management and life cycle approach that require infrastructural muscle that SMEs usually do not have, it is not possible for SMEs to not only utilise the individual tools but also manage such a complicated integration of the attributes of the tools.

With respect to the problems found in the relationships in Figure 1.13, there are few methods suggested in industry and academia including product-oriented environmental management system (POEMS) and ISO/TR 14062. POEMS has been specifically developed for bridging the gap between management approach of EMS, and product-focused approach of eco-design. POEMS concept has evolved into different models and has been used in various industry sectors. In response to the life cycle approach in product dimension, the technical report (ISO/TR 14062) on 'Environmental management – integrating environmental aspect into product design and development' was published. Although ISO/TR 14062 considers product aspects in environmental management (ISO/TR 14062, 2002), most contents and application of this manual are still underdeveloped than the existing POEMS that more actively involves product aspects. Therefore, this study focus on POEMS.

Problems found in the relationships in Figure 1.13 are developed into two sets of fundamental research questions that need to be solved. Answers for the first set of research questions can be investigated in POEMS. Answers for the second set of research questions can be searched through a critical evaluation of existing POEMS models with respect to the suggestions depicted in the central circle of SMEs' needs in Figure 1.13. The details of key research questions are summarised as follows:

1. How to complement EMS and eco-design.
   (1) Whether POEMS has strategic and management approach
   (2) Whether POEMS covers product aspects and relevant issues
   (3) Whether POEMS approach in life cycle perspectives
2. To what extent POEMS can be modified in order to solve the contradictory situation between the mainstream principles and their realisation in SMEs.
   (4) Whether POEMS provide a generic and specific guide

(5) Whether POEMS has any diagnostic approach to identify focus areas for environmental improvement

(6) Whether POEMS is applicable for SMEs with a self-help format (e.g., DIY/checklist)

1.5 Research objectives and scope

The central aim of this research is to develop a conceptual POEMS model incorporating the mainstream principles and applicable to SMEs. Very few product-oriented environmental management tools or methods have been developed and POEMS has a very short history of development. Moreover, POEMS has not widely considered SMEs sector except few countries in Europe such as the Netherlands and Denmark. Therefore, it is necessary to overview a general concept of POEMS and analyse the existing POEMS models. The scope of this research covers two main areas that include scope and contents of POEMS, and structure and procedure of POEMS with regard to key research questions.

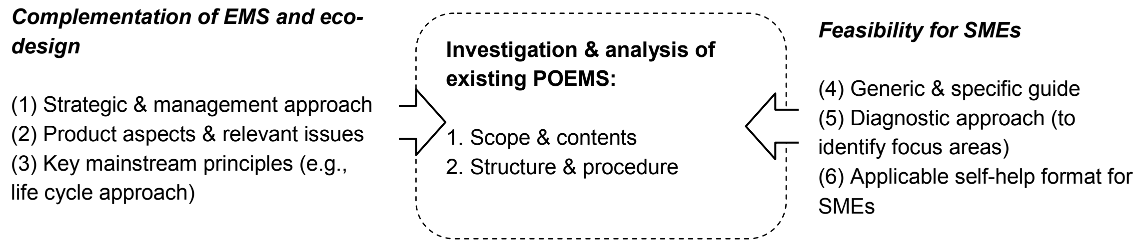

Figure 1.14: Scope and focus areas of the research

1.6 Research framework and thesis structure

The first set of the key research questions is integration of EMS and eco-design in three subjects; (1) strategic and management approach in POEMS, (2) product aspects and relevant areas in POEMS, and (3) life cycle approach in POEMS. In order to answer these questions, literature study is focused on general introduction of POEMS regarding definition and main concept, scope and strategies, and structure and process of POEMS.

There is no definitive model of POEMS so far. It is, thus, difficult to answer the second set of the research questions. More critical analysis of POEMS is necessary to develop the argument of the second set of research questions; (4) whether POEMS provide a generic and specific guide, (5) whether POEMS has any diagnostic approach to identify focus areas for environmental improvement, and (6) whether POEMS is applicable for SMEs with a self-help format (e.g., DIY/checklist). This study implements an exploratory research that conducts a critical analysis of existing POEMS models and explores feasibility of POEMS in SMEs.

Through an exploratory research, key propositions for improvements of POEMS can be made. In line with this, this study reviews a model architecture theory in information system and/or business process management, namely, component-based modelling for formation of a new conceptual model. Combined with the results of the critical analysis in exploratory research and the theory of component-based modelling, this study suggests key propositions as hypotheses for formulation of a component-based POEMS (C-POEMS).

The hypotheses are examined and tested in two ways; a semi-structured questionnaire and interviews, and case studies. Figure 1.15 shows research framework and thesis structure.

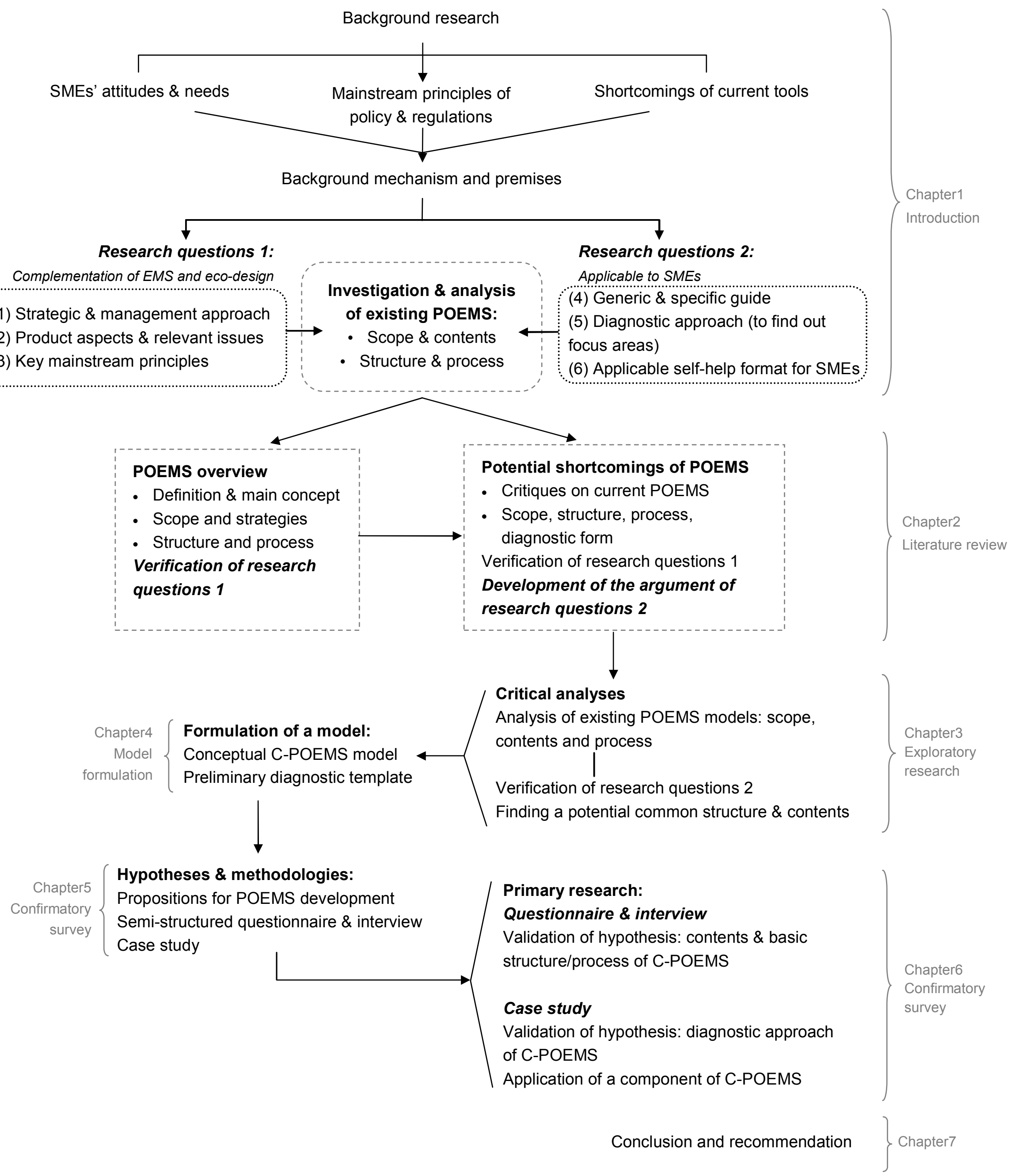

Figure 1.15: Research framework and thesis structure

This thesis consists of seven chapters as the details are explained below.

Introduction

Chapter 1 explores background mechanisms of environmental issues surrounding SMEs. Man issues include SMEs situations (nature of SMEs, current situation of environmental awareness and uptake, main drivers, main barriers of environmental improvement, and environmental support systems in particular environmental information and tools), recent trend (the mainstream principles of environmental product policy and legislations), and review of existing environmental tools (EMS and eco-design). Two sets of key research questions are raised.

Literature review

Chapter2 reviews general information of POEMS including an overview and shortcomings of POEMS. Based on this, the first set of research questions is answered.

Exploratory research

Chapter 3 explains a critical analysis of eight representative POEMS models. The result confirms that the second set of research questions exists, and suggests further development of POEMS.

Model formulation

Chapter 4, firstly, introduces a component-based modelling theory in information system and/or business process architecture. Secondly, this chapter explains a framework of a component-based POEMS model in two ways; a basic form of C-POEMS (i.e., contents, categories of functional areas, and process), and a diagnostic tool.

Hypotheses and methodology

Chapter 5 makes a statement of hypotheses for development of each C-POEMS model and diagnosis template. Based on the critical analysis of the exploratory research in Chapter 3 and the component-based modelling in Chapter 4, this study suggests propositions as hypotheses and introduces methodology acting as a confirmatory survey that validate the hypotheses.

Result and discussion: confirmatory survey

Chapter 6 presents discussions of the results of the primary research that consists of semi-structured questionnaire and in-depth interviews, and case studies. Hypotheses of the propositions for model formulation are verified, and potential feasibility of the diagnosis template is tested.

Conclusion and recommendation

Chapter 7 brings together a summary of discussion and conclusions from the whole research including methods, outcomes and limitation. Finally, suggestions are made for further development of POEMS as well as the conceptual C-POEMS model.

1.7 Research contribution

1. Methodological development of POEMS:

   The concept of product-oriented environmental management system (POEMS) has been introduced very recently, which responds to the strong need of integration between EMS and eco-design. Although there is an increasing interest that POEMS can provide benefits to industry with respect to product-oriented environmental improvements, an emerging argument is placed that POEMS lacks in methodological development. This limitation is related to the fact that POEMS has been developed in only few countries and applied to minor industries. This research aims to investigate current problems of existing POEMS models, explore potentials and directions for further improvement, and develop a conceptual POEMS model, called component-based POEMS (C-POEMS). As POEMS is a revolutionary tool, the information of this research that scrutinises problems and finds directions may contribute to future development for standardisation of POEMS.
2. Environmental improvement of SMEs compatible with and corresponding to the recent environmental trend:

Despite the considerable importance of SME sector, they are lagging behind and easily ignored in the environmental improvement in industry. Moreover, managing supply chain system is a huge challenge for multinational corporations that look for a support programme to facilitate their suppliers towards environmentally sound business. However, existing EMS and eco-design methods have shortcomings to be implemented in SMEs. For effective improvements of a product and relevant areas along its life cycle, integration of EMS and eco-design is inevitable. This research proposes a new component-based POEMS (C-POEMS) that incorporates the benefits of EMS and eco-design, and provides component-based application with diagnostic in self-help format. It enables SMEs to tackle complexity of product-related environmental issues by diagnosing a company's specific problems and defining focal areas for further improvements. C-POEMS is expected to be useful not only for initiators of environmental improvements but also various needs and levels of the environmental performance of SMEs.

Chapter 2 Literature study

In Chapter 1, this research has proposed that product-oriented environmental management system (POEMS) has potentials of compromising existing environmental management system (EMS) and eco-design. In this regards, two sets of research questions are raised in Chapter 1. This literature study aims to explore answers for the first set of research questions, whether POEMS has; (1) strategic and management approach, (2) product aspects and relevant areas, and (3) life cycle approach. This chapter describes the general concept of POEMS including a definition and objectives of POEMS, a scope and strategies of POEMS, structure and process of POEMS, and benefits and critiques on POEMS. For the second set of research questions, arguments are developed in an exploratory research in Chapter 3.

2.1 Introduction of POEMS

Early stage of debates on product-related environmental issues for decades, eco-design has been developed in separate areas (Ammenberg and Sundin, 2004a) while EMS standards have been widely used by many companies. However, the EMS standards have not sufficiently dealt with product dimensions. With respect to this, various environmental initiatives from different countries have been introduced, which attempted to embrace the life cycle thinking within an environmental management system in order to bridge the gap between product-oriented environmental strategies, such as eco-design, and traditional environmental or quality management systems (Brezet *et al*., 2000, Schmidt, Christensen and Ollgard, 2000, cited by UNEP, 2004; De Bakker, Fisscher and Brack, 2002). This movement has raised the issue that EMS standards need to consider more active interpretation of product-related environmental requirements, and integrate them into organisational environmental management systems. Meanwhile, the EU level of environmental product policies has been developed into IPP that adopted product-oriented environmental management systems in conceptual level. This approach has stimulated several EU member states as well as in international organisations such as the Organisation for Economic Cooperation and Development (OECD) and the United Nations Commission on Sustainable Development (CSD) (Rocha and Brezet, 1999).

In 1993, environmental product policy of the Dutch Ministry of Environment, Spatial Planning and Housing (VROM) had a target at information exchange with an expectation that different actors in the production chain would each take measures to reduce the environmental impact of the respective products (DIW Berlin, 2002; Van Berkel, Van Kampen and Kortman, 1999). This policy focused on the product document to establish environmental product information systems, and thus Dutch manufacturers were obliged to produce product environmental information (DIW Berlin, 2002; Van Berkel, Van Kampen and Kortman, 1999). However, the policy has failed to meet the primary objective of products' environmental improvement because it overlooked uncertainty of market response and critical objection by the industry, and of customers' knowledge on this, whereas much effort was made in developing and managing the environmental product-information systems (DIW Berlin, 2002; Van Berkel, Van Kampen and Kortman, 1999).

By the late 1990s, around 1000 eco-design projects have been completed in the Netherlands, however, most cases ended up as one-off projects according to Rocha (1999, cited by Charter and Belmane, 1999). Therefore, a more systematic approach was increasingly required, which would incorporate both technical and managerial considerations in eco-design (The Dutch Ministry of Environment, Spatial Planning and Housing 1999, cited by Charter and Belmane, 1999). Recognising the importance of product-related issues in the environmental protection and lessons from the past experience, in 1996 the Dutch government changed its environmental policy by replacing it to POEMS (or PMZ in Dutch) that was a voluntary environmental management programme for business and aimed at reducing the environmental impacts of products along the life cycle (DIW Berlin, 2002; Rocha and Brezet, 1999; Van Berkel, Van Kampen and Kortman, 1999). The POEMS programme has been implemented in industry between 1997 and 1999, which more than 60 of pilot projects were financed by the government (DIW Berlin, 2002).

In line with the Dutch policy approach, the Danish EPA has implemented a similar programme that is called a 'Product-oriented Environmental Initiative'. The Danish EPA published a discussion paper entitled 'An Intensified Product-oriented Environmental Initiative' in November 1996 (Danish EPA, 1998). It aimed to promote the development of cleaner products by improving the environmental properties of existing products within a life cycle perspective which takes energy and resource consumption and disposal considerations as integral parts of product design (*Ibid.*). Together, the Danish EPA's Green Buying Guide for public procurements contains a number of specific requirements that products must meet recommendations of the guide that they should live up to (Schmidt, Christensen and Øllgaard, 2002). The Danish EPA has developed POEMS as a part of instruments employed for the initiative and has published a 'Manual on Product-Oriented Environmental Work' in 2002. This manual covers a broad range of issues from the ground theory such as life cycle approach, as well as stakeholders and consumer aspects, to the practical methods such as life cycle assessment (LCA) and supply chain management (SCM).

2.2 Definition and objectives of POEMS

Summarising the various definitions of POEMS in Table 2.1, the basic concept of POEMS can be encapsulated as a framework for continuous environmental improvement of the product and whole media (i.e., air, water, land) in its life cycle by strategically incorporating eco-design within the corporate environmental management system. The objectives of POEMS are to fundamentally reduce the total environmental impact from the entire life cycle of a product, namely its eco-efficiency. In more literal sense, POEMS aims to optimise the contents of EMS from an eco-design point of view while relying on the structure that the standardised EMS offers (Brezet and Rocha, 2001). In other words, POEMS is a combination of the operational cycle (focused on the improvement of products' features via eco-design) with the managerial cycle (focused on providing the managerial support for eco-design) (*Ibid.*).

Therefore, the fundamental objectives derive the main principles of POEMS. Firstly, an integrated approach that combines product aspects (through eco-design) with a company's environmental management system is crucial. POEMS is supposed to cover a whole life cycle of a product. Most environmental activities can be considered in the POEMS system. These activities are generally called POEMS elements and performed in relevant functional areas of a corporation. POEMS intends to encourage and fully utilise the functional areas for a support for environmental improvements of products and product chain, strategically in a corporate management level. Main purpose of strategic management support for eco-design activities are induced from the need of continuity of environmental improvement via product influencing most areas and media of the life cycle. Thus, continuous improvement is a part of POEMS principles. The following discussion unfolds how and to what extent these principles of POEMS are strategically implemented in organisational environmental performance.

Table 2.1: Various definitions of POEMS (author's own compilation)

De Bakker (2002)	POEMS can be defined as an approach for organising and operating a firm in such a way that improving the environmental performance of its products becomes an integrated part of operations and strategy.
Dutch Ministry of Housing, Spatial Planning and the Environment (Charter and Belmane, 1999)	POEMS is an instrument to integrate product aspects into environmental management systems in companies…
Klinkers *et al*., (1999)	Product-oriented environmental care (PEC) is an extension of environmental management and a logical supplement. With respect to its systematics, PEC does not differ from the existing management system. In both cases, the aim is to reduce environmental impact by continuously passing through the management cycle.
Rocha and Brezet (1999)	An EMS with a special focus on the continuous improvement of a product's eco-efficiency (ecological and economic) along life cycle, through the systematic integration of ecodesign in the company's strategies and practices.
Danish EPA manual (Schmidt, Christensen and Øllgaard, 2002)	A product-oriented approach means, including in the preventive environmental work, an assessment of environmental impacts and possibilities for improvement in relation to both the production and the product's life cycle – and acting on the basis of the resulting knowledge. In other words, it is a question of using life cycle approach.

2.3 Scope and strategies of POEMS

2.3.1 Systematic approach in life cycle context

Life cycle thinking is the core principle among most recent environmental approaches. For example, UNEP's life cycle initiative introduces POEMS in conjunction with life cycle management (LCM) or, to be more precise, corresponding to the environmental dimension of LCM. The purpose of the life cycle approach is to provide a picture from resource consumption to environmental impacts along the individual stage of a product's life cycle. Although it depends on product sort and a company sector, it generally covers following areas in Figure 2.1. Relevant information of the resource consumption and environmental impacts along the life cycle of a product is essential and needs to be measured, producing the so called environmental profiling of the product. Life cycle assessment (LCA) is the tool most frequently used for this preliminary picture in order to clarify the product's environmental requirements.

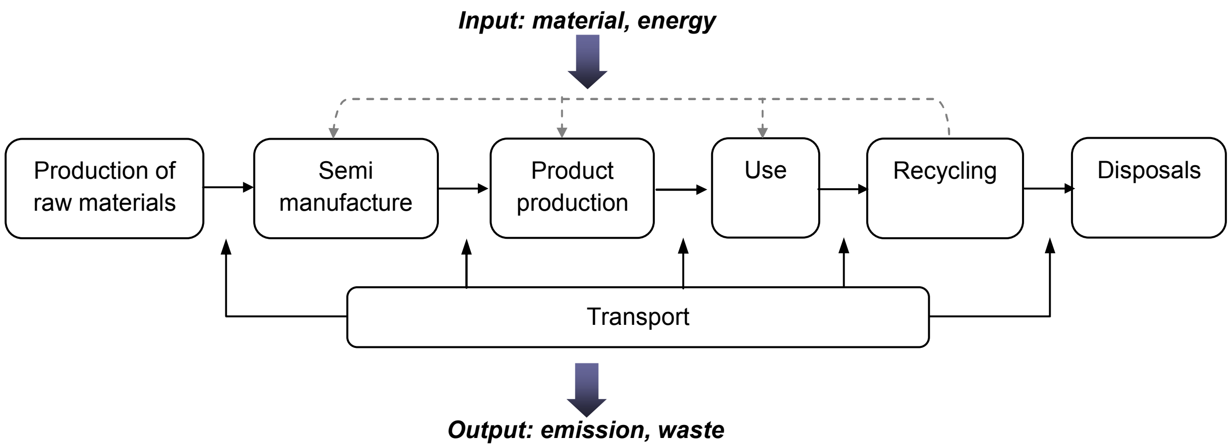

Figure 2.1: Product's life cycle

Based on the knowledge and information from the environmental profiling of the product, a company can establish an environmental policy, strategies or plan for improvement actions aligned with other management decisions such as market and commercial aspects. However, the POEMS manual of the Danish EPA aims to not only define the knowledge related to the product's environmental profile but also emphasise that POEMS is a base for extending improvement actions in overall corporate functions. According to Schmidt, Christensen and Øllgaard (2002), the procedure of implementing the life cycle approach is:

- *to create a picture of the significant environmental impacts and/or potential improvement in the life cycle,*
- *to prioritise environmental action on the basis of the knowledge and information, in accordance with the company's business strategies,*
- *to establish dialogue and cooperation in the product chain along identifying environmental impacts, exploiting the market potentials, and actual improvement,*
- *to develop policies and methods so that the various functions/managers can incorporate the product dimension in their daily work and ensure active involvement of the employees,*
- *to ensure that the product aspects are embedded in continuous improvement with a ongoing innovation system.*

2.3.2 Integrated approach

The integration of environmental management with product development is the main principle of POEMS. The Danish EPA explains that '*the purpose of incorporating the product dimension in real environmental management system is to ensure a product-oriented approach at the strategic (management) level in the company*' (Schmidt, Christensen and Øllgaard, 2002)'. As a result, Schmidt, Christensen and Øllgaard (2002) describe that the effects are expected as follows:

- *To increase environmental aspects in the marketing and business strategy,*
- *To save time and money,*
- *To avoid sub-optimisation in connection with measures to improve environmental performance,*
- *To ensure continual improvement at the product level as well,*
- *To use well functioning routines and documentation,*
- *To ensure communication and responsibility across the organisation*.

In conjunction with life cycle considerations, the great strength of POEMS is its flexibility in interpreting life cycle concepts for different corporate functional areas and specific purposes of environmental improvement. For example, life cycle thinking can be meant in EMS that the life cycle approach can contribute to a better understanding of which flows of materials and energy are most important, which would reduce the risk of sub-optimisation (Ammenberg and Sundin, 2004a). In this case, companies should improve cooperation in the entire supply chain, and the interaction between internal and external organisation can be a learning process by allowing other firms in the supply chain to reduce the impacts (*Ibid.*). The life cycle approach of POEMS can strategically support firms by providing overview of the environmental flows and increasing communication in supply chain.

In the design side, a POEMS approach offers a chance to broaden knowledge of the product including its financial aspects (Schmidt, Christensen and Øllgaard, 2002). Better understanding of consumers and cooperation with suppliers also can improve product quality and the satisfaction of consumers. In addition, various functions within corporate activities can be associated with product development. For example, designing a product for environmentally efficient use or for safe and effective end-of-life treatment require such information related to methods to reduce energy consumption in the use phase or technologies to decrease waste or emission in the disposal stage. Therefore, these functions and tools as seen in Figure 2.2 can be integrated in order to fulfil the objectives of environmentally sound product development within the POEMS framework.

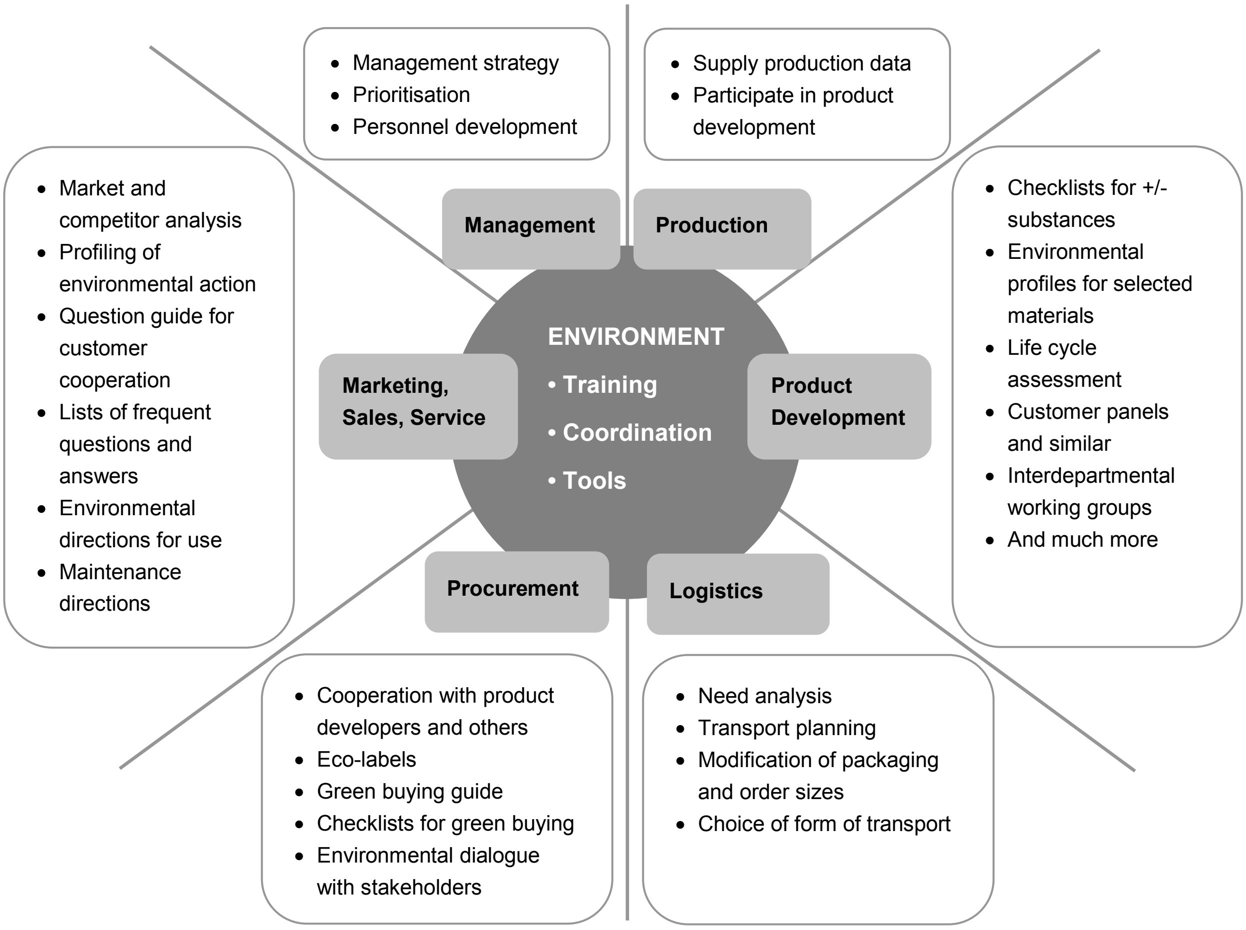

Figure 2.2: Functional areas and tools of POEMS (Schmidt, Christensen and Øllgaard, 2002)

Incorporating a product dimension in POEMS is aligned with not only environmental aspects but also other values of product's internal and external properties such as market or commercial aspects (see Figure 2.3). Some suggestions for product-related strategies in POEMS include LCA, eco-design, market potentials, benefits of a firm and its stakeholders, environmental purchase guidelines, green marketing, etc. Schmidt, Christensen and Øllgaard (2002) also suggest that companies can set up a goal in the product dimension combined with specific aspects such as eco-label acquisition.

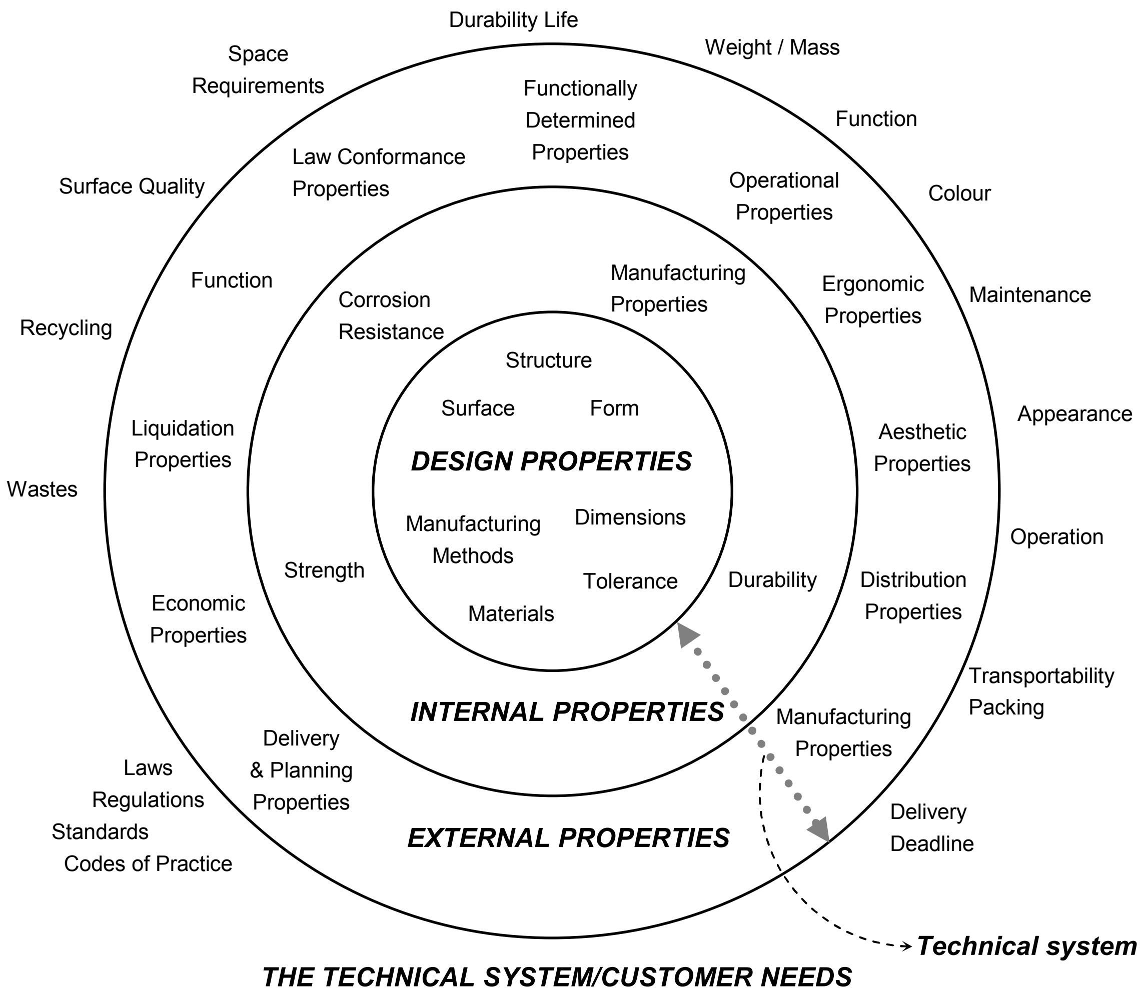

Figure 2.3: Relationships between classes of product properties (based on Hubka and Eder, 1988, Ammenberg and Sundin, 2004a)

2.3.3 Integrated supply chain management

Any environmental impact along the product's life cycle can be targeted in POEMS, which means that this tool aims to achieve integrated product chain management (Klinkers *et al*., 1999; Rocha and Brezet, 1999). Stakeholders in supply chain have a great influence to motivate the company to reach better environmental performance (Ammenberg and Sundin, 2004a). For instance, Rocha and Brezet (1999) state that the company participated in an eco-design project is supplied 70 -80% of 'bought-in components'[1] from its suppliers. Regarding this, environmental profiling of the product defines not only environmental impacts but also many other requirements affecting the firm, for instance, regulation compliance, customers' demand or third parties' expectation, and so on. Thus, maintaining a good relationship with stakeholders is considered in POEMS. For this, the company must have close communication and collaboration with its suppliers.

Integrated supply chain management became an important part of strategic environmental management in POEMS. When trying to gain an insight into the environmental impact of a product in the life cycle perspective, chain analysis is essential, which translate the results of the impact analysis into measures or change that the company can implement within its practice (Klinkers *et al*., 1999). For instance, UNEP (2004) states that an organisation's procurement policies and procedures are effective routes that provide opportunities to work with suppliers in life cycle management (LCM) because supply chain management is a typical issue and already on the agenda of most companies. Enterprises originally manage suppliers in order to optimise the supply chain, track flows of information, materials and

[1] Components (or subassemblies) that are pre-made by and purchased from outside suppliers instead of being made within a company.

funds, manage the logistics of supply and distribution, minimise cycle times and costs, and integrate processes and functions along the supply chain (Sanchez, 2003, cited by UNEP, 2004). The frameworks of both LCM and POEMS have the common ground such as life cycle thinking in full system of supply chain, integrated approach, and continuous improvement. In this regard, the traditional management of supply chain can be transferred to not only LCM but also POEMS. In particular, a collaborative approach along the supply chain for a product's environmental profiling can be effective in improving the environmental performance of the product as well as the product chain.

Furthermore, customers increasingly ask their suppliers to share information about products such as materials and substances, and systems for tracking and management of environmental impacts (UNEP, 2004). This close system and culture between suppliers and customers sharing information can spread through the supply chain. This is called a learning process by which a leading company can improve the performance of up- and down-stream suppliers by collaborating on programmes, tools and efforts, which the understanding of environmental impacts of supply chain can be extended into other parts of the company to begin a more comprehensive and integrated life cycle management approach (*Ibid.*). There are suggestions from studies (Johansson, 2002, cited by Ammenberg and Sundin, 2004; Brezet and Rocha, 2001; Hunkeler *et al*., 2004, cited by UNEP, 2004) on how to deal effectively with supply chain management. These include a strong customer focus such as education of customers in environmental issues, interactive relationship with suppliers as part of eco-design activities, information sharing with customers, and setting up demands of information on suppliers.

2.3.4 Increased communication and cooperation

The scope of POEMS is based on the product life cycle approach which covers almost all relevant areas in the product chain as illustrated in Figure 2.4. Therefore, more stakeholders can be involved in a decision making process of reducing environmental impacts of a product than any other production/process oriented tools (e.g., EMS, cleaner production) could (van Berkel, van Kampen and Kortman, 1999, cited by De Bakker, Fisscher and Brack, 2002). In its extended approach, a company may find where the environmental impacts come from and who is involved in the process. When the company decides to solve the problem, they need to incorporate internal departments, in particular those directly related to product development, also external stakeholders in the product chain (Schmidt, Christensen and Øllgaard, 2002).

The elements around the left side of circle in Figure 2.4 represent a traditional approach of the organisation-oriented environmental management that the various departments in a company are usually involved in an ad hoc-basis projects (*Ibid.*). Some elements such as customers may be incorporated in the activities of this approach. However, the main focus is still on the environmental impacts in the 'production process' (*Ibid.*). The right side of circle in Figure 2.4 represents the product-oriented environmental approach of POEMS. In this approach, most of the departments in the company can more actively participate (*Ibid.*). External determinants such as market demands and a wide range of stakeholders can be handled in the strategies of the product's life cycle (*Ibid.*). Thus, extended cooperation and communication in the product chain are more required in POEMS. However, it may hard or unnecessary to reach the whole suppliers in the product chain when a company attempts to initiate POEMS project for the first time. In this case, a dialogue with its close and direct suppliers and customers will be expected (IPU/DTC, 2005).

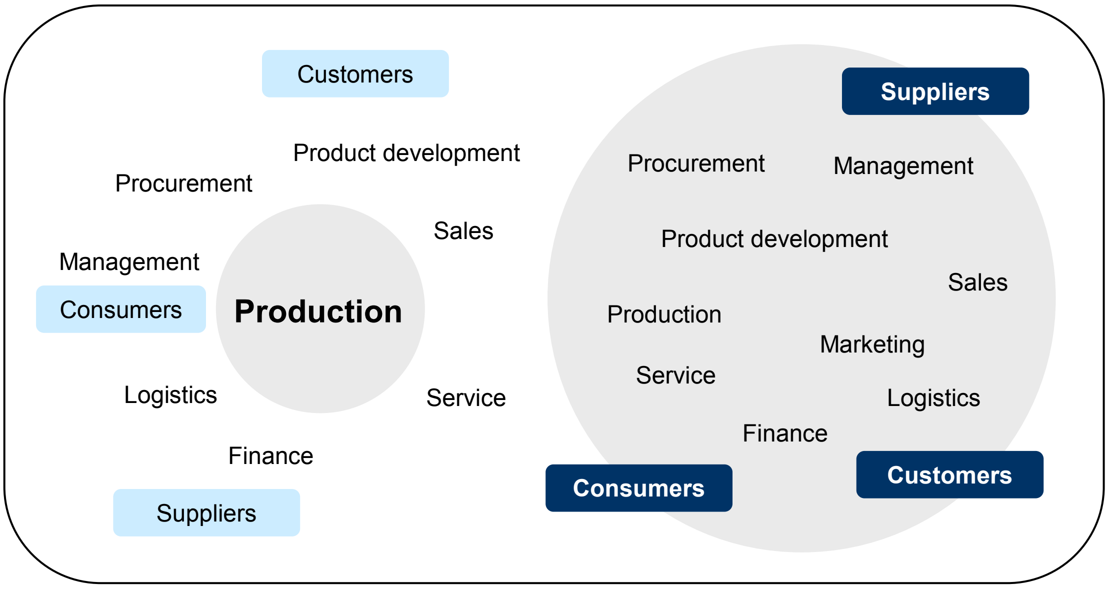

Figure 2.4: From company-oriented to product-oriented environmental management (Schmidt, Christensen and Øllgaard, 2002)

2.3.5 Continuous improvement and routinisation

Ammenberg and Sundin (2004a) address that ongoing improvements in environmental performance is a key commitment for an organisations using EMS. However, as environmental performance varies to a great extent, better understanding of how to apply the requirements for continual environmental improvement into product development is needed (*Ibid.*). In order to avoid discontinuation of environmental improvements, long-term strategic and organisational change that guarantees strong management support needs to be assured by which the whole process of environmental improvement should be formalised within the management system.

For instance, ensuring the continuous improvement can be achieved first by a mutual commitment to product and product chain improvements in an organisation. For this, the company may announce an environmental statement and disseminate the environmental policy and objectives in the organisation. Secondly, audits and measure of environmental performance need to take place in regular basis (*Ibid.*). Thus, a stable ground to proceed to fulfil the environmental policy and goals (e.g., strategic environmental management) can be settled within the business routine. Thirdly, the strategic management should embrace eco-design activities within the operation and practice, and the outcome and feedback is taken in the regular assessment. Strategic integration with other business policy could influence on keeping motivated toward sustainable business. For example, UNEP (2004) notes that '*often a good link between the environment and the market is what it takes to keep POEMS a continuous effort. Therefore, the environmental assessments should be complemented by analyses among the interested parties and market assessments*'.

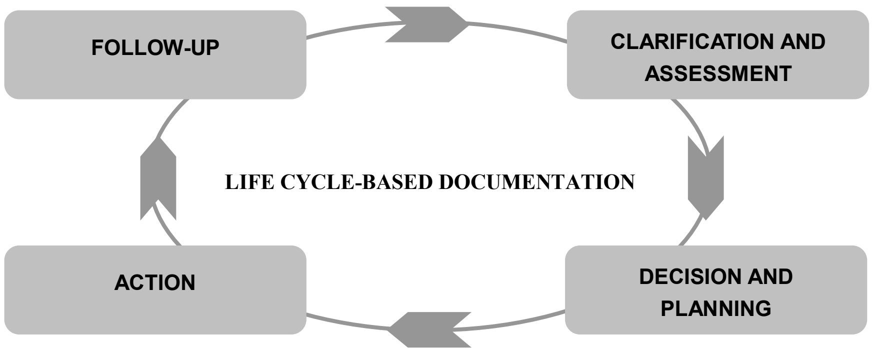

Figure 2.5: A continuous process circle (Schmidt, Christensen and Øllgaard, 2002)

The Danish EPA's POEMS manual (Schmidt, Christensen and Øllgaard, 2002) states that the process of continuation in POEMS is ideally systemised by life cycle-based documentation consisting of evaluation, planning, action and follow-up, with the follow-up leading to new evaluation, decisions and action (see Figure 2.5). From these POEMS studies (Ammenberg and Sundin, 2004a; Ammenberg and Sundin, 2004b; De Bakker, 2002; UNEP, 2004), the following actions in POEMS could influence continuous improvement of environment:

- Investigation of a company's strengths and weaknesses
- Establishment of clear goal and appropriate strategies
- Allocation of teams and experts
- Set up of procedures and principles
- Check of detailed requirements
- Monitoring and tracking of environmental performances
- Assessment and audits of implementation
- Clarification of results of success or failures
- Investigation of key reasons of successful or failed results
- Feedback to management and operation
- Feedback of the final assessment into internal and external organisation
- Selection of next level of goal or sub-goals from the first level of the goal
- Iteration of performances above

2.3.6 Education and training of human resource

Due to the diverse nature of company businesses especially in SMEs, an allocation and involvement of internal staff as well as external partners are significant when implementing POEMS. Ammenberg and Sundin (2004a) argue that an EMS is generally designed and administered by environmental managers and to the extent such a system reaches different groups of employees greatly varies amongst companies. A product design department would be directly affected by this approach. Despite growing attention to an integrative manner of eco-design concepts in EMS, the main problem has been seen in the poorly developed interface between environmental management functions and departments for R&D (*Ibid.*). It may have a relation to a lack of knowledgeable staff and mutual understanding between departments. It is also found in the fact that designers are not familiar with the language used in eco-design tools in particular when technical experts are engaged. Therefore, running a regular course for education and training as well as cross-functional team work will be important before initiating a POEMS project.

2.4 Structure and process of POEMS

POEMS has been known for very short period of time, and then only within a few countries, and is still at an initial state of theoretical and methodological development. It is assumed that there is no generalised form or structure of POEMS so far. This is shown by the fact that POEMS approaches are largely different depending on researchers or practitioners. Moreover, only limited number of POEMS studies has been conducted and most of them have modified different methods and tools in particular an EMS process. Therefore, it is hard to define a clear structure or definitive form from the existing POEMS models. Therefore, it is reasonable to revise the key methods adapted in POEMS in order to understand its structure or procedure. In this review study, 18 relevant studies[2] are chosen, and reviewed in terms of what methods they have taken and how the processes or

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[2] Ammenberg and Sundin, 2004a; Ammenberg and Sundin, 2004b; Baas, 2002; Baumann, Boons and Bragd, 2002; Brezet and Rocha, 2001; Charter and Clark, 2002; de Bakker, 2002; de Bakker, Fisscher and Brack, 2002; de Graaf, 2002; IPU/DTC, 2005; Klinkers *et al*., 1999; Pinkse and de Graaf, 2002; Rocha and Brezet, 1999; Ries, Winkler and Züst, 1999; Schmidt, Christensen and Øllgaard, 2001; Schmidt, Christensen and Øllgaard, 2002; UNEP, 2004; van Berkel, Van Kampen and Kortman, 1999

structures have been formed into POEMS. The key processes or structures adopted by existing POEMS studies are categorised into Deming cycle (so called, PDCA cycle), integrated models between PDCA and eco-design, preliminary stage-focused programmes, integrations of POEMS in product chain management, and modifications of quality management to POEMS. The following sections explain the details of each category.

2.4.1 PDCA cycle-based POEMS with eco-design

The PDCA (plan-do-check-act) method is known as the Deming cycle from the name of its developer, Dr. W. Edwards Deming. PDCA is an iterative problem-solving process consisting of four steps, and initially adapted in quality management. This PDCA model is for continuous improvement of quality control through the learning process. In brief, to 'plan' aims to improve operations by identifying problems and establishing objectives and processes necessary to deliver results. To 'do' is to execute the plan and take sub-steps in the processes, which extend the knowledge. To 'check (or study)' is to monitor and evaluate the defined processes and results. Finally, to 'act' aims to correct and improve the plans or processes, and then standardise the process.[3] PDCA is supposed to be repeatedly implemented in spirals of expanding knowledge of the system. Since the PDCA cycle has been applied to international quality management standards such as ISO 9001, this circular tool became the overall framework of management standards including environmental management standards, ISO 14001.

Amongst the POEMS models reviewed here that have a management structure or process, more than half of them are based on the PDCA method. For instance, Brezet and Rocha

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[3] For further information, see: 'Out of the crisis' by W. Edwards Deming (1986).

(2001) have developed a POEMS model with a combination of EMS and DfE processes, which the structure of the model relies on the Deming cycle of ISO 14001 (see Figure 2.6). The procedure of the POEMS model suggested by Brezet and Rocha (*Op.cit.*) combines a operational cycle oriented to the improvement of products' feature through eco-design (the sequence in the centre of Figure 2.7) and a managerial cycle to provide the managerial support for eco-design (the sequence on the left side of Figure 2.7).

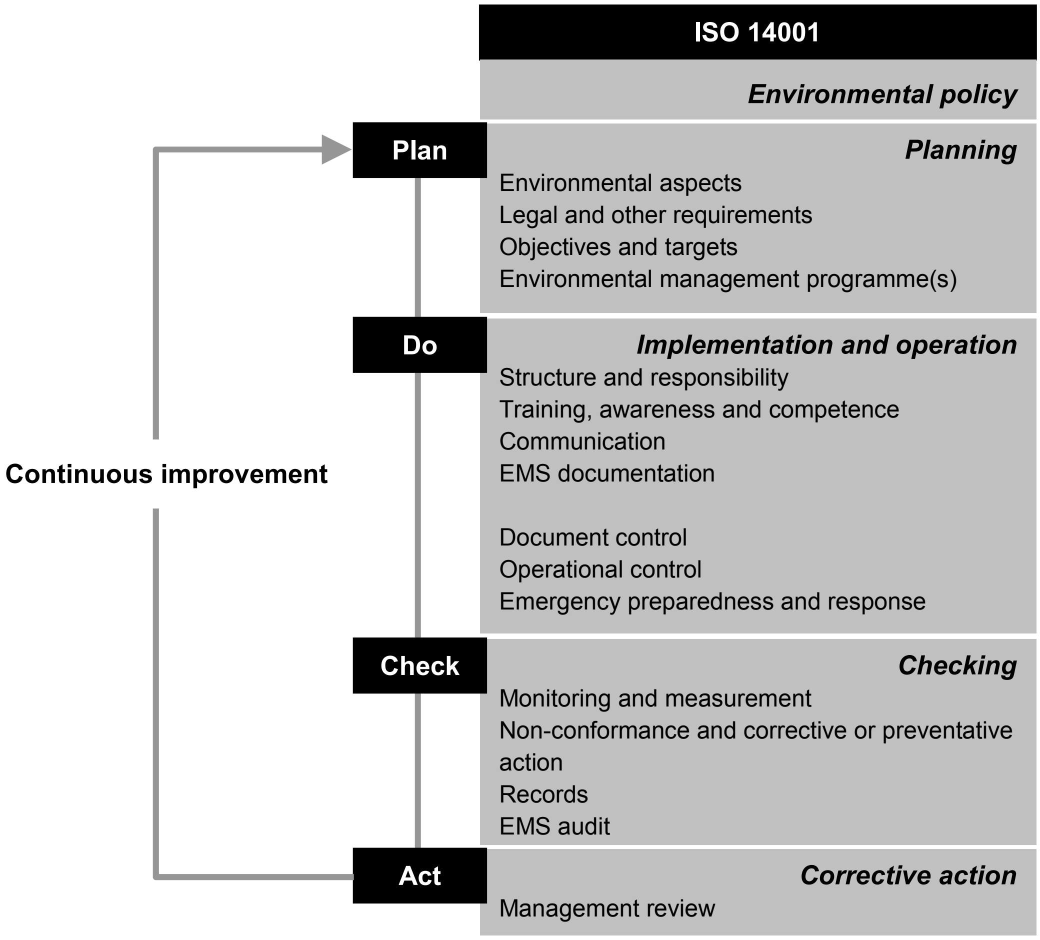


Figure 2.6: The continuous improvement cycle and ISO 14001 requirements (Brezet and Rocha, 2001)

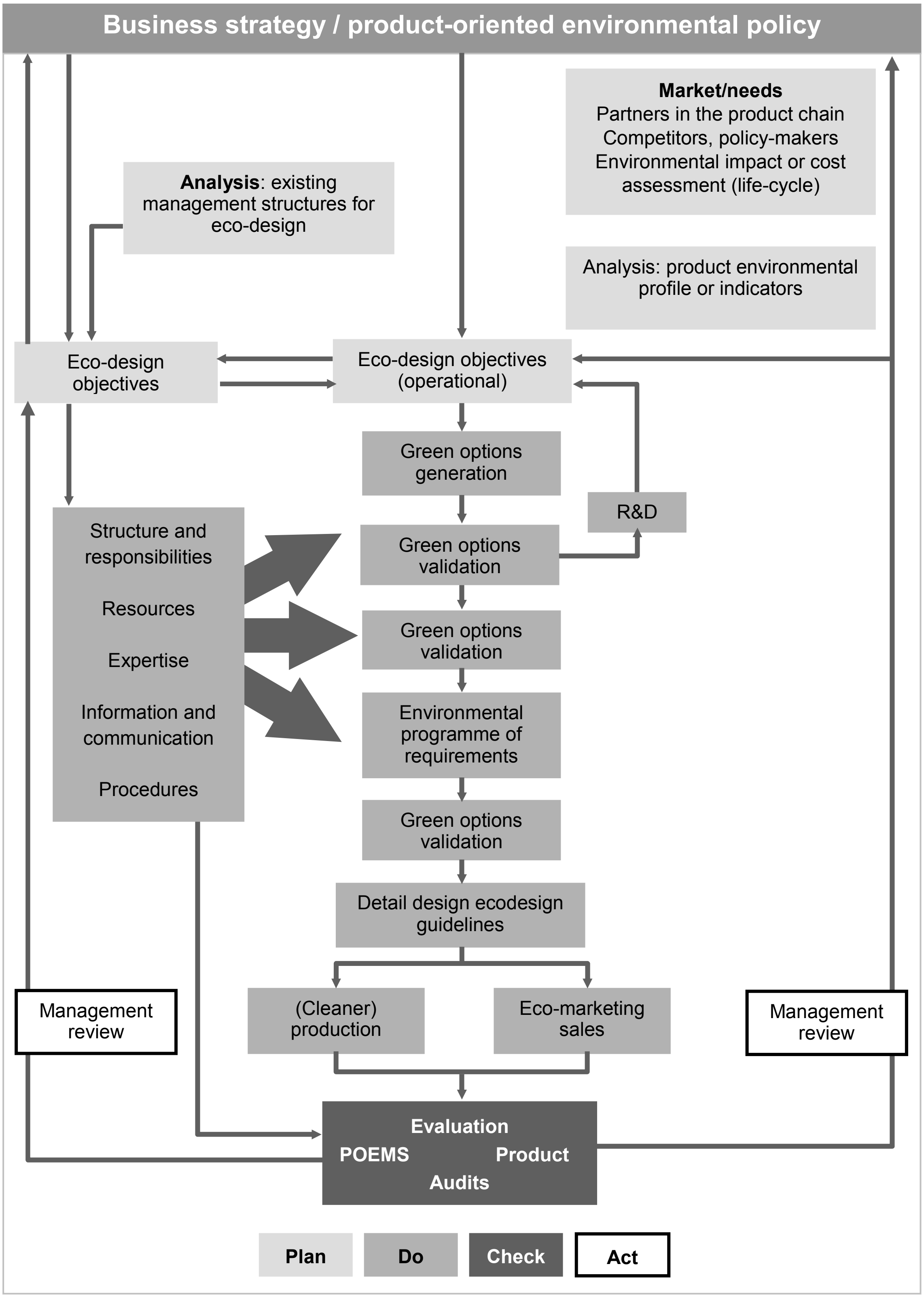


Figure 2.7: POEMS model (Brezet and Rocha, 2001)

In Figure 2.7, the ‘plan phase’ is to establish a business strategy with a dimension of environmental value crystallised in product-oriented environmental policy. In this part, product-oriented environmental policy should provide a framework for objectives for environmental improvements in the relevant areas and stages of the product’s life cycle. The primary stage of the POEMS cycle, the plan stage in Figure 2.7, analyses the current situation of the company including market demand and environmental requirements of the product. In general, the environmental profile of the product is initially established by using LCA tools (Brezet and Rocha, 2001).

The ‘do’ phase indicates the operational cycle that is directly related to the product development processes, in which environmental options are generated and their validations are carried out. Separate R&D projects may be conducted when more accurate information and technologies are not available or cannot be translated directly into the environmental programme of requirements (*Ibid.*). In the POEMS implementation, the managerial part needs to be considered in order to build capacity for eco-design for example in order to, for example, allocate appropriate resources, assign responsibilities in the adequate structure, build expertise (training and tools), and promote internal and external cooperation and communication (*Ibid.*).

Finally, the ‘check and act’ phase aims to review the process and address a plan of future directions. Depending on the results of the evaluation of the improved product, corporate willingness for further improvement, and its changing environment for continuous improvement, the company would change its corporate environmental policy, objectives and/or other elements of the POEMS (*Ibid.*). Brezet and Rocha (*Op.cit.*) summarise the core elements of this POEMS as follows:

- *The consideration of the eco-efficiency of the company's products at a strategic level through definition of an environmental product policy,*
- *An evaluation, on a regular basis, of the environmental performance of products (throughout the life-cycle),*
- *The consideration of environmental criteria in product development processes,*
- *The formulation of goals to ensure that, in addition to compliance with environmental regulations, the company continuously improve the eco-efficiency of its products, in co-operation with other companies of the product chain.*

Similar approaches have been found in the review study, for instance, 'Four-step POEMS' (Ammenberg and Sundin, 2004a), 'PEC combined with product chain management' (Klinkers *et al*., 1999), and the Danish EPA's POEMS programme (Schmidt *et al*., 2002). The POEMS structures of the studies above basically follow the PDCA procedure of ISO 14001. However, it was found that only a few POEMS models actually integrate and define relatively clear eco-design criteria in the process although most of them address products' environmental profiling. Unlike what POEMS intends, the integrative approach of POEMS with the eco-design flow has not been sufficiently explained and demonstrated. Thus, how the management side of POEMS strategically support eco-design is unclear.

2.4.2 Preliminary approach before POEMS implementation

Some POEMS models focus on a preliminary stage and merge other methods such as SWOT (strengths-weaknesses-opportunities-threats) analysis or the AIDA (attention-interest-desire-action) model in order to identify a company's or sector's specific interests or capability for POEMS implementation.

First example of the preliminary work is based on the ground theory of Dutch POEMS, which an application project was conducted by BECO group (Baas, 2002). This preliminary phase of POEMS is combined with SWOT (strengths, weaknesses, opportunities, threats) analysis. The key concept of the project intends to develop a sector-specific POEMS model – Dutch plastics recycling industry in this case – by identifying the position and opportunities of the sector using tailored SWOT analysis. Baas (*Op.cit.*) summarises the five-step process of POEMS incorporating the SWOT, which consists of: establishment of project objective and teams; preliminary investigation of the company through tailoring the general SWOT tool and product profile; execution of finding additional information on environment or market related issues, and setup of a programme of requirements for new product development; checking and improvement of alternatives with necessary R&D work; embedding of timeframe for further action, preparation for production and market, and evaluation of the project or potential integration of the requirements from the project into other management systems.

Main activities of step 1 are for preparation of a POEMS project that builds up management support, allocation of resources, and project objectives and plan.
Then the second step conducts investigations of a general SWOT analysis to the participated companies and it intends to identify new market opportunities and encourage them for environmental innovation. It mainly includes environmental profiles of their products, which helps select target areas. Therefore, the main activities of this stage cover

organisational performance in the sector in terms of the environmental perspective, assessment of their products' environmental impact, and identification of potential market and targets for improvement.

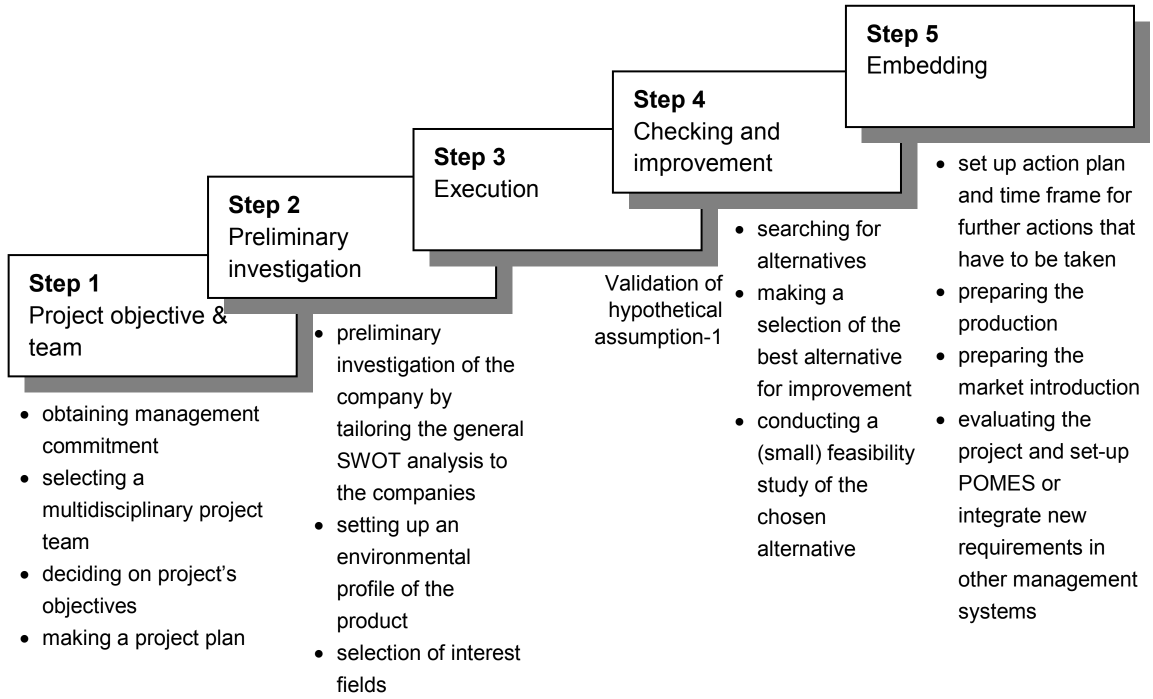


Figure 2.8: POEMS for the Dutch plastics recycling industry (Baas, 2002)

The third phase executes the programme for new product development or new market initiatives. It may require additional information on environment and/or market related issues. In this case study, the programme is regarded to concentrate on product development or market cultivation considering that the potential market of reuse of the recycled plastics is the major concerns for the Dutch plastics recycling industry. The fourth step of checking and improvement carries out the improvement based on the data from the previous stage. Seeking options for improvement and selecting the best alternatives are the major activities. It might need additional R&D to take a test of feasibility of the selected options. This step is recognised as a part of eco-design activities. The fifth stage of embedment has several main branches that firstly carry out the production and subsequently market introduction, evaluation of the project, and finally setup of full POEMS project or routinisation that integrate new requirements into existing management system.

This POEMS model shows possible benefits of using preliminary phase of SWOT analysis in order to explore motivations of implementing POEMS as a starting point of environmental improvement. However, some questions remain. For example, whether the information is applicable to other sectors or companies as the main focus of the project for the Dutch plastics recycling industry could be the material or energy of plastics. Whether an individual SME can implement POEMS without the sectoral support and a common ground of information and knowledge. The details are explained in Chapter 3.

In another example, De Graaf (2002) introduces a preliminary programme, namely, AIDA (attention-interest-desire-action) model. Recognising the difficulties for SMEs in understanding the concept of POEMS and in utilising it for business practices, a research project was conducted by BECO group in order to develop the AIDA model. This project focuses on the preliminary research to prepare all stages of POEMS process for its successful implementation.

The research project started with development of AIDA model and tested it in eight volunteer companies. Then, the tested AIDA model was incorporated in POEMS. Procedure of the initial AIDA model consists of four steps, i.e., attention, interest, desire, and action (see Figure 2.9). In the attention step, the research group focused on communication with participant companies in order to introduce POEMS. In the interest step, the companies express interest areas of POEMS. The desire step generates the companies' particular expectations such as potential benefits through implementation of POEMS. The final step, action, shows required activities of POEMS.

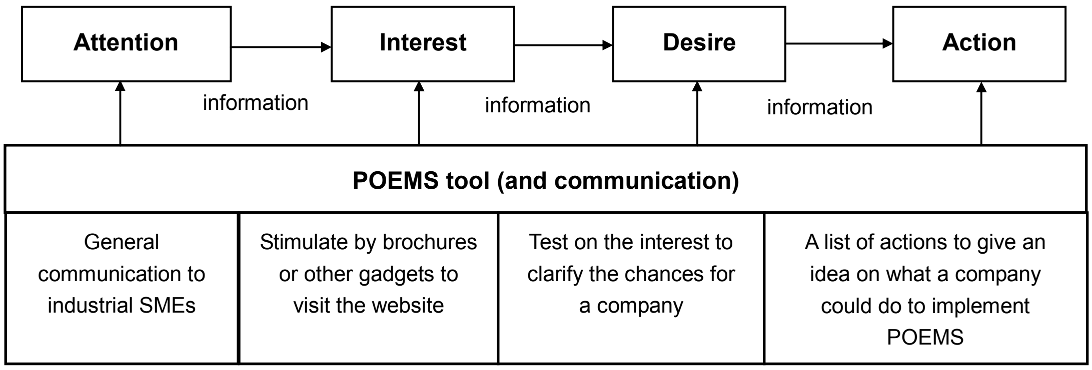


Figure 2.9: Relation between the POEMS tool and the AIDA model (De Graaf, 2002)

After the companies go through the preliminary project of AIDA in order to figure out potential benefits and required fields of performance, a POEMS project can be launched. The project has three steps, i.e., analysis, development and review. This POEMS model has a relatively simple structure as the most work concentrates on initial preparation for implementing POEMS and, thus, mainly handles communication with companies in terms of their interests, and dissemination of POEMS concept among them.

From the experiences with dozens of SMEs that participated in preliminary POEMS projects, De Graaf (2002) summarises the results. First, the outcome of the introductory programme for promoting the POEMS concept in the target group can specify requirements for a further POEMS project. For this, second, close communication and cooperation among people involved in the project are necessary. For instance, feedback from the participant companies was gathered by the researchers in the way of project description and evaluation, and identification of other tools to use. Third, this work is dedicated to tailoring the general POEMS concept and strategies into the corporations' specific needs and conditions. Through this stage, a POEMS model in concept stage can be streamlined.

This POEMS approach integrated with the AIDA model has a possibility of sector- or company-specific model development. It could provide a broad view of corporate environmental activities in a simple way. The project emphasised sufficient communication among the POEMS tool users and encourages them to establish a cooperative environment. Moreover, the preliminary work has a strong advantage to build up a capacity of a company undertaking POEMS more smoothly.

However, this research has not expressed enough in examining the potential applications of the product development process and other required or relevant POEMS elements. Instead, this tool has shown a particular focus on the communication among actors in supply chain at the expense of core work of POEMS such as building strategic support or integration of product aspects, elements which might be veiled. Therefore, it still remains how the experience of the preliminary model can be linked to green product development. The details and further argument are presented in Chapter 3.

2.4.3 Integration of POEMS in product chain management

One of the topic areas of POEMS is product chain management, which promotes good standards of environmental and social governance within the supply chains. A POEMS study provides a possibility of how this tool can be integrated in the product chain system. Klinkers *et al*., (1999) suggest product-oriented environmental care (PEC) and discuss product-oriented environmental improvements in three aspects; a product-oriented policy approach, a chain-oriented approach, and PEC integrated with chain system. This study particularly introduces the PEC model and integration process of the PEC with supply chain system.

Product-oriented environmental care (PEC) model:

Klinkers *et al*. (*Op.cit.*) introduced a product-oriented environmental care (PEC) model as seen in Figure 2.10 and a six-phase process of PEC integration into the chain system. The six-phase process of PEC integration can take place from the fourth phase as illustrated in Figure 2.11.

(1) PEC manual integrated with EMS:

The integrated PEC method consists of eight steps within four categories of the Deming cycle (plan-do-check-evaluate) in Figure 2.10. The summary of the Deming process of the PEC model is presented below (*Ibid.*):

- *Plan: this might involve drafting and reviewing the environmental policy (products), drafting an environmental programme and determining goals and tasks,*
- *Do: this includes process control, implementing the environmental programme, conducting an integrated chain analysis, making resources available and determining and maintaining registrations for monitoring,*
- *Check: this includes monitoring, inspections and may, for instance, involve internal and external audits,*

- *Evaluate: specifically, evaluations and reports, improvement options and corrections are given attention*.

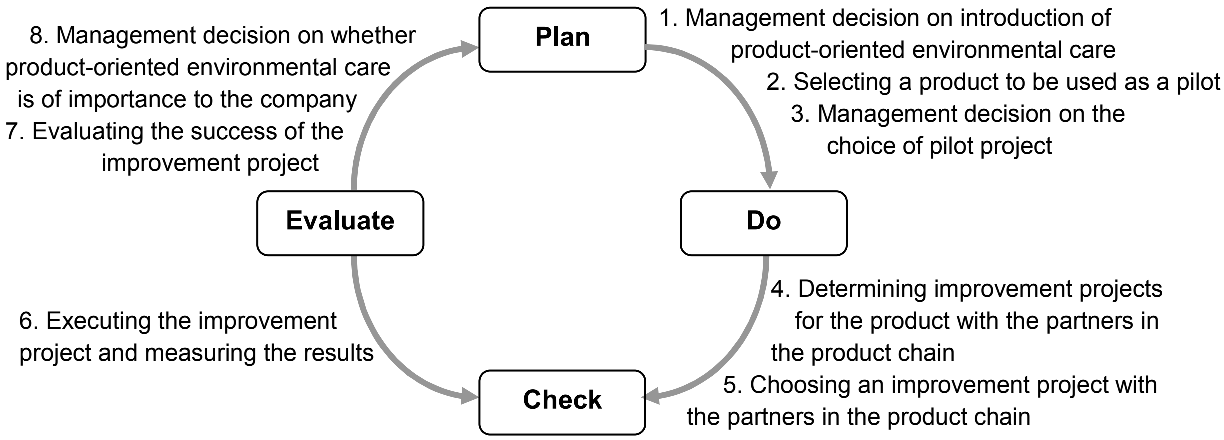


Figure 2.10: The eight-step plan for implementing product-oriented environmental care is a management cycle (Klinkers *et al*., 1999)

For the companies with a rare experience in this type of management system, the authors claim that PEC can still be initiated with a strong suggestion to use the management cycle of PDCA. The eight-step plans can be repeated along the management cycle, but the quality of the activities must be followed by and incorporated into procedures and instructions (*Ibid.*). For the companies that already have a management system, Klinkers *et al*. (*Op.cit.*) describe that quality and environmental management systems are mainly related to this process, while PEC is product-bound. Therefore, the companies in this group need to incorporate product aspects into the process aspects of existing management systems. For example, on the management side, under the 'ISO 14001 system'[4], a

[4] The authors supplement the basic structure of ISO 14001 as follows. "*ISO 14001 is the internationally accepted standard for environmental management systems. It defines an environmental management system as 'that section of the general management system of the company that relates to organisation, planning,*

company may start with policy setup; objectives, tasks and an environmental programme in detail, and then evaluate the achievement. Subsequently, corrective actions lead another management cycle again. On the product side, PEC can be interlinked with the ISO 14001 system using assessment tools such as LCA and/or qualitative assessment of products and product chain, which also create feedback for the adjustment of the existing format of the ISO 14001 measures.

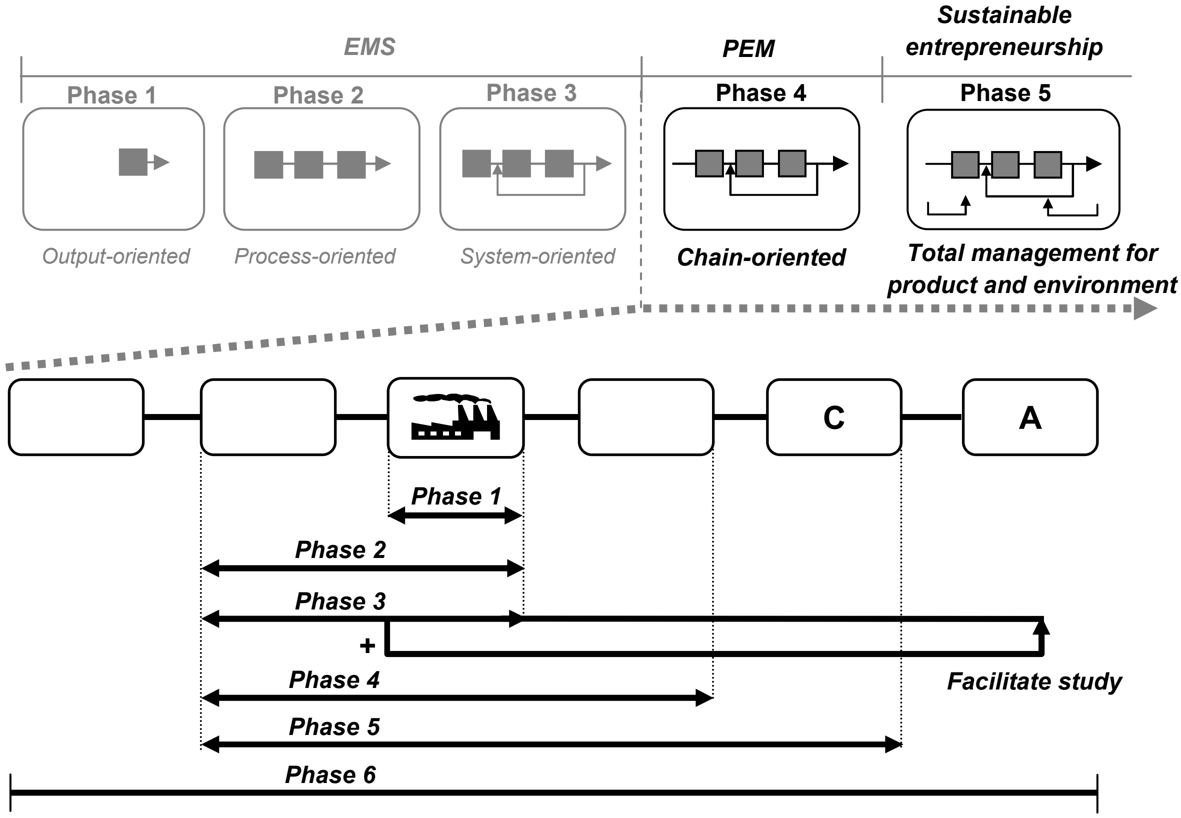


Figure 2.11: The six phases of product orientation within PEC (Klinkers *et al*., 1999)

(2) A process of six-phase PEC integration into chain system:

Although all types of companies can implement PEC and indeed some have already partly adopted certain aspects of PEC as logical supplement to environmental system, the authors

procedures and tools for the drafting, implementing and evaluating environmental policies of the company' (Klinkers *et al*., 1999)."

pinpoint how enterprises delay reducing the environmental burdens of a product or service until their internal environmental care is in order. Also, the authors remarked that a systematic approach of environmental improvement is strongly related to the internal and external management of the organisation in relation to chain system, and there are benefits of integrating PEC into the chain management. In this regard, Klinkers *et al*. (*Op.cit.*) suggest a six-phase process of product orientation of PEC integrated with the chain system, which can be considered in the fourth phase of the sustainable business (see Figure 2.11).

In brief, the six phases are mainly connected to other developments and tend not to stem from environmental motives with the fact that companies may search the chain not only for environmental aspects but also for potential quality improvements, product developments, and cost reductions (*Ibid.*). Key issues of the six phases are summarised in Table 2.2.

Table 2.2: Six phases of PEC integration in product chain (key issues summarised and reorganised from Klinkers *et al*., 1999)

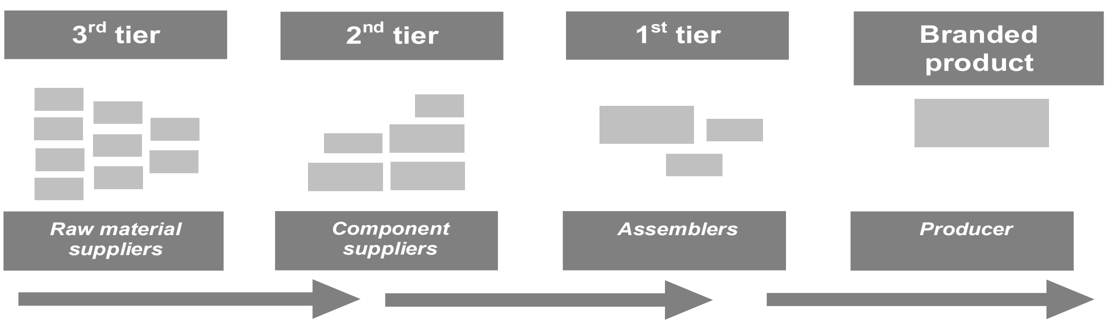
	Aims and actions in integration of PEC in the product chain
Phase 1: PEC within the company	**Aims:** • Environmental measures for improvement of the product process, other possibilities to increase the efficiency and continuation of environmental improvement • PEC integration within and outside the company in strategic, tactical and operational levels. **Actions:** • Chain analysis and translation of the analysis results into measures or changes within production process or product design • Decision-making on purchasing such as the quantities of materials or components, and wasted and possible alternative materials based on the analyses • Marketing decisions integrated with PEC policy on product range, price or quality • Reinforcement of internal communication to overcome the distinction between the areas

	of environmental care/quality/safety and the sales departments, product development and marketing departments • Significance of the company management outlining a policy for the various functions and departments working towards a common goal • Internal communications with great importance in external integration
Phase 2: One step backwards in the chain	**Aims:** • The first steps outside the company **Actions:** • Assessment of suppliers in order to judge quality, price level, service and punctuality. • Dissemination of environmental issues • Intensified communications with suppliers about substances of products, identification of environmental care system and possible substitutes with a more environmentally sound variants • Establishment of ecologically preferable purchasing process
Phase 3: One step backwards and forward orientation	**Aims:** • Forward orientation to the sector such as by the obligations related to product stewardship, full responsibilities for the products in life cycle **Actions:** • Usage of product-safety datasheets providing information on the product use, potential risks during product use, personal safety measures and substances of the product • Additional research in the chain. • External communication providing relevant information
Phase 4: One step backwards and one step forwards	**Aims:** • Combining the previous two steps – phase 2 and 3 • Addressing chain aspects systematically rather than piecemeal **Actions:** • Search for opportunities in all areas for collaboration in the chain to obtain best results • Decision-making on chain-oriented thinking and the use of development in the chain
Phase 5: The chain emerges	**Aims:** • Developing the first chain layer further to the second and third tiers of the whole 'supply hierarchies'[5]

[5] Production lines may be developed by several tiers of suppliers. Figure 2.12: The basic structure of supplier layers of product lines (Martin, 2005), illustrated as follows:

	Actions: • Institutionalisation of supply chain management • Appointment of a person responsible for the chain, preferably someone on the company's management team, whose job it is to acquaint themselves with the developments in the chain and to judge what opportunities are offered to the organisation
Phase 6: The chain is covered	**Aims:** • Cooperation between all parties in the chain system **Actions:** • Regularly conferring with consultative bodies and/or platforms with all links in the chain about new developments • Creating a stronger position together, with respect to comparable sectors or products fulfilling the same function

This incorporative approach of product orientation from environmental management to chain system shows the extent to which the life cycle principle with continuous improvement by POEMS can be interpreted to chain system management. The authors developed not only the procedure of POEMS with eight-step process but also addressed the key aspects of POEMS integration within chain system. Therefore, a company can establish and manage its own system of POEMS in the product chain. As most companies are relatively more familiar with chain management than POEMS itself, the integration of POEMS and product chain could be a medium for smoother implementation of POEMS.



2.4.4 Modification of quality management to POEMS

Among the POEMS studies, De Bakker (2002) developed a POEMS model (named as POEM by the author) from total quality management (TQM). The author believes that a coherent set of several elements from TQM can contribute to composition of a POEM model and has modified TQM to fit into a POEM matrix. This application may provide guidance in developing the environmental characteristics of products and in organising an integrated perspective on the organisational elements for designing a POEM model. For the reason to modify TQM for a new POEM, De Bakker (*Op.cit.*) suggests common traits between the two methods and lists the benefits from their integration as follows:

- *Both management concepts concern products and processes. This makes quality management a suitable basis for investigating POEM, because both are concerned with such integrated approaches,*
- *Both concepts are aimed at prevention, working toward a more proactive attitude, for example, through continuous improvement,*
- *Both concepts apply a chain perspective, looking beyond the borders of the individual firm into the product chain,*
- *Technological and organisational changes are important in both management practices, while both concepts aim to go beyond the mere development of tools,*
- *By using insights from quality management in POEM, firms could be more open to POEM-like ideas, because most firms are already aware of the principles of quality management,*
- *Both management concepts could apply the idea of 'stretching goals' (Hamel and Prahalad, 1994, Cramer, 1997, cited by De Bakker, 2002). A substantial misfit is deliberately created between a firm's quality or environmental*

competencies and objectives in order to encourage substantial improvements in performance.

De Bakker establishes organisational models of TQM before developing a POEM model. The author adopts the approach by Spencer (1994, cited by De Bakker, 2002) of bridging the gap between TQM practice and management theory that examine the relationship of TQM in three types of organisational models in management: mechanistic, organismic and cultural. De Bakker (*Op.cit.*) summarises the main concepts of three models. The *mechanistic* models can be regarded as approaches in which efficiency, conformity, and compliance are important (*Ibid.*). The *organismic* models can be characterised as contingency approaches, indicating that the organisation's situation dictates the correct management approach (Daft, 1998, cited by De Bakker, 2002). Finally, the *cultural* model, which is associated with the elements of communication, commitment, motivation and reflects in lower level in the organisation in concert with the corporate vision and goals (Chaffee, 1985, cited by Ikävalko and Aaltonen, 2001), resembles a more constructivist approach, which aims for employee satisfaction rather than customer satisfaction (De Bakker, *Op.cit.*). De Bakker (*Op.cit.*) states that these models broaden the traditional customer focus in quality management into stakeholder focus.

With these three models, De Bakker (*Op.cit.*) claims that cross-fertilisation between different approaches is more fruitful than strict adherence to one model. With respect to this interdisciplinary approach, the author defines the instrumental and technical aspects of the models into 'the system-technical elements', and organisational and cultural aspects of the models into 'social-dynamic elements'. Although a purely technical approach of TQM (the system-technical approach) tends to ignore the social-dynamic (organisational and cultural) aspects of such processes of change, an integrative way of thinking is inherent to TQM and might also benefit POEM (De Bakker, 2002). Using the cross-functional interpretation of the management models, the author illustrates four dimensions and elements of a TQM matrix in Figure 2.13.

TQM	***System-technical organisation***	***Social-dynamic organisation***
Operational level	• Quality management systems • Control techniques/data-driven processes (management by fact) • Budgeting	• Communication and consultation • Motivation and commitment • Team building • Increased (quality) training
Strategic level	• Planning/strategic orientation • Division of tasks, responsibilities, and authorities • Vertical deployment	• Shared norms and values • Dynamics in decision making • Employee empowerment • Leadership • Supplier partnerships

Continuous improvement
Teamwork
Customer focus

Figure 2.13: Total quality matrix. TQM (De Bakker, 2002, adapted from Fisscher, 1994)

As TQM claims that improving quality can decrease costs and facilitate the attainment of other demands and objectives (Spencer, 1994, cited by De Bakker, 2002), getting a firm to control not only its products' technical and economic performance but also the environmental performance could make a valuable contribution to both quality and environmental management (*Ibid.*). Thus, such environmental characteristics can be regarded as elements of product quality (*Ibid.*). TQM can be extended into total quality environmental management (TQEM). TQEM broadens a view of environmental performance from production processes or operations management, item upon which traditional EMS mainly focuses, towards the product life cycle in strategic approaches, which look beyond operational measures and encompass various issues such as product development, end-of-life treatment, supply-chain management and others (*Ibid.*). In this respect, the author transformed the integrative approach and elements of TQM into a new framework of POEM matrix as depicted in Figure 2.14.

POEM	*System-technical organisation*	*Social-dynamic organisation*
Operational level	• Environmental information management systems • Control techniques; performance measurement • Budgeting (1)	• Cross-functional consultation and communication • Increased environmental training • Motivation and commitment (2)
	(3) Continuous improvement Cooperation and learning Stakeholder focus	
Strategic level	(4) • Planning/strategic orientation • Vertical deployment • Formal interface management (internal and external) • Division of tasks and responsibilities (including environmental ones)	(3) • Shared norms and values (including environmental ones) • Employee empowerment • 'Transformational' leadership • partnerships and integrated chain management (ICM)

Figure 2.14: Product-oriented environmental management matrix (De Bakker, 2002)

De Bakker (*Op.cit.*) pleads that this POEM matrix could be used both to embed the concept of POEM within theories of management and organisation, and to provide practical guidance to practitioners. A logical structure between TQM and POEM matrix is identical as, for example, both pursue continuous improvements that require the inclusion of elements such as training and performance measurement (*Ibid.*). The author approaches all elements of the POEM matrix within the strategic level of planning phase.

Elements of each quadrant in Figure 2.14 are working as an integrated whole with other aspects. For example, plans to change a firm's environmental performance may affect the *operational system-technical level*. At this level, one needs to determine which goals are achievable, probably by using forms of 'environmental performance measurement'[6] and information systems which both are system-technical elements, emphasising issues such as regulatory compliance and conformity (*Ibid.*). Budgeting is also treated as operational – as is supported in the operational/social-dynamic quadrant (*Ibid.*).

In terms of *Operational level*, there are system-technical elements and social-dynamic aspects. **(1) *Operational system-technical area*** in the corporate level are involved in various management systems, for example, certification for international environmental standards such as ISO 14001, risk management, data management, and translation of environmental issues or requirements into a product (development) that is still under progress (*Ibid.*). **(2) *Operational social-dynamic elements*** could include increased training in the handling of environmental information (van Hemel, 1998, cited by De Bakker, 2002). Given the lack of familiarity with POEM in many organisations, the author suggests that cross-functional consultation and communication might be more important in POEM than in TQM. Also external support could help organisations understand and implement POEM as such advisors play an important role in the success of new eco-design strategies in a company (van Hemel 1998, cited by De Bakker, 2002). Integrating the various functions involved could be achieved by using concepts such as green concurrent

[6] Environmental performance measurement in this study by De Bakker (2002) implies comprehensive meaning. In general terms, according to the Ministry of the Environment of Japan, environmental performance can be indicated in operational, management and management related areas. On the operational side, total input and output of resources throughout product life cycle can be measured while management encompasses various activities such as environmental accounting, technologies for environmental protection, research and development for eco-design, green procurement, safety and health, compliance with environmental regulations, social contribution in environment, and establishing and maintaining environmental management systems. Also management-related indicators consider management efficiency issues (Ministry of the Environment of Japan, 2003).

engineering (Karlsson, 1997, cited by De Bakker, 2002). Hence, integration, communication and cross-functionality are important aspects in this quadrant (*Ibid.*).

The *Strategic level* also consists of social-dynamic and system-technical elements. Two elements at the **(3)** ***strategic social-dynamic level*** in the POEM matrix that differ from those in the TQM matrix are 'transformational leadership' and 'partnerships and integrated chain management (ICM)' (*Ibid.*). The author regards employee empowerment and shared norms and values as relevant to both TQM and POEM. Transformational leadership can be promoted in which the management level develops green norms and values within a company and preserves these norms and values as a corporate culture (*Ibid.*). However, those inspirations at senior management level might not be apparently seen in practice (Cramer, 1997, cited by De Bakker, 2002). Thus, convincing an effect of environmental transformation in an organisation remains necessary before senior managers demonstrate transformational leadership (De Bakker, 2002). Using more system-technical elements such as measurement and strategic orientation could possibly achieve this, which underlines the integrated character of the POEM matrix (*Ibid.*). 'Partnership and ICM' in this level are considered more important in POEM than TQM and need to cover the entire product life cycle due to the wide awareness of which environmental problems are determined along the overall product life (*Ibid.*). Integrated chain management (ICM) is the integrated management of a supply chain in terms of environmentally, socially and economically responsible management of the production, consumption, distribution and final disposal of a product (Cramer, 1996, cited by De Bakker, 2002), and thus is closely related to the POEM concept, but with a greater emphasis on 'materials'[7] (De Bakker, 2002). In addition to suppliers, other partnerships might address recycling or 'reverse logistics'[8] (*Ibid.*).

At the **(4)** ***strategic system-technical*** planning stage, a company develops objectives or measurable goals to achieve within a given time (Starik *et al*., 1996, cited by De Bakker, 2002). Measurability is important in comparing the firm's performance with its environmental goals (*Ibid.*). Starik *et al*. (1996, cited by De Bakker, 2002) called this stage as a strategic position that '*the organisation describes its orientation towards how it will develop 'green' characteristics'*. The main activities of this phase are to list environmental product characteristics, to identify product requirements, and to prioritise them (*Ibid.*). In this stage, the author implies that great improvement may lead to the extension of environmental goals and some challenging approaches. However, as the company may not continue to make such quantum leaps, managing a good corporate environment for gradual

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[7] The author supplements comments about the relation of material within the POEM concept. *"The integrated chain management concept is closely related to the definition of POEM applied in this article, because it considers the material cycle from cradle to grave (*Wolters et al., 1997, cited by De Bakker, 2002*). POEM, however, does not focus on materials as such, but on products, which can make the application of a chain perspective more tangible for firms. Attempts to label the life cycle or product chain as exclusively product-based or material-based phenomena are prone to debate because products consist of materials. To emphasise the central role of manufacturing firms in determining product characteristics, including material selection, the POEM concept is considered to be more appropriate for this article.* (De Bakker, 2002)".

[8] Definition by The Reverse Logistics Executive Council (http://www.rlec.org): '*The process of motive goods from their typical final destination to another point, for the purpose of capturing value otherwise unavailable, or for the proper disposal of the products* (cited by Rengel and Seydl, 2002)'. The reverse logistics activities include: '*Processing returned merchandise for reasons such as damage, seasonal, restock, salvage, recall or excess inventory, recycling packaging materials and reusing containers, reconditioning, remanufacturing and refurbishing products, obsolete equipment disposition, hazardous material programmes, and asset recovery* (Rengel and Seydl, 2002)'.

improvement also remains important (De Bakker, *Op.cit.*). The information system can assist this by keeping the company informed a corporate environmental strategy and performance in regular basis (*Ibid.*), for example, the concept of life-cycle-oriented environmental management (Shaft *et al*. 1997, cited by De Bakker, 2002) and an approach to regularly align a firm's environmental strategy with signals from its surroundings (Starik *et al*. 1996, cited by De Bakker, 2002).

The other *strategic system-technical elements* of the matrix comprise the involvement, at the senior management level, in changing tasks and responsibilities, and in the vertical deployment of POEM that is up and down the firm hierarchy (*Ibid.*). While task setting mainly takes place at the management level, vertical deployment should be applied throughout the entire company (*Ibid.*). Formal interface management, both inside and outside the firm, is added in the POEM matrix by the author. Cross-functional activities and joint operations such as ICM require a more systematic approach to these interfaces (*Ibid.*). Formal aspects, for instance, creating a supportive structure are placed in this quadrant whereas the more informal aspects of interface management such as innovation and commitment or shared norms and values can be observed in the social-dynamic quadrant (*Ibid.*).

The elements of **(5)** ***core concepts*** are applicable to all four quadrants. But, some of the elements except 'continuous improvement'[9] in the POEM matrix differ from the ones of

[9] The author supplements comments in terms of the meaning of the terminology between 'continuous' and 'continual' as follows. *"Instead of 'continuous improvement', the term 'continual improvement' might be better to highlight the fact that improvement demonstrates more a repetitive character than a permanent*

the TQM matrix. For example, 'cooperation and learning' in the POEM matrix have a broader meaning than 'teamwork' in the TQM matrix (De Bakker, 2002). In the POEM, not only is intra-firm cooperation important (such as cross-functional design activities), but inter-firm cooperation also plays a role, for instance in ICM (*Ibid.*). System-technical aspects such as interface management and budgeting are relevant in facilitating this cooperation (*Ibid.*). The 'customer focus' has a broader meaning towards 'stakeholder focus' in the POEM matrix than TQM (*Ibid.*). It is believed that POEM requires more stakeholders' involvement than that of the just customers alone, which is seen in, for instance, environmental programmes such as 'product-stewardship'[10], implementing product-development and planning processes (Hart, 1995, cited by De Bakker, 2002), and which positively affect competitive capability in addition to learning and continuous innovation through environmental stakeholder integration (Sharma and Vredenburg, 1998, cited by De Bakker, 2002).

In conclusion, the POEM matrix suggested by De Bakker shows general aspects of corporate environmental management of product orientation in the strategic planning. It integrates both the strategic and operational level. It extends the scope of stakeholders' involvement from customer focus to stakeholder focus (*Ibid.*). The author claims that the

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nature. Yet, because the dominant terminology in quality management speaks of 'continuous', I stick with this term." (De Bakker, 2002).

[10] Product stewardship also called extended producer responsibility (EPR) means that '*all parties (designers, suppliers, manufacturers, distributors, retailers, consumers, recyclers, and disposers) involved in producing, selling, or using a product take responsibility not only for normal business performance and standards but also aspects of health, safety, and environment throughout the product's complete life cycle* (Institute for Self Reliance,)'. For further information, see the research paper, 'Defining product stewardship and sustainability in the Australian packaging industry' (Lewis, 2005), *Journal of Environmental Science and Policy*

POEM matrix offers a framework for linking the different goals of TQM and EMS by identifying weakness of both practical management areas. This research emphasises that cross-functional collaboration will benefit environment and quality management.

Despite potential contributions to constructing a management approach through integration of the POEM with TQM and EMS, this research does not specify a particular procedure of environmental work and does not sufficiently deal with the issues in product side and its incorporation into environmental management although they are the core concept of POEMS. It is rather focused on an early stage of product-oriented environmental management. Nevertheless, a theoretical study emphasising integrative approach across corporate functions would be useful for analysing existing POEMS models.
So far, some examples of development and application of POEMS models have been discussed. More details of POEMS models are examined and analysed in the next chapter – exploratory research. Following sections discuss benefits and shortcomings of POEMS in general.

2.5 Benefits of POEMS

The benefits of POEMS are, firstly, to improve environmental performance of products and the product chain of a company. It provides opportunities to identify environmental impacts throughout a product’s life cycle. Based on this, the company can choose better options and start up improving the identified problems. POEMS emphasises the organisational support for the product dimension in life cycle perspective that includes improvements of relevant areas in product chain.

In addition to this, the company can use POEMS to advance their management systems by tracing, measuring and improving environmental performance. Brezet and Rocha (2001) explain that companies can develop new management tools for an ‘environmental product care system’ that have a cyclic process of continuous improvements of products through eco-design and that provide insight into what extent these goals have been reached. The continuity of environmental improvement is the key concept of POEMS.

For this, many studies (Ammenberg and Sundin, 2004; DIW Berlin, 2002; Rocha and Brezet, 1999; Schmidt *et al*., 2001; Schmidt *et al*., 2002; UNEP, 2004) highlight that POEMS should encourage cooperation and communication between various players internally and externally involved in the company’s environmental improvement. The United Nation Environmental Protection (UNEP) (2004) already expressed, in the report about life cycle management (LCM), that these contribute to improvements in the transparency in the organisation and among the companies in the supply chain. The motivation for changing business culture and patterns can be fostered by the structured process of POEMS by dealing with product dimension and involving various organisational functions and the interdepartmental communication and cooperation.

Also, the UNEP (*Op.cit*.) report explains that other benefits from the systematic approach include the advancement of information system by requiring documentation in terms of products’ environmental profile as well as relevant business operations. In so doing, it may extend the greater knowledge about products and thus a better basis for price calculation (Ammenberg and Sundin, 2004; Schmidt *et al*., 2001; Schmidt *et al*., 2002). According to the experience of Rocha and Brezet (1999), POEMS is closely related to R&D, purchasing, production, sales, and especially marketing. It may mean that POEMS can be a threshold of corporate innovation associated with the environmental aspect particularly.

2.6 Critiques on POEMS

Nevertheless, there are also some drawbacks of POEMS in methodology and practices. First of all, some studies (Brezet and Rocha, 2001; Charter and Clark, 2002; UNEP, 2004) consider that most obstacles to the implementation and maintenance of POEMS are related to limited resources such as time, costs and staff in general. According to Ries, Winkler and Züst (1999), when an environmental manager in a company has to justify a budget by a cost benefit analysis, he/she often faces problems such as measuring environmental improvement (e.g., performance evaluation), expressing environmental improvement (e.g., economic benefits) and justifying not only short-term but also long-term investment. The authors note that especially the long-term investments do not return immediate benefits and the outcome is highly uncertain and difficult to predict. Thus, POEMS is often less prioritised in the corporate strategies and is hardly considered by companies without strong motivation.

A monitoring by KPMG of POEMS implementation in Dutch industry tells that there are few stimuli for companies to improve the environmental aspects of their products with regard to the Dutch government's policy agenda. However, it might not only be a policy issue but also connected with internal issues that especially SMEs face in understanding what POEMS is and its benefits for the companies. Therefore, an indirect approach to introduce POEMS may help in understanding and directing attention to POEMS, which may need to be supplemented within its framework. This all can be bound up with the fact that POEMS has too broad a scope to be handled by especially small firms and a lack of methodological development in tailoring the tool for specific needs. It is fairly similar view seen in the contradictory situation between the mainstream principles of holistic approach and pragmatic attitudes of SMEs, which was discussed in Chapter 1.

A more important critique applies to the POEMS tool itself. According to the study by Ammenberg and Sundin (2004a), the methodological aspect of POEMS has not been given much attention by the existing POEMS researchers as most of them are based on the practice and application of POEMS. It may mean that POEMS implementation can be considerably different depending on who is conducting it (*Ibid.*). This reality implies that there is no basic structure of the existing POEMS methods. Therefore, the consistency of measuring the environmental challenges and the improvements among POEMS projects may not be possible, which could affect the general perception of POEMS with the result that SMEs in particular are confused when using the tool.

Furthermore, Brezet and Rocha (2001) underline an imbalanced approach between elements of POEMS, which existing POEMS methods have emphasised on profiling environmental impacts of product as an important element whereas the influence of the other elements in the product chain is far less remarked on. It may have a relation to the issue that contents of POEMS are not clearly defined or comprehensible within a clear process, which a company might unable to understand overall structure or potential elements of POEMS at once. Regarding this, the workshop of European Commission in 2001 reports the results of monitoring POEMS projects describing that POEMS needs to be potentially standardised, be simple to understand, and be easy to implement (European

Commission, 2001b). It may mean that POEMS needs to be established with a common, comprehensible and applicable format. Especially in life cycle management, the report also states that interactions between various stages in life cycle of products need to be described. It is assumed that current POEMS methods lack in identifying the relationship between the elements or stages of the life cycle.

Lessons from the EMS evolution may give insights towards our understanding of possible problems in terms of POEMS development. Ries, Winkler and Züst (1999) point out that a majority of companies with the first set-up of an EMS has implemented the system only few years ago, which means that there is a situation whereby it usually takes time to establish a management system such as administrative stage of defining procedures and assigning competence. Therefore, product aspects of environmental improvements are less likely to receive any attention than establishment of management system. POEMS as a developing method is likely to take a similar path as seen in the past situation of evolutionary EMS. In implementation as well as methodological development of POEMS, reducing the time to identify a basic structure and relevant areas would be beneficial for SMEs not only for establishing a systematic approach but also for increasing an opportunity to focus on product aspect.

2.7 Conclusion and further research problems

In the preceding literature study of POEMS, the main characteristic, scope, strategies and various structures of POEMS have been overviewed. One of the distinctions that POEMS potentially has is to provide a strategic approach in establishing a procedure for a product development process integrated within environmental management system. Also, POEMS covers a broad range of activities along the life cycle of products. Therefore, the review study has provided the answers for the first set of the research questions below.

(1) Strategic and management approach: POEMS theoretically has the strategic integration between EMS and eco-design, and involvement of various people inside and outside a company
(2) Product aspects and relevant areas: POEMS theoretically defines organisational support for product dimension including relevant areas of product chain
(3) Life cycle approach: POEMS emphasises the principles and strategies of products' life cycle approach

For the second set of the research questions, whether POEMS provides; (4) a generic and specific guide, (5) any diagnostic approach to identify focal areas for environmental improvement, and (6) an applicable self-help format for SMEs, the review study has developed further arguments as follows:

(4) Generic and specific guide: POEMS covers generic and fairly specific areas, however it is found that most POEMS methods deal with very general information while some practice-based POEMS approaches have the information of very specific industries that may not be applicable to other sector or companies. Ammenberg and Sundin (2004a) state that, as every company has its own needs and capabilities, it is not possible to develop a POEMS model that expressly fits every company. In this respect, it should consider whether POEMS can be modifiable or flexible at least in its format covering the overview of relevant areas and identifying focus areas. Therefore, further investigation needs to be carried out about the possible modification of POEMS format.

(5) Any diagnostic approach to identify focal areas for environmental improvement: there are two cases that have developed preliminary programmes of POEMS (SWOT analysis and AIDA model), which may be used for diagnosis to clarify focal areas or main interests of a company. However, both programmes are focused on specific sectors and there is a potential to develop a more general approach in the diagnostic tool combining benefits of both methods. Therefore, it needs to be further investigated.

(6) Applicable self-help format for SMEs: critiques on POEMS has raised some debates such as a broad scope to be handled by SMEs, no basic structure (diverse processes and stages), imbalanced approach to overall elements, lack of identification of relationship between elements or phases of the life cycle, lack of clarification of contents, and lack of diagnostic approach. These problems should be investigated and overcome.

To conclude, this literature study approved for the first set of the research questions, but remained more research problems in relation to the second set of the research questions. These further research problems of POEMS from the research questions 2 are condensed into six subjects in Figure 2.15 about whether the existing POEMS models have the following problems or not. The six research problems are scrutinised in an exploratory research in Chapter 3, which representative POEMS models are selected and analysed.

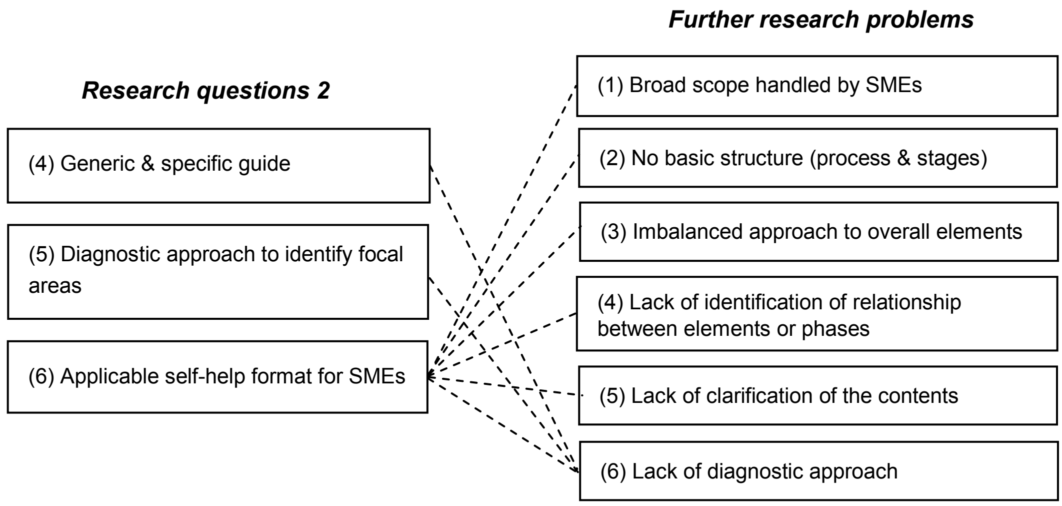

Figure 2.15: Further research problems developed from the research question set 2

Chapter 3 Exploratory research

This chapter presents an exploratory research that aims to discover the answers for the developed research problems from the research question set 2. So far, there is no standardised POEMS approach. Therefore, it is reasonable to take a closer look at the representative POEMS models and studies that have contributed to development of the tool. This exploratory research implements a series of critical analyses of the existing POEMS models and presents the main findings.

3.1 Overview of analysis of existing POEMS models

This section gives an overview of the analysis including aim, procedure, subjects and materials. The critical analysis aims to investigate the current state of the existing POEMS models with respect to the following research problems: 1) a broad scope handled by SMEs, 2) no basic structure (process and stages), 3) an imbalanced approach to overall elements, 4) a lack of consideration of relationship between elements or stages of the life cycle, 5) a lack of clarification of the contents, and 6) a lack of diagnostic approach to increase motivation or discover focus areas for POEMS implementation.

As seen in Figure 3.1, the procedure of the analysis comprises four main steps and two sub-activities. Each main step of the analysis contains relevant subjects to be scrutinised in order to explore the answers of the research problems. First of all, the representative POEMS models are carefully selected regarding the issues of the mainstream principles and environmental supporting tools (see Figure 1.13 in Chapter 1). The analysis 1 conducts a comparison of processes and stages of the chosen POEMS models. It aims to investigate whether the existing POEMS models have a variety of structure (process and stages). The result of the analysis could provide a response to the research problems (2) or (5). The result is also used to establish a preliminary common process and main stages of POEMS.

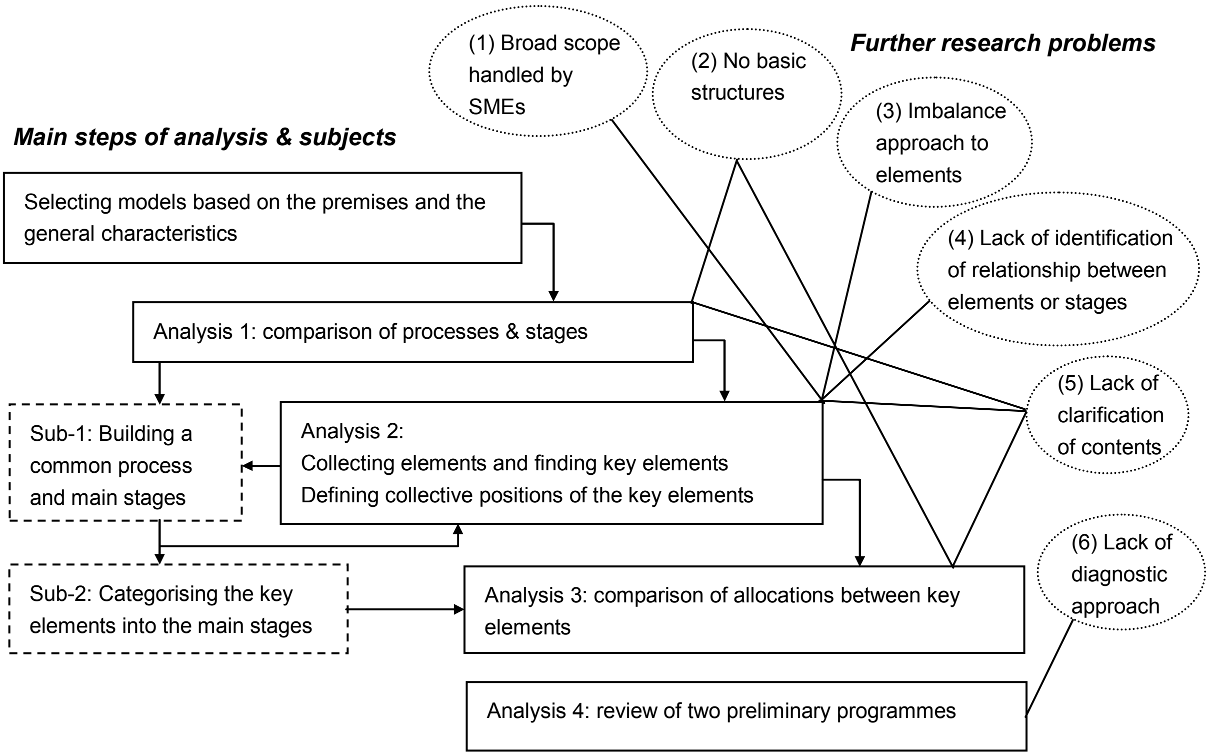

Figure 3.1: Procedure of analysis corresponding to the six further research problems

The analysis 2 implements three tasks; collecting elements of the chosen POEMS models, finding key elements, and defining collective positions of the key elements. The result will show the following issues: the rage of areas dealt with by the existing POEMS models (for the research problems (1)); the areas of elements upon which the models are mostly focused (for the research problems (3)); and whether any models consider the relationship between elements or stages (for the research problems (4)). Combining the results of the second step and third step of the analysis, the key elements are rearranged and re-categorised into the main stages of the common process.

In the analysis 3, the positions or allocations of the key elements of each chosen model are compared to each other according to the common process and the main stages established in the sub-activities. The results may show whether the current POEMS models have a clear definition of which elements are performed in certain stages or for specific purposes. This may answer to the research problems (2) and (5). The analysis 4 separately reviews and examines relevant diagnostic tools of POEMS for the research problems (6).

3.2 Result of analysis of existing POEMS models

3.2.1 Selection of POEMS models

Amongst the 18 studies covered in the literature review (see Chapter 2.4), around twelve contains methodological aspects of POEMS. Ten out of the twelve studies actually have their own structure (a process and defined stages) in theory or practice. For selecting appropriate POEMS models, this research has considered the following criteria: first, whether a POEMS model has its own framework in a theoretical or empirical base including main structure (a process and defined stages) and parallel tools adopted; second, whether it encompasses the key mainstream principles in its contents such as the life cycle approach and product dimension; and whether it has an integrated approach of eco-design and environmental management. In this regard, 'Ten POEMS models'[1] were finally chosen and numbered in order to scrutinise the details of the research problems. The relevance of each ten model to the criteria is summarised in Table 3.1.

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[1] [1] Ammenberg and Sundin, 2004a; [2] Baas, 2002; [3] Brezet and Rocha, 2001; [4] De Bakker, 2002; [5] De Graaf, 2002; [6] Klinkers *et al.*, 1999; [7] CBM, 2001 and Pinkse and De Graaf, 2002; [8] Rocha and Brezet, 1999; [9] Schmidt *et al.*, 2002; and [10] Van Berkel *et al.*, 1999.

Table 3.1: General characteristics of the POEMS models

No.	Title of model	Criteria of POEMS model					
		Main method or process	Parallel tools	Life cycle approach	Product aspect	Incorporation with eco-design	Managerial approach
[1]	General steps of POEMS	EMS (PDCA)		√	√	√	√
[2]	POEMS integrated with SWOT analysis	SWOT-based POEMS		√	√		√
[3]	POEMS developed from PDCA cycle	EMS (PDCA) & eco-design	LCA/ LCC	√	√	√	√
[4]	POEM matrix modified from TQM	POEM matrix		√	√		√
[5]	AIDA tool for tailoring POEMS	AIDA combined with POEMS	AIDA	√	√		√
[6]	PEC integrated with product chain management	EMS (PDCA)/ ICM	ICM	√	√		√
[7]	Step-by-step PMZ	PMZ steps	LCA	√	√		√
[8]	Integrative approach of POEMS	EMS (PDCA) & eco-design	LCA/ LCC	√	√	√	√
[9]	The Danish EPA's POEMS programme	PDCA	LCA	√	√		√
[10]	Plan-phase P-EMS for retail & manufacturing industry	Plan-phase-focused EMS (PDCA)	LCA	√	√	√	√

In terms of the main structure (process and stages), more than half of the models have adopted the PDCA cycle from the standardised EMSs. In the models, LCA is the major parallel tool, which provides a quantitative data of environmental impacts of product life cycle. Some models also recommend using life cycle costing (LCC)[2]. Integrated chain management (ICM) is actively adapted in the model 6 by Klinkers *et al*. (1999) (see Chapter 2.4.3). All models embrace the life cycle scope in their approaches. As POEMS was born with the environmental product policy that is oriented to life cycle approach, it is

[2] LCC: Life Cycle Costing is a 'assessment of all costs associated with the life cycle of a product that are directly covered by the any one or more of the actors in the product life cycle (supplier, producer, user/consumer, end-of-life-actor), with complimentary inclusion of externalities that are anticipated to be internalised in the decision-making future' (Rebitzer and Hunkeler, 2003, cited by Saur *et al*., 2003).

natural that the tool inherently possesses the concept.

Strategic and management support of environmental improvement of a product is significant for long-term innovation. Products are the key medium to cobweb most of corporate functions and various parties in the product chain. This is accomplished by integrating product side into the environmental management side. Even though most models mention managerial approach and product aspects, only four POEMS models actually integrate eco-design or any other product development tools in their procedure. Those models that describe product side partly deal with it through, for example, environmental impact assessment of products. This may reflect the fact that most POEMS methods focus on environmental impact assessment while other elements are relatively underemphasised. Details are provided in the following analyses.

3.2.2 Analysis 1: processes and main stages

In the first analysis, the comparisons of various processes and stages of the POEMS models were conducted. This comparative analysis could provide an overview of general process of the existing POEMS models. The analysis result might serve as a response to the research problems (2) and (3). This section firstly introduces a brief description of the process of an individual POEMS model and displays the procedure of the analysis.

Process or structure of individual POEMS model

The individual model uses different formats or graphical shapes, and terminologies for a same or similar context of some elements. Therefore, it is difficult to define or clearly understand the process and contents of POEMS. In this regard, the first work of this analysis is to translate the literal as well as contextual meaning of each stage of the processes of the models. Then, they are rearranged in a same form so that a comparison is apparent between differentiated processes and stages. The processes or structures reshaped are illustrated in Appendix A (Figure A.1 to Figure A.10).

Comparative analysis of processes and stages

The processes and stages that each model presents are compared. In Figure 3.2, the ‘step order’ means the sequence of the process of each model and the four horizontal lines across different models signify the steps that have similar activities of POEMS. The first distinction seen among some models is that they start with fairly different steps. For example model 2 and 7 take a ‘plan’ stage at first, which sets up targets, objectives and strategy, or forms a project team. On the contrary, most models initiate POEMS with the activities – such as profiling the environmental impacts of products or reviewing organisational capacity for environmental improvement – in a separate ‘review’ step.

Some models collectively deal with different types of activities in the same stage. For instance, as depicted in Figure 3.2, the model 3 includes products’ environmental profiling into the ‘plan’ stage together with other managerial or operational preparation such as establishment of strategies and targets. However, most models deal with these preparations in ‘plan’ and environmental profiling in the ‘review’ stage. Unlike most models, the model 8 manages the eco-design support process across ‘plan’ and ‘do (implementation)’ stage, which may be reasonable to support product development in management level. This approach is also found in particularly the mergence of ‘evaluation’ and ‘continuation’ stages in which overall seven cases of the models carry out evaluation activities by embracing either routinisation (integrating the outcome of the POEMS project within existing systems) or continuation (using the achievement as a base for further work).

Several models including model 2, 7 and 8 split some elements into two stages while other models deal with the elements as a whole. For instance, the model 2 separates ‘preliminary investigation’ and ‘additional investigation’. The ‘preliminary investigation’ is to identify the organisational ability to implement POEMS by using SWOT analysis and environmental profiling of the product whereas ‘additional investigation’ such as market related issues is separately dealt with in a different stage. The model 7 has similar approach that divides investigation activities in two stages, the first of which, the ‘preliminary investigation’ is to collect general information such as internal and external influences (see Figure A.7 in Appendix A), and a second, the ‘deepening’ stage, handles more detailed and additional data by tracing advantages and disadvantages of the environmental improvement along the life cycle of the product. However, the rest of the models collectively deal with these issues in a single stage as part of either the ‘review’ or ‘plan’.

Three cases, i.e., model 4, 5 and 10, are more focused on a management plan rather than an action plan in operation and thus most elements are involved in establishing a management structure to support POEMS. Furthermore, the use of different terminologies among the models is prominent especially in the context of ‘evaluation’ and ‘continuation’ of POEMS. For instance, some models intend ‘evaluation’ by their use of terms like ‘audit’, ‘revision’, ‘(management) review’, ‘check’, ‘fixation’ and ‘embedment’. Similarly, ‘embedding’ and ‘fixation’ are translated as ‘continuation’ or ‘routinisation’ in other models. Therefore, the elements need to be clarified in their literal as well as contextual meaning, as related to

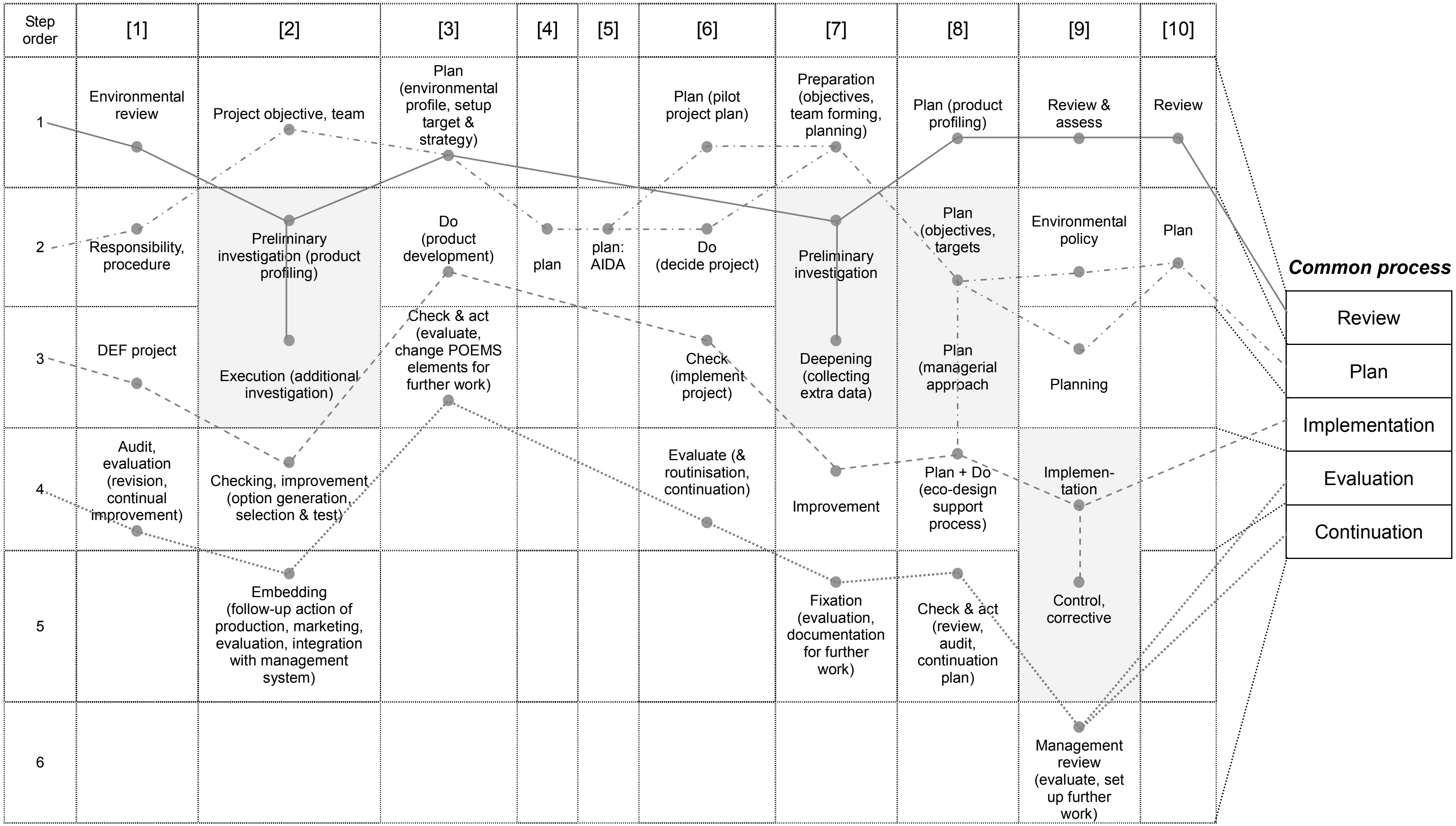


Figure 3.2: Comparison of processes and main stages of the POEMS models, and generation of a common process and stages

the research problems (5).

In brief, it is found that the POEMS models implement some elements that have same or similar meaning in different stages. This is found even in the most commonly performed activities such as environmental profiling of products or planning of a POEMS project. Also, the processes are fairly diverse as some models (4, 5 and 10) only carry out the initial step of activities such as plan or review work while only few models (3, 7 and 9) cover a wide range of activities of POEMS. Thus, diverse structures are identified, as alluded in the research problems (2). This phenomenon may lead confusion those who do not know about POEMS and may require sufficient time to understand the structure and establish their own view. Besides, various expressions of similar elements (or stages) can be problematic although the purposes of the elements in certain stages are generally similar. So, it is reasonable to say that a further research on POEMS should consider establishing a basic common procedure, and at least the main stages of POEMS need to be articulated in a single term.

Despite the various processes with different allocation of same stages, it is arguable that the stages of the models have common elements which serve same or similar purposes on the basis of contextual comparisons. So, it is possible to categorise those common elements among the models into a same stage, which apply to other elements. In so doing, overall five main stages are produced including ‘review’, ‘plan’, ‘implementation’, ‘evaluation’ and ‘continuation and routinisation’. These five stages derived from the reallocation of common elements are entitled as ‘common process’ in Figure 3.2. As a result, a basic structure with a common process with main stages is established.

3.2.3 Analysis 2: key elements and their collective positions

In the analysis 2, three steps were carried out. At first, all potential elements of POEMS were collected from the chosen models. Overall 100 elements are regarded as directly or indirectly associated with POEMS, a substantial number. Although most of the models emphasise a strategic approach in the initial stages, they generally cover a wide range of areas and activities that possibly take place in POEMS. Regarding detail working tasks (such as selection of tools or methods, allocation of responsibilities, etc.), under the elements, the range of environment-related work could be even larger.[3]

Secondly, the elements frequently involved in more POEMS models were examined. About 42 key elements were selected, re-arranged and classified into several stages according to the similarity of their attributes. This result was compared with the outcome of the firstly comparative analysis of the processes and stages of the models so that the common process of POEMS previously formed in Figure 3.2 could be amended. The final key elements were categorised into the five main stages, i.e., review, plan, implementation, evaluation, and continuation and routinisation (see Table 3.2).

In the Table 3.2, the first column on the left-hand side presents the five stages of POEMS process, and the second and third column present 42 key elements. The right section shows which key elements are involved in the ten models. For example, model 1 (represented to [1]) has overall 19 key elements. According to the result, the most important ones amongst the 42 key elements are 'environmental impact of product and product chain' and 'market

[3] For example, a company may consider using various technical tools (e.g., LCA, LCC, industry guidelines or checklist of material declaration, etc.) for environmental profiling of products.

and customers' demand' in review stage, and 'product and/or business policy and strategy' and 'project target and objectives' in plan stage.

Comparing the key elements of the first two stages (review and plan) with the three follow-up stages, there is a considerable imbalanced approach to the elements between two groups. Key elements of 'review' and 'plan' gain twice more attention than the follow-up stages in average. When comparing the 'review' stage alone with any other follow-up stages, the level of attention to the first stage is even more distant. It means that most POEMS models concentrate on the activities in the 'review' and subsequently the ones in 'plan'. It also may mean that the activities in 'implementation', 'evaluation' and 'continuation/routinisation' could have less chance to be considered in a POEMS project.

Some key elements are frequently mentioned in different stages of some models. For example, 'cooperation' and 'communication' are appeared in the 'review' and 'plan' stages. These two elements are required in both managerial and operational sides. In operational function, collecting relevant information and data of a product and its environmental impacts requires close cooperation and communication with suppliers in the product chain. This activity would take place in the 'review' stage. On the other hand, building and maintaining information might be related to managerial performance requiring internal communication and collaboration. These activities may happen in any stages depending on the situation or business routine of an individual company. Many models do not clarify characteristics or particular stages where some elements (e.g., cooperation and communication) belong to.

Table 3.2: Key elements and main stages derived from the POEMS models

	Key elements		[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
Review	1	Existing corporate capacity: management & operational structure & performance	●	●	●				●		●	
	2	External situation: market & competitors	●	●	●				●	●	●	●
	3	Existing product development process	●		●			●	●			
	4	Environmental impact of product	●	●	●	●	●	●	●	●	●	●
	5	Environmental impact of product chain	●		●	●	●	●	●	●	●	●
	6	Compliance with regulation & policy			●	●	●		●	●	●	●
	7	Market/ customers' demand	●	●	●	●	●		●	●	●	●
	8	Other stakeholders' demand (internal/external)			●	●	●		●	●	●	
	9	Environmental cost assessment			●		●	●	●	●	●	
Plan	10	Plan management commitment/ support	●	●	●	●		●	●	●		
	11	Plan managerial/operational improvement in routine			●	●	●			●		
	12	Allocation of responsibility & resources	●	●	●	●			●	●	●	
	13	Product (business) policy & strategy	●		●	●		●	●	●	●	●
	14	Plan project target & objectives (incl. eco-design)	●	●	●	●		●	●	●	●	●
	15	Plan programme/procedure: product development	●	●	●			●	●	●		
	16	Set up programme/procedure: product chain improvement						●	●			
	17	Set up marketing objectives, strategy		●	●				●	●	●	
	18	Plan tools and methods to use	●							●		●
	19	Plan measurement of performance, product, data			●	●		●		●	●	
	20	Set up additional training, expertise support			●	●		●	●	●	●	
	21	Plan internal communication/cooperation			●	●	●	●	●	●	●	
	22	Plan external communication/cooperation/ ICM			●	●	●	●	●	●	●	
	23	Plan information building & supply	●		●	●		●	●		●	
Implementation	24	Product development (ecodesign)	●	●	●			●	●	●	●	
	25	Product-related R&D (technology etc.)	●	●	●			●	●	●	●	
	26	(Cleaner) production		●	●				●			
	27	Marketing & sales		●					●			
	28	Organisational improvement/competence	●							●		
	29	Product chain development	●			●		●			●	
	30	Integrated performance with existing systems		●	●					●	●	
Evaluation	31	Product improvement	●		●			●	●	●		
	32	Product chain improvement						●	●			
	33	Project, procedure	●	●	●			●	●	●		
	34	Objectives, strategies								●		
	35	Organisational performance (managerial/operational)							●	●	●	
Continuation/routinisation	36	Dissemination of project result							●			
	37	Information system & documentation							●			
	38	Integration of improvement with existing managerial/operational system/procedure		●	●				●	●	●	
	39	Change or set up policy/ objectives/ targets etc. for further work			●					●	●	
	40	Plan for further improvement: product		●	●			●	●	●		
	41	Plan for further improvement: product chain						●	●			
	42	Documentation/dissemination of standard guidebooks or further plan							●	●		

However, very few models such as model 3 and 8 specifically address the characteristics of particular elements in managerial and operational aspects. For instance, the model 3 describes the managerial aspect in the ‘plan’ stage that review existing management structure for eco-design support (e.g., eco-design practice and procedure), and current organisational ability and support system (e.g., resources for eco-design or relevant subjects). The model describes that the review of existing management structure and organisational ability is the base to define objectives and targets of both managerial and operational sides in the ‘plan’ stage. Given more details, the managerial approach in the ‘plan’ aims to build up capability and routines into the regular implementation of eco-design and exploration of its potentials, by planning development and management of information system such as database of environmental characteristics of materials used in production, an LCA and/or the definition of the required level of expertise in eco-design (Brezet and Rocha, 2001).

In the operational side, the company need to consider stakeholders’ view, consumers’ expectations and response to the products, and direct impacts of environmental improvements on the company’s position in the market (*Ibid.*). These information need to be interpreted into establishing the objectives and targets of a POEMS project, and the product attributes for environmental improvement (*Ibid.*). Clear objectives and targets in both managerial and operational sides help the company set up an appropriate goal and plan for environmental improvements through POEMS. This interlocking approach of the managerial and operational sides of POEMS is a fundamental difference from the (production) process-oriented environmental management system.

However, most models either vaguely handle many elements with a lack of articulation of responsible functional areas of a company, or more concentrate on particular aspects of the elements without consideration of the relationship between the elements. For instance, some elements such as ‘marketing and sales’ are highly remarked in the model 3 and appeared to be important across all follow-up stages from ‘implementation’ to ‘continuation’, whereas these elements are not even considered in other models. Regarding this, a company may be hard to take those elements into account when implementing a POEMS project and potential opportunities from the elements could be diminished.

To conclude, potential problems of existing POEMS methods are found in relation to a broad scope of areas handle by SMEs, an imbalanced approach to overall elements and a lack of consideration of relationship between elements, which are related to the research problems (1), (3), (4) and (5).

3.2.4 Analysis 3: comparison of allocation of key elements

The third analysis compared the positions or allocations of the 42 key elements of each model. The main stages of the common process developed from the analysis 1 were applied to the analysis 3. For example, in the analysis of the element 13 ‘product (business) policy and strategies’ in Figure 3.3, the far left-hand side column indicates the main stages of the common process. As seen in the central area, each model implements the element 13 in the ‘plan’ stage that the models originally place the element. In so doing, each position of all 42 key elements were identified along the main stages of the common process, and the variation of the positions was able to be compared.

From the first examination of the positions of the key elements, they could be approximately categorised into four groups, allocated in the same stages, allocated in fairly similar stages, allocated in various stages and immeasurable. Around 30 per cent of elements are unable to identify whether their positions of the models are varied or not (see Appendix B). Except the immeasurable elements, this research scrutinised the rest three groups. Firstly, about 21 per cent of the elements (9) are in the same or fairly similar stages while more than 38 per cent (16) elements are placed in completely different stages. Among these elements, the most distinguished ones are presented in Figure 3.3 and 3.4. The result shows that the existing POEMS models have a wide variation of formats and different understanding of the elements of POEMS.

In Figure 3.3, most POEMS models unanimously allocate the elements in the same stage. These elements are mainly included in the 'plan' or 'implementation' stage. On the contrary, as seen in the Figure 3.4, some elements are considered in various stages depending on the models, which most of these elements are in the 'review' and 'plan' stages. For instance, four models (1, 5, 7 and 9) place the element 5 ('investigating environmental impacts of product chain') in the 'review' stage whereas another four models (3, 4, 8 and 10) put it in 'plan' and model 6 states it in 'implementation'. The elements 19, 21 and 23 show the same result. This phenomenon may confirm the issue, stated in the critiques in the literature study, that the contents of POEMS are unclear and incomprehensible. Therefore, the diverse variations of the structure of the existing POEMS can decrease the possibilities of potential standardisation and feasibility of the tool.

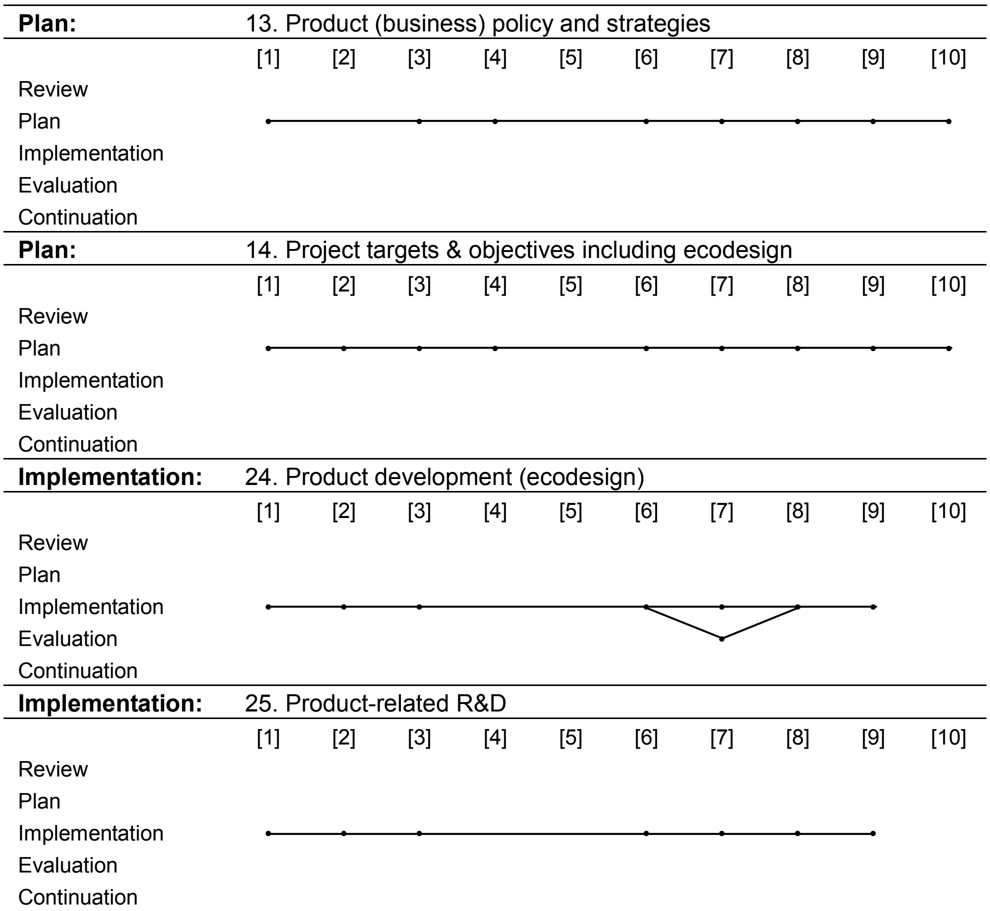


Figure 3.3: Key elements performed in a same or similar stage

In conclusion, almost 40 per cent of the POEMS elements are considered in different places of the POEMS models. Even some prior elements such as profiling environmental impacts of products and product chain are performed in different stages in some models. The result of the analysis shows that diverse approaches of POEMS, as shown in various positions of elements in different stages, approve the fact that POEMS has not been developed to a basic structure. Also, the lack of clarification of the elements could contribute to this result that is, therefore, problematic in using and facilitating the tool in SMEs. The comparative analysis can answer to the research problems (2) and (5).

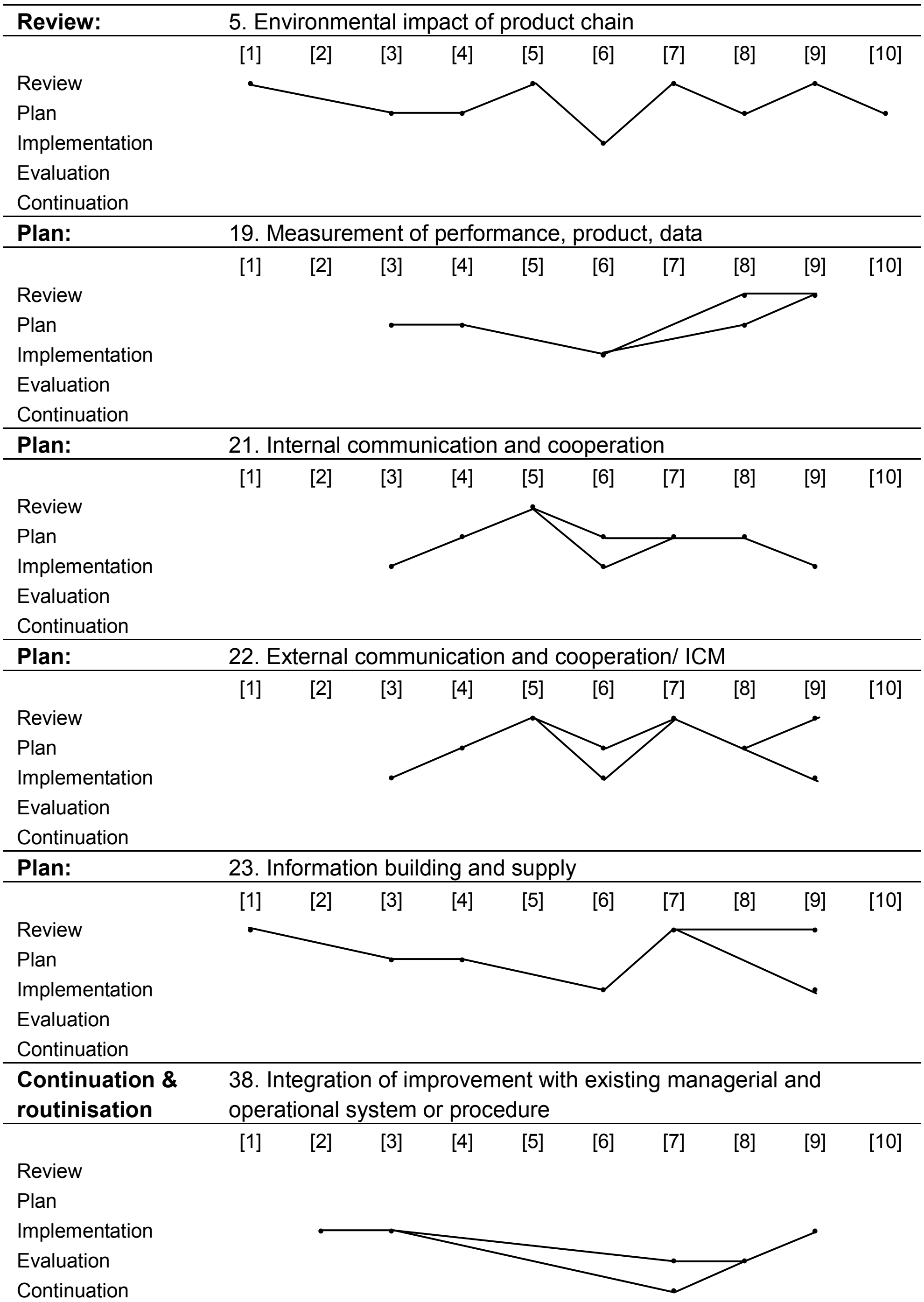


Figure 3.4: Key elements performed in different stages

3.2.5 Analysis 4: review of two preliminary programmes

There are two models that have a preliminary stage before POEMS implementation. Each model translates the outcomes of the initial step in its own way. The details are explained in particular to explore to what extent the preliminary tools of the models can be developed to a diagnostic approach, which is related to the research problems (6).

Model 2: POEMS integrated with SWOT analysis

A POEMS method was applied to a project, subsidised by the Netherlands government, over the Dutch plastics recycling industry mainly SMEs during 2001 and 2002. This project aimed to promote POEMS concept in the industry and develop a sector-specific POEMS model (Baas, 2002). This model was intended to discover a company's interest or capability for POEMS implementation by using SWOT (strengths-weaknesses-opportunities-threats) analysis. Through this, initial attention of the company on product and product chain would be increased. As seen in Figure A.2 (Appendix A), after the first step of defining and establishing project objectives and team, a preliminary investigation is performed including SWOT analysis. The preliminary work is conducted in a demonstration project that has roughly four steps comprising investigation of the sector's SWOT, interpretation of opportunities, transfer of knowledge to the actors in the chain, and tailoring POEMS in company level based on the sectoral information. The outcome of this initial work would be integrated in five-step POEMS process afterwards.

The first aim of the preliminary investigation is to identify the sector's environmental problems and potential opportunities. For this, the sector organisation (or the industry association) can make a decision of which opportunities the sector needs to focus on. The first investigation requires several companies to participate in the demonstration project. From these companies, relevant information is gathered, for instance, environmental profile of recycled products, characteristics and possibilities of utilisation of recycled plastics, etc. Then required activities of recycling business (and sectoral core issues) are shared by environmental covenants between the government and the companies in the sector.

In the second part, the analysis of the environmental profile is interpreted to opportunities in the sectoral level. With this information, new markets and competitiveness in the market can be explored in the company level. The third step would be transferring the knowledge to recycling companies including plastics processing companies and other important people such as designers in the plastics product chain, which aim at establishing the strategy where most environmental gain can be realised (Baas, 2002). In the final part, the opportunities derived and developed from the previous investigation, analysis and interpretation in sectoral level are translated and applied at the company level. During this, companies can implement a POEMS project by using the sectoral information. For instance, Baas (*Op.cit.*) introduces several exemplary companies that have utilised the result of the preliminary work. PRS (Plastics Recycling Simons) is the company that produces recycled polystyrene (PS) which can contribute to environmental benefits compared to virgin PS (*Ibid.*). The data and knowledge of the environmental analysis of recycled plastics can be a used for this company. AKG (Aufderhaar Kunststofgroep BV) was looking for new clients to buy its product called high-grade polypropylene (PP) compounds that have environmental benefits and profits for the company (*Ibid.*). This company used the environmental profile of recycled PP which is needed to optimise environmental improvement (*Ibid.*). Through the validity of the energy covenant, AKG in this specific sector could select a new market segment.

The benefit of this POEMS project was that the SMEs in the sector could utilise the information that the sector established, and was able to modify POEMS for a company's specific need. However, a precondition exists that a sector specific environmental information system should be established first. For this, government support, the industry association or at least a form of cooperation and coalition of a group of companies is required. In addition, the project was focused on the plastic industry which mainly deals with eco-efficiency of energy and material. Therefore, questions still remain whether this approach can be applicable to other sectors or companies, and how individual SME can build up and use this preliminary work for the POEMS implementation, which seem implausible to be happened.

Model 5: AIDA tool for tailoring POEMS

De Graaf (2002) presents a POEMS model that integrates a preliminary method, namely, AIDA (attention-interest-desire-action) programme. The motivation of this idea was driven by the recognition that most companies especially SMEs are not interested in POEMS or they are more likely to partly apply POEMS elements such as green purchasing or logistics. Hence, there was a need of preliminary work to increase the awareness of companies on POEMS and allow them to prepare for full implementation of POEMS. So, a first-step tool needed to be developed, which could be imbedded in POEMS model. A research project was conduced by BECO group commissioned by the Ministry of Housing, Spatial Planning and the Environment of the Dutch government. The whole project for creating an integrated tool consists of two main parts that, first, develop and test a first-step AIDA tool, and, second, integrate the tool with the POEMS process.

(1) AIDA model development

The first part of this project was to prepare organisations to understand the POEMS concept and the relevant areas. It aimed to increase initial attention of companies on the environmental aspects of their products and the product supply chain and, therefore, finally achieve an integration of POEMS into the companies' strategy of environmental improvement (De Graaf, 2002). The background of adopting AIDA is that the research group recognised a strong connection between the development and marketing of a new product and thus they implanted the AIDA communication model in the development of a preliminary model (*Ibid.*).

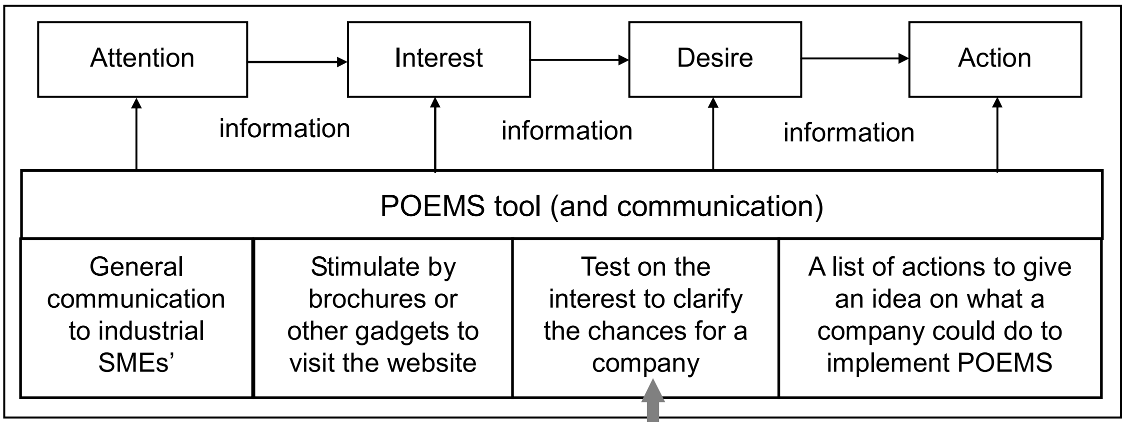
The procedure of the AIDA comprises four steps – attention, interest, desire and action. The assumption is that information offered to a company first has to draw attention, after which the user decides if this offer is interesting (*Ibid.*). When the desire exists, the potential user might develop actions to fulfil the desires (by using the product) (*Ibid.*). Considering that the company has to pass all four stages before they start with POEMS activities, the AIDA model helps developing an effective and balanced POEMS tool that pay attention to all stages of life cycle (*Ibid.*).

The first step, getting 'attention', is achieved by effective and proper communication. For example, to identify available and appropriate contacts inside and outside of the company, and to build up a communication network can be worked out. However, there is not much work of the major part of POEMS such as design and other elements, because the main purpose of this stage is just that the company recognises existence of POEMS tool (*Ibid.*). Second part is for generating 'interest' by offering information that is geared toward the firm's fields of interest (*Ibid.*). In 'desire' stage, POEMS is now able to translate the user's expectation into the company's specific recommendations best by creating and clarifying the potential benefits (*Ibid.*). Final step is to stimulate the company to take 'action' and it needs to show the possible POEMS activities and the relevant areas (*Ibid.*).

(2) Integration of AIDA with POEMS concept

Since the preliminary model had been developed in order to identify potential benefits and required fields of performance, the second part of the research was launched to integrate AIDA with POEMS concept. This research took three steps in the integration process that are analysis (desk- and field-research), development (of a conceptual tool), and review (De Graaf, 2002). Through this process of integration of AIDA and POEMS concept, the company can create (or tailor) its own POEMS.

The analysis step started with introductory work for promoting POEMS concept among the target group and translating the experiences from literature study (e.g., the outcome of the preliminary project and the company's own environmental issues) into specifications for the POEMS tool (*Ibid.*). Not only project descriptions and evaluations were considered but also existing tools to support companies were investigated (*Ibid.*). The researchers interviewed eight companies to test the initial assumptions that were drawn from the desk research (*Ibid.*). From this information, they identified barriers, causes and possible solutions, and translated and categorised them into specifications according to the AIDA model (*Ibid.*). Overall five SME sectors – industry of metal product, publishers/printers/copiers, food, machinery and furniture and toy – were chosen due to their direct influence on the environmental aspects and impacts of their products (*Ibid.*).



3. Desire (checklist test)

Proposition (question)	Expla-nation	agree	Dis-agree	Un-known
1. You know what the benefits of POEMS can be for your company				
2. Your customers ask questions about the environmental aspects/performance of your product				
3. Environmental aspects of your products are important for your company's image				
4. You are never surprised by new environmental legislation				
5. You have a quality or environmental management system				
6. Your competitors pay attention to the environmental aspects of their products				
7. Your workers are interested in the environmental aspects of your products				
8. There are labels available that communicate the environmental benefits of products in your market				
9. You are investigating the environmental impacts of your products				
10. You know what your customers do with your product				
11. You are familiar with the (production) processes of your suppliers				
12. You are planning to develop a new product or to re-develop an existing product				
13. You want to improve the quality of your product				
14. (Cost) Price is an important aspect of your product				
15. You are considering a change in the production technology				

Figure 3.5: Integration of 'desire' checklist of AIDA with POEMS (De Graaf, 2002)

Second step (development) aimed to construct a concept tool based on the specifications of the first step of analysis, which would be then tested in the final step ‘review’ (De Graaf, 2002). Through a creativity session with members of the steering committee and field experts such as entrepreneurs, specialists in marketing communication, education and training experts, communication interface or types of POEMS and practical solutions on the contents and design of the tool were generated (*Ibid.*). The result from the analysis and development of the steps was dedicated to tailor a conceptual POEMS model and its strategies into the corporations’ specific needs and conditions.

Finally, ‘review’ as a final step was to test the POEMS, which was in the process of integration of the AIDA and POEMS, by the user companies. As a result, the POEMS could be improved for individual needs and implemented. Among six companies who initially took part in the project, few companies expressed interests in carrying on the rest of the POEMS procedure and provided suggestions for supplement (e.g., examples) and improvement of texts (more concise) of the POEMS tool (*Ibid.*). As seen in the lower part of Figure 3.5, the preliminary model provided a test sheet to the companies that wanted to proceed with the POEMS. This test was combined with the POEMS in order to gain a feedback about attention and first interest from the companies that had an intensive communication about the subject within the company and the research group (*Ibid.*). The companies were led to a website that offered a short explanation about the POEMS and benefits of other cases (*Ibid.*). These companies could take the test or go to the next step for possible actions (*Ibid.*). The test has 15 propositions and four options that consist of ‘explanation’ (when the user needs more information), ‘agree’, ‘disagree’, and ‘unknown’ (when the user does not know the situation or does not have sufficient information to answer). An example of feedback on proposition is provided by the author (*Ibid.*) in Table

3.3.

Throughout the whole experiences of AIDA and its application to POEMS, the companies could decide to take actions with a help from a 'web-based service'[4] provided by the research group. The company could choose any categories of activities for improvement such as strategy, purchasing, marketing/sales, product development, training and education, and management systems (quality, environment, 'OHS'[5]) (De Graaf, 2002).

Table 3.3: An example of feedback on the proposition 3 (De Graaf, 2002)

Proposition 3 – Environmental aspects of your products are important for your company's image
Explanation If your company, product, material of process gets special attention from the environmentalists, this can influence the public opinion about your company. You can also distinguish your company in a positive way because of your good environmental performance. You 'green' image can be important for the surrounding community and investors.
Agree Environmental aspects are important for your company's image. By implementing POEMS will be informed about the environmental aspects of your products throughout the product supply chain. You can reduce the environmental impact and improve the company's image.
Disagree Environmental aspects are at this moment not important for your company's image. Keep in mind that this might change in the future.
Unknown Environmental aspects could be important for your image. By implementing POEMS, you can find out if it is important and you will be informed about the environmental aspects of your products in the product supply chain. You can reduce the environmental impact and improve the company's image.

[4] The website was entitled as 'Products & Environment', and was planned to launch in January 2003 as an extension to www.milieuwinst.nl (De Graaf, 2002).

[5] OHS (or OH&S): Occupational Health & Safety

This AIDA model combined with POEMS shows the possibility of a sector- or company-specific approach that participated firms can primarily understand the basic concept of POEMS and tailor this tool according to their own needs. It demonstrates that the preliminary work increases motivations of adopting POEMS and has a strong advantage to build up capacity and desire so that company can effectively deal with potential barriers in the POEMS project. It also indicates that the integrated approach provides a framework for sufficient communication among the users. In particular, a customisable form of the POEMS supported by the AIDA can be helpful for SMEs regarding the nature of a variety of SMEs.

However, there is an arguable issue of whether this tool can be used by new users or those who want to find out their own motivations with less effort and without expert support (self-help format). Thus, this exploratory research particularly scrutinises the linkage between the checklist test of the 'desire' phase of the AIDA and the POEMS process because it may give an insight in terms of the diagnostic approach of POEMS. Each proposition in Figure 3.5 may be involved in particular subject(s). For instance, POEMS benefits (proposition 1), customer demand (proposition 2), company image (proposition 3) or legislation compliance (proposition 4) can be the subjects of drivers or motivation of implementing POEMS. Hence, this research translated the propositions and categorised into five subjects, presented in Table 3.4. It might be helpful to make a clear understanding of the specific consideration or implication of the propositions.

Table 3.4: Issue categories interpreted from the test propositions in the checklist test of the 'desire' (see Figure 3.5)

POEMS-related information	
Understanding of POEMS	Q1: POEMS benefits
Drivers or motivations	Q1: POEMS benefits
	Q2: Customer demand
	Q3: Company image
	Q4: Legislation compliance
	Q7: Internal demands of employees
	Q8: Market benefits from environmental product labels
Managerial and operational performance	Q5: Existing quality or environmental management system
	Q9: Environmental profiling of products
	Q12: Product development/innovation plan
	Q13: Product development/innovation plan
Product-related subjects: product's environmental aspects associated with	Q3: company images
	Q6: competitors
	Q7: employees' awareness
	Q8: environmental labels
	Q9: environmental profiling
	Q10: customer use
	Q14: cost or price
Product chain-related subjects	Q11: Information of (production) processes of the suppliers

The checklist briefly covers the relevant areas of POEMS such as the product dimension, the management aspects incorporating product side, supply chain, etc. The companies that have gone through the AIDA process should be sufficiently informed about POEMS so that they could already comprehend the relevant areas of the issue categories, answer the propositions, and proceed with the rest of the actions required in the POEMS.

However, there is a condition that this checklist might be only feasible when the preceding phases of the AIDA model are executed and the information and knowledge are sufficiently appreciated by the users. For those who have no experience or knowledge about POEMS or relevant activities and who do not have an external support, it is hard to expect that they can effectively use the checklist or the POEMS itself which the follow-up actions unable to be realised. It may be because the project was performed as a speaker rather than a listener. The tools were designed to specifically give a full attention to the tools themselves, which led the project team to concentrate more on the introduction of the tools than on identification of the general interest of environmental issues for the companies. In order to overcome these problems, POEMS with a diagnostic approach needs to be developed in a self-help form for inexperienced users.

3.3 Result and discussion

This research conducted the comparative analyses in terms of processes, main stages and elements of POEMS, and also in-depth scrutiny of the preliminary approach of the two POEMS models. The main findings are summarised in Table 3.5.

Table 3.5: Summary of the analyses results

Analysis 1: processes and stages Analysis 2: key elements and their position Analysis 3: comparative allocation of the key elements	
Research problems 1: A broad scope to handle by SMEs	
Analysis 2	• Even in 10 POEMS models, a substantial amount of elements (more than 100 elements) is directly and indirectly associated with the product-related environmental work
Research problems 2: Diverse structures in process, stages and elements	
Analysis 1	• Different stage for same or similar elements depending on the models • Some models focus on initial step (e.g., review, plan stages) while others cover entire process • Some models focus on management structure rather than practical or operational elements • Some models handle the elements collectively while others handle separately (e.g.,

	management dimension or product dimension)
Analysis 3	• A wide variation of the positions of the key elements (about 40%) in the process while only 18 % of the elements in the same stage
Research problems 3: An imbalanced approach to overall elements	
Analysis 2	• Too much concentration on review and plan stage: some activities in review and plan stages, compared with the three follow-up stages, are regarded as most significant, and thus many POEMS projects end up implementing the first part of the process • A lack of addressing potential elements or detail information in other follow-up stages
Research problems 4: A lack of the relationship between the elements or stages	
Analysis 2	• Some elements are influential across many stages (e.g., communication, cooperation, establishment, maintenance and supply of information system), but no consideration of relationships with other elements in most models • Some models consider marketing and sales throughout whole process of POEMS whereas others do not even mention it • A lack of relationship (integration and interpretation) between managerial and operational areas
Research problems 5: A lack of clarification of the contents	
Analysis 1	• Diverse terminologies and interpretation of the same elements: e.g., 'evaluation' covers too general scope of elements, which some models translate it as revision or monitoring of POEMS performance while others mean evaluation or assessment. The meaning of 'fixation' or 'embedment' includes evaluation, and continuation and routinisation in some models.
Analysis 2	• A lack of clarification of functional areas of the elements: most models did not clearly define some elements in both managerial and operational (e.g., setup of objectives/targets) • Some key elements can be widely considered in the POEMS process (e.g., cooperation and communication) but lack in specification • Integration of POEMS in existing system is appeared in various stages in the models. For instance, in plan stage, some models emphasise integration of the first results of environmental profiling into existing system while others interpret integration as applying the achievement of the project into existing EMS or other systems which is happened to be final stages such as evaluation or continuation and routinisation. However, the contextual meanings between different translations of the models are quite consistent about the concept of integration. It clearly shows that lack of clarification of contents embedding a certain implication exists and no considerations of the relationship between the differently defined or named elements that have same contextual meaning, as well as some other elements that are performed in similar functions or have similar purposes.

Research problems 6: A lack of diagnostic approach	
Case 1 (SWOT)	Benefits • Potential development of POEMS for sector-specific support (but unrealistic for individual SME)
	Shortcomings • Focused on a particular sector (plastics recycling industry) mainly dealing with particular issues such as eco-efficiency of material and energy • Not feasible to directly apply to other sectors or individual SMEs as it requires pre-conditional establishment of environmental information system in sectoral level
Case 2 (AIDA)	Benefits • Potential development of POEMS comprising diagnostic programme by increasing motivations and desires • Briefly covers important and relevant areas of POEMS • Flexible and possible to tailor POEMS toward sector- or company-specific approach • Encouraging communication among the users with suppliers
	Shortcomings • Not feasible for new or inexperienced users about POEMS or the relevant areas • Not self-help tool

3.3.1 Research problem 1: broad scope

The result of the analysis 1 shows that the POEMS-related activities have a very wide scope to be handled by SMEs. Due to the fact that POEMS was fundamentally designed to cover whole life cycle of products, the POEMS method inherently encompasses various subjects. However, it is a huge challenge for SMEs to collectively tackle the extensive scope of POEMS. Therefore, identification of the prior problems not only in product aspects but also in organisational performance of management and operation is significant.

If a company would recognise which elements of POEMS are highly and frequently related to others, it would be much easier to make a decision for the company on which prior problems need to be tackled, in particular under the lack of competence. However, analysis result shows that there is no consideration of relationship between the elements. Hence, it is difficult to find prior areas of POEMS. In addition, many POEMS models concentrate on the establishment of environmental management system while the realisation of the management support into the practice of the product dimension especially eco-design development is hardly demonstrated. This is the reason that most models focus on the first two stages (review and plan) of the POEMS process and have a lack of clarification of the elements

With respect to this, how to present and deliver the elements of POEMS can be important more than to what extent of this tool would comprise the relevant elements. Considering the fact that SMEs tend to favour pragmatic approach focusing on a single environmental aspect instead of dealing with various issues at the same time, further development of POEMS can be directed at how to practically and user-friendly integrate the fundamental principles of POEMS within its framework.

3.3.2 Research problem 2: diverse structure of process, stages and elements

From the analysis 1 and 3, the various elements of POEMS are not delivered in a unified format. Although many elements that have similar or same purposes, only 18 per cent of the elements take place in the same stage while 40 per cent are allocated in different stages. Thus, it is hard to justify a clear structure and contents of POEMS, which SME users are hard to comprehend. The considerable diversity in the structure of the existing POEMS models means that POEMS can be far different depending on conductors. Moreover, the POEMS models have been developed and applied to particular industries with specific purposes and areas of environmental improvements.

One of the reasons of these different interpretations about the POEMS elements is related to a lack of methodological development such as a standardised structure and a clear outline of the contents. Ammenberg and Sundin (2004a) support this opinion that POEMS has been mainly developed in practice-based approach rather than methodological development. Another reason is presumed to lack in a collective consideration, which certain elements of POEMS, such as information system (gathering, maintaining, using etc., see the element 23 'information building and supply' in Figure 3.4), need to be taken account throughout the whole process. However, the analyses results show that those elements are not dealt with in consistency. Besides, some models stress certain elements while other models completely ignore them. Conclusively, it is found that a substantial number of the key elements is disconnected throughout the process and translated differently. In this respect, POEMS needs to be developed in the sense that the process and structure can be more generalised and standardised. In line with this, the prioritisation of elements can help companies' decision-making by identifying the relationship between requirements, and, thus, a company would be able to manage them in a collective way.

3.3.3 Research problem 3: imbalanced approach to elements

As seen in the analysis 2, imbalanced approach of contents and overall elements are found. Most POEMS models concentrate on first two steps in their processes especially the 'review' stage. Some activities in review and plan stages, compared with the three follow-ups, are over emphasised as Brezet and Rocha (2001) state too much attention to the profiling environmental impacts of product than other elements in the product chain. For instance, potential activities in relation to continual improvement towards innovation of organisational system are relatively untouched in most models. There is a variety of needs and levels of ambition depending on companies' capabilities and situations. A company that has achieved certain level of improvement may step further towards a system innovation. In this case, an introductory or preliminary level of POEMS approach would not work. It reflects the fact that not enough cases of research or experiences in the subject of 'continuation or routinisation' have been done and POEMS has not been sufficiently introduced to industry yet. It is expected that formulation of a certain rule in this stage can help a company take further actions. In the future, POEMS needs to evolve to dealing with all possibly relevant elements in a systematic way.

3.3.4 Research problem 4: lack of considerations of relationship between stages or elements

Although many elements in different stages have a close relation to or effects onto other factors, possible relationships are hardly exploited in the models. For example, in the analysis 2, some elements such as communication and cooperation, and information system (build-up, maintenance and supply) are appeared along the most stages in some models but there is no consideration of relationship between relevant sub-activities. in addition, there is also an insufficient consideration about integration and interpretation between the managerial and operational areas as described in the analysis 2. Thus, a supportive structure between the two sides cannot be established, which is difficult to overcome the reality, as mentioned in Chapter 1, that most SMEs perceive the environmental improvement (e.g., environmental profiling of products) is responsible for the design areas (Woolman and Veshagh, 2006).

Furthermore, a lack of consideration of relationship between elements may hamper to identify prior elements and increase efficiency to handle the elements in collective way. There are some tasks that are not selected as important elements but certainly have a relation to anther key element. For instance, evaluating existing information system in the review stage could be the basis for building or improving information system and also related to corporate capability. However, this aspect is not much mentioned in the models but can be categorised in the information management. Therefore, identifying relationship between elements of similar activities across stages could improve the effectiveness for dealing with POEMS activities in a collective way within the limited time and staff in SMEs.

3.3.5 Research problem 5: lack of clarification of contents

In analysis 1, 2 and 3, clarification of POEMS contents are exposed. Firstly, many models use and translate the terms differently. Secondly, functional and responsible areas of the elements are unclear at least by addressing which managerial or operational sides are involved. Thirdly, some key elements can be widely considered in the process (e.g., cooperation and communication, information and integration) but lack in specification. For instance, integration of POEMS in existing quality or environmental management system is seen in various stages in the models. Some models state the integration of the results of environmental profiling into existing system in 'plan' stage whereas others interpret the integration as applying or embedding the achievement of the project into existing EMS or other systems, which are happened to be in final stages such as 'evaluation' or 'continuation and routinisation'. However, the contextual meanings of the concept of integration between different translations along the models are quite consistent. It clearly shows that lack of clarification of the contents embracing a certain implication exists. In addition, there are is no consideration of the relationship between the differently defined or named elements, which have same contextual meaning, as well as some homogeneous elements, which are performed in similar functions or have similar purposes. Therefore, the contents of POEMS need to be clearly outlined in a collective way, in which the elements are clarified with specific functional areas or stages and/or defined by priorities.

3.3.6 Research problem 6: lack of diagnostic approach

Through the in-depth review of two cases of preliminary tools, there are benefits and shortcomings are drawn up. The SWOT analysis integrated with the POEMS model could be useful in improving POEMS for sector-specific support. However, the project focused on the plastics recycling industry mainly dealing with particular issues such as eco-efficiency of material and energy. Besides, to utilise the tool, it requires the pre-conditional establishment of environmental information system in sector level. Therefore, it does not guarantee that this tool can be feasible to directly apply to other sector or individual SME.

In the second case, AIDA tool for tailoring POEMS shows potential development of POEMS comprising a diagnostic programme by implementing additional process in order to increase motivations and desires. It also briefly covers important and relevant areas of POEMS, which is a strong benefit. However, the successful implementation might be fulfilled only when sufficient communication and information are supplied to the companies. It is questionable whether it is practicable for those who are not familiar to or inexperienced in POEMS or the relevant areas.

In summary, there are several points need to be addressed in developing a POEMS model with a diagnostic approach. Firstly, a diagnostic tool needs to start with general issues in business context of environmental aspect such as a firm's interest areas as identified in the main drivers before, rather than straightforwardly go to the point of POEMS. Secondly, it needs to be approachable to the companies relatively new in the environmental business so that they can use without additional help or preceding stages. Thirdly, the diagnostic tool can be used within the POEMS framework, which means that the diagnosis result should serve in tailoring the POEMS for the company's needs. Regarding this, the checklist format in the second model has a great advantage to identify the current situation and interest or focus areas of a firm. Hence, it is recommendable to develop this format for further improvement of the diagnostic method.

3.4 Conclusion and propositions for model development

In the discussion of the results and findings from the analysis of the exploratory research, directions have been deduced for further development of POEMS. In the Table 3.6, each validating subject of the further research problems is summarised in the left column, and potential directions by interpreting the arguments from the findings are represented as key words in the right column. Overall five propositions are drawn up as follows:

1. Establish a basic procedure and usable format
2. Clarify contents and specify key functional areas
3. Prioritise functional areas or elements
4. Identify correlations between elements, stages or functional areas
5. Develop a diagnostic tool reflecting three aspects
6. Minimise the extent of expert intervention

Table 3.6: Propositions for the six research problems to improve POEMS

1. Broad scope to handle by SMEs	
• Identify prior areas in order to focus • Possible to collectively tackle POEMS activities or elements	Prioritisation Correlation
2. Diverse structures in process, stages and elements	
• Establish a basic structure • Clear outline of the contents and their right allocation into categories of functional areas or units • Prioritisation of elements • Identification of relationship between requirements	A basic structure Clear outline of contents Prioritisation Correlation of elements
3. Imbalanced approach to overall elements	
• Outline the relevant elements in the follow-up stages • Meet the various scope of needs in different level of ambitions	Clear outline of contents Diagnostic / customisable
4. Lack of considerations of the relationship between the elements or the stages	
• Establish a framework of the contents with a consistency between homogeneous elements • Lack of interpretation and integration of the elements in managerial and operational sides • Prioritisation of elements	Correlation Clarification/ specification Prioritisation
5. Lack of clarification of the contents	
• Coherent use, implications (meanings) and interpretations of terms • Clarify functional and responsible areas of the elements at least by addressing which managerial or operational sides are involved • Specify the implication of an element even performed or considered in different stages • Consider relationship between elements and identify homogeneous elements • Clearly outline the contents of POEMS in a collective way → clarify elements, specify functional areas or stages, and define priorities	Clarification Clarification Clarification Clarification Correlation Clarification
6. Lack of diagnostic approach	
• Start with general issues such as identifying a company's main drivers or interest and focus areas • Provide an approachable self-help format to new users or those unfamiliar with environmental issues • Integrate diagnosis within POEMS or tailor POEMS	

Chapter 4 Model formulation

Chapter 4 delineates the procedures needed to compose a conceptual C-POEMS model and a diagnosis template. Additionally, it also provides an overview of background theory, and finally a description of how the model was formulated. This chapter is comprised of two parts: firstly, the modelling framework of background theory, and secondly the development of the conceptual C-POEMS model and its diagnosis template.

4.1 Modelling framework

In this section, a component-based modelling approach is introduced that can embrace the propositions derived from the exploratory research of Chapter 3. In addition, POEMS itself is an organisational management approach specialised in environmental areas and the component-based approach is mainly related to enterprise systems and information systems. Therefore, considering the possible common ground between these two fields, the component-based approach could provide important insights for building a conceptual C-POEMS model. This section reviews the basic concept and main characteristics of the component-based architecture in enterprise systems.

4.1.1 The concept of component based approach

The component-based concept is widely applied to various fields that range from knowledge and information management to business processes. The theory initially developed in the software engineering field. According to De Cesare *et al*. (2006), '*component-based development (CBD) is a broad paradigm for the development of software. It was discovered very early in the software-development game that system ought* *to be built in modular fashion, rather than as monoliths incapable of work subdivision and incremental development, as well as devilishly difficult to modify as the requirements for them inevitably evolve. Software is built to be modified and thus needs to be modifiable. With time, the ideas regarding modules, each encapsulating a relatively independent aspect of the overall design, has evolved into the concept of software components*'.

The general meaning of 'component' is: '*components are for composition' as most people perceive* (Szyperskik, 1998, cited by Larsson, 2000). However, a broadly acceptable definition that every body agrees may not be possible. Although there are many attempts to define 'component', there are still differences that exist between definitions (Cox and Song, 2001; Larsson, 2000). Among the plethora of definitions of components, some researchers (Cox and Song, 2001; Darby *et al*., 2001; De Cesare *et al*., 2006; Finneran, 1999; Larsson, 2000) summarise key issues of definition as depicted in Table 4.1.

Table 4.1: Definitions of component (author's own compilation)

Author	Definition of component
Philippe Krutchen, Rational Software*	A component is a nontrivial, nearly independent, and replaceable part of a system that fulfils a clear function in the context of a well-defined architecture. A component conforms to and provides the physical realisation of a set of interface.
Gartner Group*	A run-time software component is a dynamically bindable package of one or more programs managed as a unit and accessed through documented interface that can be discovered at run-time.
Clemens Szyperski, Microsoft*	A software component is a unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third parties.
Wojtek Kozaczynski, SSA*	A business component represents the software implementation of an 'autonomous' business concept or business process. It consists of all the software artefacts necessary to express, implement, and deploy the concept as a reusable element of a

	large business system.
D'Souza D.F. and Wills A.C. (1997)**	A component is a coherent package of software that can be independently developed and delivered as a unit, and that offers interfaces by which it can be connected, unchanged, with other components to compose a larger system.
Kara (1998)+	Component-based development is defined as the process of building systems by way of combination, aggregation, and integration of pre-engineered and pre-tested software objects.
Darby *et al*. (2001)+	Component software allows complete applications to be created out of small pieces of software, or components.
Stevens *et al*. (1997)+	Each component has well defined functionality and will blend with existing pieces to form a completely integrated application.
Finneran (1999)++	A component is a self-contained, reusable building block that can be used independently or assembled with other components to satisfy enterprise requirements.

* Referred to in De Cesare *et al*. (2006), and Larsson (2000)

** Referred to in Cox and Song (2001)

+ Referred to in Darby, Bishop and Ciliers (2001)

++ Referred to in Finneran (1999)

4.1.2 Characteristics of component-based framework

From the various definitions, there are some distinctive characteristics of the component-based development. The common features of the component-based development concept can be abstracted into a componentisation process that: 1) breaks down a complex system and mass of problems into simpler pieces, which can be independently deployable; 2) describes and performs specific problems, which require well-defined functional units; 3) provides the functionality in a coordinated manner by defining interfaces and integrating the components and functional units, which hide the implementation, namely, 'black-box', but mainly oriented in software system.

(1) Modularity and decomposition for componentisation

Regarding the self-contained functionality, Goodman and Rozen (1994) explain the profound notion that '*the component-based approach is appreciated in the classical method of modular software design, and shares its many benefits*'. In a general context, the idea of modularity is inspired by the problem-solving approach in human history (*Ibid.*). Complex problems can be clarified and simplified by dividing a complicated system and problems into a set of simpler and more comprehensible components and sub-problems, and the problems of integrating the sub-solutions into a complete solution (*Ibid.*).

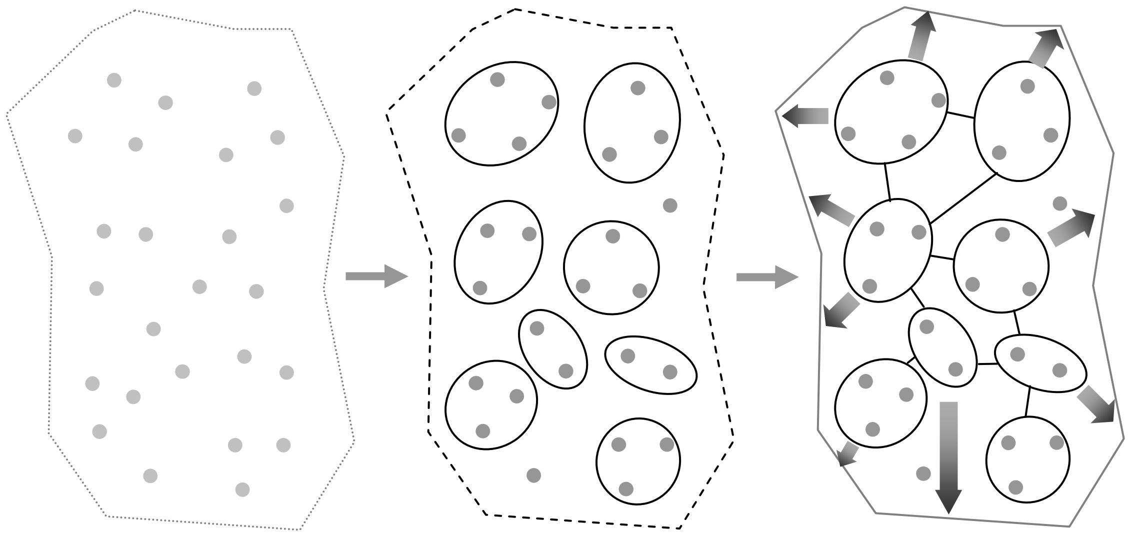


Figure 4.1: Decomposition, modularity, and integration of componentisation in problem-solving process

In a complicated system, problems are often unidentifiable and ambiguous, which limits the ability to see problems structurally. Decomposing the system into sub-problems makes the problems simpler and clearer, and allows one to be able to see the whole picture of the problems constructively. Also it is easier to recognise the interface between problems or functions, once the problems are decomposed to a number of functions. Hence, the problems can be resolved either by the sub-solution of the independent components or the complete solution of integrating sub-solutions of assembled components with others. Therefore, it is said that the essence of a good system design is finding decomposition within the properties of a system, which requires skill and experience (Goodman and Rozen, 1994).

(2) Well-defined functional areas or units

De Casare *et al*. (2006) note that 'unit of composition and independent deployment' are relative concepts and dependent on context. However, in composing units, the overall number of elements needs to be appropriately defined along the relevant enterprise architecture. For example, in knowledge management and enterprise systems, a component handles a specific event or a related set of events, and provides a particular function or group of related functions through a clear and balanced interface as all components inherently consist of one or more interfaces, component decision event handlers, and component behaviour activators (Finneran, 1999). Gudas and Pakalnickas (2006) argue that information systems (IS) using component-based systems of management should have a clear definition of functional domains in enterprise architecture as well as collaboration between the components. The components need to capture the business requirements (*Ibid.*) and can be developed and loaded to respond to specific tasks (e.g., data collection, material accounting, scheduling or control of machines) (Darby *et al*., 2001). This attribute makes each component a self-contained and functional unit (*Ibid.*). Gudas and Pakalnickas (2006) quote an example of the paths of the component-based system model from the business point of view as follows:

- *Business processes domain (BPD): include the business processes, critical to the enterprise's functionality and development, for marketing, operation strategy, manufacturing planning, and human resources management;*
- *Information processing domain (IPD): identifies the major information processing activities that the enterprise performs to produce business driven decisions and products;*
- *Information domain (ID): includes the activities aimed to organise data and knowledge, necessary for the enterprise management and product development; for example quality control standards, products and process definitions, inventory files and etc.;*
- *Product technology domain (PTD): includes the technological processes and facilities for the development of the enterprise products and services; for example product design, materials processing and handling;*
- *External environment domain (EED): includes the activities aimed to organise the processes with the enterprise suppliers and clients.*

(3) Integration and interface between components and functional units

Problem-solving process based on component structure requires integration of sub-solutions into a complete solution as explained before by Goodman and Rozen (1994). Under this incorporation, each group of the components can interact with the systems as well as other sub-systems by sharing the information and ultimate goals. Regarding this, it is important to define logical interfaces of components that could include the interface between data or information of components, and participants (or handlers). Therefore, the participants can utilise the business rules, and determine component behaviours by which component needs to be activated, during the componentised application (Finneran, 1999).

For instance, in the application of component-based concept to information system (IS), the research in component-based IS has broadened the topic areas from organisational to technological issues (De Casare *et al*., 2006) and is aligned with IT architecture (Gudas and Pakalnickas, *Op.cit.*). The need for improvement in IS by adopting the component-based approach was based on how the created system would interact with and support various functions in the business whereas the traditional approach to engineering IS often focus on identifying business requirements (Takeshita, 1997, cited by Gudas and Pakalnickas, *Op.cit.*) and delivering the specific functionality required to automate some activities (Gudas and Pakalnickas, *Op.cit*.). Since there have been attempts to reduce the gap between business requirements and systems implemented to support these requirements, enterprise architecture has been developed by many organisations in order to provide a holistic vision of the support mechanisms (*Ibid.*).

In this regard, Gudas and Pakalnickas (*Op.cit.*) show the evolution of IS by integration of component-based development. For instance, in Figure 4.2, the authors illustrate IS development in three approaches: enterprise architecture (EA), the business process models (BPM), and the object-oriented analysis and design (OOAD), which are used in different levels of domains in the IS development process. However, it is found that BPM, EA and OOAD development are often disconnected (*Ibid.*). Considering the fact that either from BPM to OOAD, or from EA to OOAD are common methods of processing IS development as seen in Figure 4.2, Gudas and Pakalnickas, (*Op.cit*.) claim that the disintegration among the three models could create problematic gaps in translation between the business's vision and structure of hierarchical levels and the system implemented to support business requirements. A component-based approach (the dotted circle in Figure 4.3) was suggested in order to bridge the gap between the activities of IS development by integrating elements from different modelling techniques (*Ibid.*).

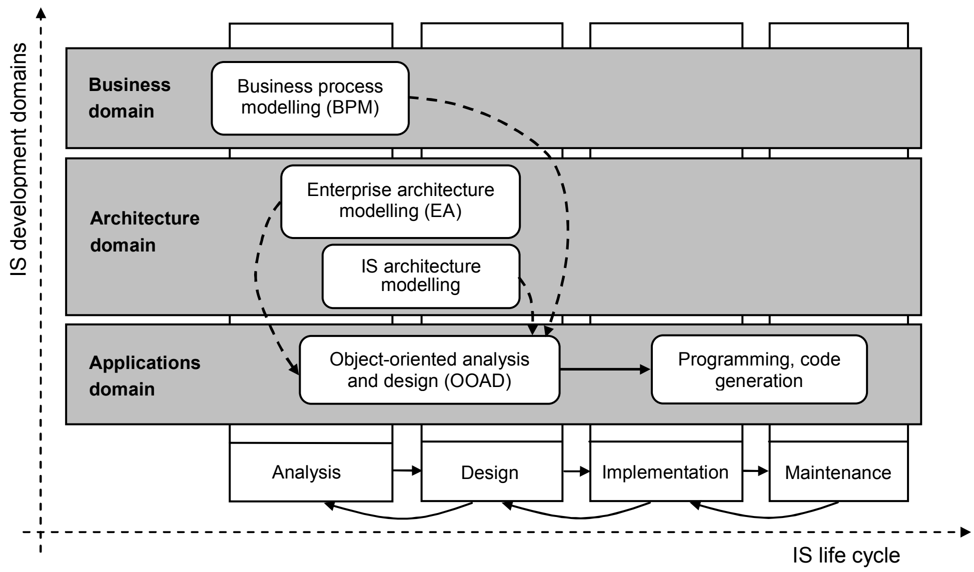


Figure 4.2: IS development activities (Gudas and Pakalnickas, 2006)

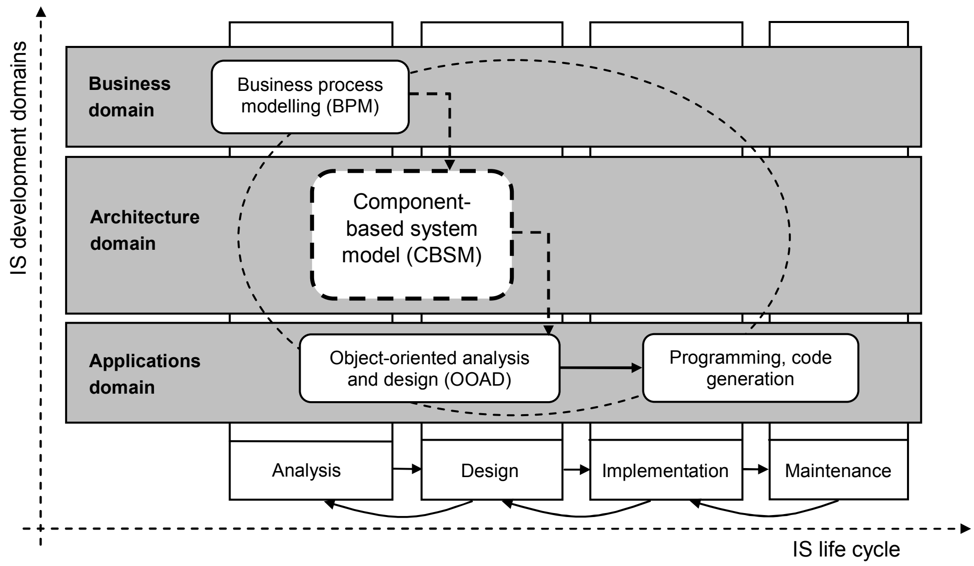


Figure 4.3: The place of the component-based system model in the IS engineering process (Gudas and Pakalnickas, 2006)

In summary, a successful componentisation can bring business solutions by handling interrelated components to satisfy enterprise requirements while sustaining its objectives and achieving its vision. For this, it is required to have appropriate decomposition, and well-defined functional areas with elements, integration and interface of components and functional units, which business requirements are integrated into and which have semantic consistency throughout relevant functional units as well as relevant business tools.

4.2 Development of a conceptual C-POEMS model

Taking advantages of the component-based development, a new POEMS model can be formed in the way that decomposes its structure into main stages (or phases) of the process, functional areas, and elements. In Figure 4.4, the strategies of the componentisation are translated into that;

- decomposition of a system into elements can mean ‘factorisation’ that identifies and clarifies elements of POEMS,
- decomposition of a system into functional areas or units can mean ‘categorisation’ of relevant elements, and
- relationship between functional areas can be identified by ‘correlation’ between categories and/or elements.

This research additionally highlights ‘prioritisation’, which aims to discover more important areas of POEMS. Both ‘correlation’ and ‘prioritisation’ can help companies clarify focal areas for environmental improvement and enable them to collectively deal with priority areas. However, the existing POEMS models have not considered this approach at all. Thus, prioritisation and correlation need to be defined through later primary research.

This research proposes four concepts (factorisation, categorisation, correlation and prioritisation) as hypotheses. The details will be explained in Chapter 5. Primary research into methodologies validates the four suggested concepts, which is also explained in Chapter 5. In particular, the 'prioritisation' of categories of functional areas and/or elements of POEMS will be clarified, which is assumed as a first attempt in the field of POEMS research. The following section presents a set of propositions for developing a component-based POEMS (C-POEMS) model. The aforementioned componentisation process is applied in three ways to a C-POEMS modelling procedure.

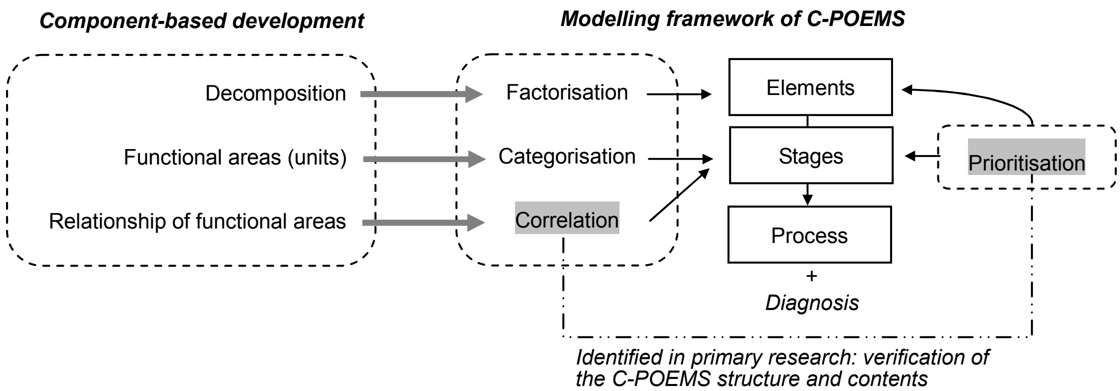


Figure 4.4: Componentisation of modelling framework of the conceptual C-POEMS model

4.2.1 Component-based structure

For developing a conceptual C-POEMS model, a procedure of componentisation consists of the following steps. Firstly, the factorisation of relevant elements is made by collecting all possible activities or considerations associated with product-related environmental improvement, from the 18 POEMS-related studies in Chapter 2. It is because the key research question (4) (provision of a generic and specific guide – see Chapter 1.4) should be sustained in the new model. Regarding this, the 42 elements initially established in the exploratory research in Chapter 3 might not be sufficient to cover the generic information. The potential activities or considerations of POEMS are then decomposed into elements if necessary. However, most of them are sustained as they are.

Secondly, the elements derived from the previous step are 'categorised' into functional areas or units. It means that all relevant elements of POEMS are re-defined and classified into several categories of functional areas or units which can be performed in the functional level of an organisation.

Thirdly, the categories of functional areas or units are allocated into the associated stages. In this step, the common process with main stages, which were derived from the exploratory research in Chapter 3, was used as a base. However, some stages need to be changed. For instance, in order to establish a diagnostic approach integrated with the C-POEMS, the previous 'review' stage is replaced to 'diagnosis' that includes most elements of the 'review'. But, the new 'diagnosis' stage is designed by classifying the elements into different categories, while the most existing POEMS models consider them collectively. Also, the 'evaluation' and 'continuation' stages that have been separately performed are combined together into 'evaluation/continuation', because some of the elements in the two stages are closely connected, overlapped or continued throughout the process of POEMS in many existing POEMS models. A new stage, named 'knowledge building', is added and its relevant elements are defined. Although many POEMS models significantly considered information building, maintenance or supply, etc., these elements did not clarify which functional areas or units could comprise of the elements of the information system. This research attempts to provide a clearer structure for elements within the 'knowledge building' stage.

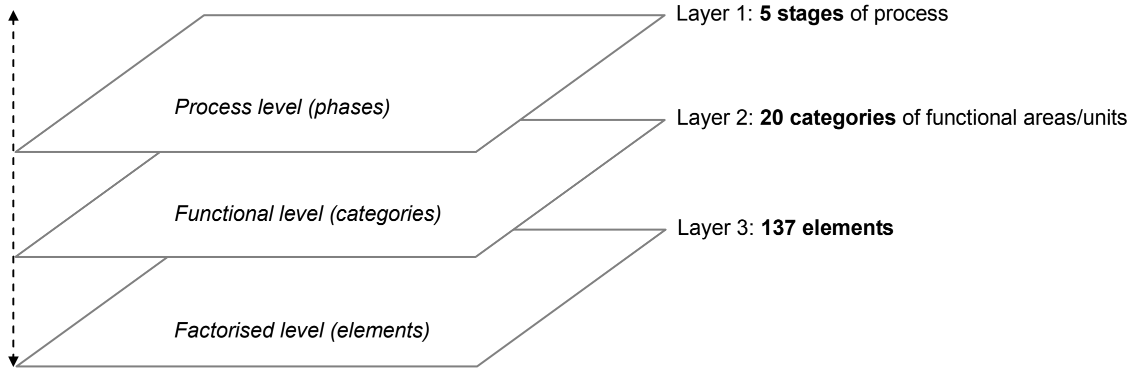


Figure 4.5: Hierarchical structure of the conceptual C-POEMS model

Through the procedure of componentisation, the component-based structure of a C-POEMS can be finally generated. Components in the C-POEMS mean main sub-systems that have three layers in a hierarchy depicted in Figure 4.5. The first layer from the top indicates the process level comprising of the main stages (Diagnosis-Plan-Implementation-Knowledge Building-Evaluation/Continuation). The second layer means categories of functional areas or units that implement key business operations of POEMS in a corporate functional unit or multi-functional units with different disciplines. Compared with the functional areas defined in the model by Schmidt, Christensen and Øllgaard (2002) (see Figure 2.2 in Chapter 2), the C-POEMS has more categories (up to about 20). In the third layer, there are 137 elements that are re-defined and re-arranged according to the categories. The details of the categories and elements are explained in the following sections.

4.2.2 Process with main stages and categories

The C-POEMS process (layer 1) consists of five stages; diagnosis, plan, implementation, knowledge building, and evaluation/continuation. Each phase has its own categories of functional areas or units (layer 2) as illustrated in Figure 4.6. Each category is denoted (e.g., PS1, PS2, etc.) with which PS signifies ‘process step’ and PR means ‘process routine’. The categories in ‘process step’ likely take place in a certain stage of the process when implementing a C-POEMS project whereas ‘process routine’ can be considered along the entire process of the C-POEMS. For instance, information system (PR14) in the ‘knowledge building’ is the case of process routine.

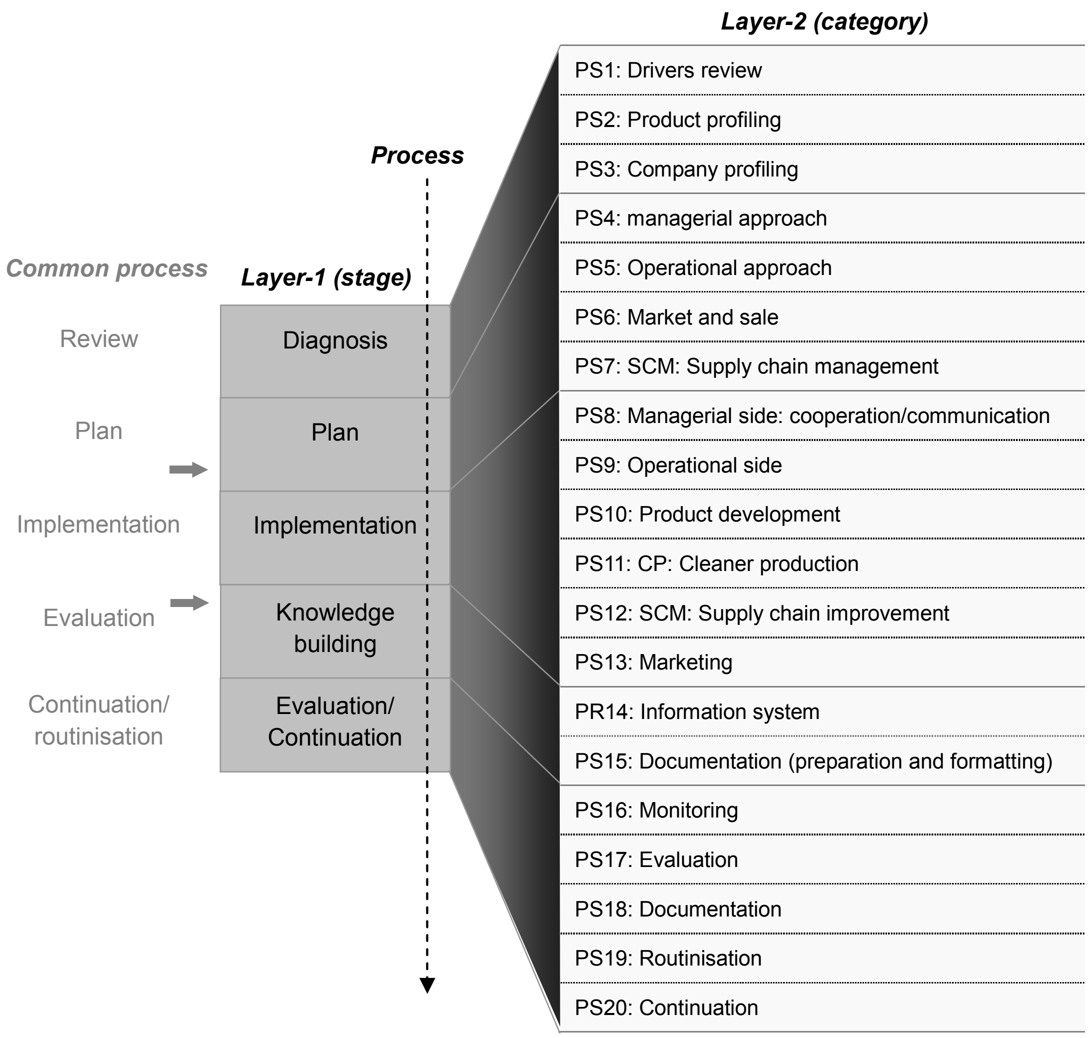


Figure 4.6: Main stages and categories of the conceptual C-POEMS model

In order to deploy POEMS elements into categories of functional areas or units, this study examined the structure of the POEMS programme of the Danish EPA (see Figure 2.2 in Chapter 2). According to the POEMS manual of the Danish EPA (Schmidt *et al*., 2001), the functional areas of POEMS cover six parts; management, production, marketing, sales and services, product development, procurement, and logistics. However, this structure offered very basic and limited information in each functional area, which means other activities of POEMS potentially related to certain functional areas might be ignored. Also the issues in the functional areas are handled collectively or defined vaguely. For instance, 'management strategy' in the management function would have more detailed issues such as corporate environmental strategy, environmental product strategy, management support for eco-design, etc. Therefore, some issues implying more sub-issues need to be factorised into more detailed categories of functional areas. This research has employed the basic structure of the Danish EPA programme, but elaborated the architecture of the C-POEMS by adding or dividing and re-deploying the categories of functional areas.

In addition, the supportive approach between management and operational sides of the POEMS model by Brezet and Rocha (2001) (see Figure 2.7 in Chapter 2.4.1) was adopted in the categorisation of the C-POEMS development. According to the model of Brezet and Rocha (2001), managerial and operational sides have their own roles, but are both oriented to support the product dimension through, for instance, eco-design. This supportive structure is hardly demonstrated in the other POEMS models, although it is the key characteristic of POEMS distinguished from the EMS standards. Thus, this research has taken this account and applied to the C-POEMS structure, when especially constructing the 'plan' stage of the process by dividing managerial and operational sides and clarifying the relevant elements.

The stages and categories of a C-POEMS can be implemented as a component (selectively) or as a whole (collectively). For example, if a company wants to conduct an assessment of a product's environmental impacts in the 'product profiling (PS2)', the company can use LCA for full and in-depth screening of environmental impacts of the product and product chain by using 'various LCA tools'[1], or go for more streamlined LCA just by applying the life-cycle concept in qualitative assessment of environmental issues. The following section presents the details of each stage of a preliminary C-POEMS model.

(1) Diagnosis

Most existing POEMS models emphasised the elements of the review stage as a crucial part as well as the starting point of a POEMS application. The 'diagnosis' stage consists of three areas including drivers review (PS1), product profiling (PS2) and company profiling (PS3). It aims to gain a clear overview of environmental issues surrounding a company, and to inspect the environmental impacts of a product and product chain. The product dimension (e.g., the regulation compliance of a product) is not the only issue to be covered, but also other requirements such as consumer (customer) demands or an existing system's ability to deal with environmental product development need to be outlined.

By doing so, a company can reveal the internal and external drivers of product-oriented environmental care so that it can obtain a clearer view of what specific management

[1] For more information: IVL (Jöbbrink and Erixon, 2000) has published 'LCA software survey' report that provides comparative information about 24 LCA software in price range for a licence, time of learning, data format, etc.

support is required and who would be involved. Moreover, identifying the most significant environmental impacts and/or benefits would direct decision-making on selecting targets and forming strategies and policies for the environmental improvement of products or product chains. Some other elements such as the systematic management of environmental information can be examined in the ‘diagnosis’ stage.

(2) Plan

In this stage, the company establishes an environmental strategy, product policy, and so on, based on the diagnosis results. Detailed targets and objectives for the C-POEMS project (including separate eco-design project) are set up too. The ‘plan’ stage encompasses four functional units; managerial side (PS4), operational side (PS5), market and sale (PS6), and supply chain management (PS7). The ‘managerial side (PS4)’ focuses on the environmental support for a product dimension within the existing system. For instance, planning includes the establishment of a strategy, the determining of innovation targets, the identification of related areas as well as the networking and coordination of a corporate system (between product development and the rest of the system). On the operational side (PS5), the preparation and improvement of operations are required. For example, a company needs to allocate resources such as human, finance, technique, etc. Also, the relevant information of POEMS is gathered, for instance, general environmental information, management issues relating to the environment, the best available technique (BAT) for product improvement, information on markets and supply chains, and so on.

The elements of managerial and operational sides need to be incorporated, which is often disregarded in many POEMS models. For example, most POEMS models reviewed in the exploratory research in Chapter 3 concentrated more on setting up project targets and objectives, and on management support such as the allocation of responsibilities and resources, whereas marketing strategies and applicable tools are relatively untouched. Even though the POEMS models underline the importance of the market aspect in the 'review' stage, a strategic approach towards understanding market issues (e.g., marketing strategy, plan, etc.) is missing and not consistent during the 'plan' or 'implementation' stages. It might be because companies generally deal with marketing in the existing management system, and, therefore, the POEMS may not necessarily utilise it as a main area unless it is specifically required. In addition, product-related environmental certifications or schemes such as eco-labels are not sufficiently understood nor incorporated into organisations' environmental policies.

In this regard, although some elements may not necessarily take place in the 'plan' stage, this stage should generally ensure operational and managerial preparation and provide support for both so that every potential for environmental improvements in the C-POEMS project can be recognised. For instance, the C-POEMS model deploys market and sales units in the 'plan' phase, when environment-related certifications may be more appreciably and strategically used. Through incorporation of both operational and managerial sides, the initial ambition of improvements is also more likely to be maintained throughout the project.

(3) Implementation

The 'implementation' stage has five functional areas that aim at the execution of improvement actions in product and product chains. Product development via eco-design or other activities is implemented and the requirements of cleaner production (CP) are considered and adopted. Eco-design presumably is the main part of this stage, but a company may need to focus on other relevant issues of its product chain or production rather than product development. Such a strategic decision depends on the areas chosen by the company in the 'diagnosis' and 'plan' stages. The working group may need to carry out additional investigations in sub-projects on areas prioritised for improvements.

Interdepartmental cooperation and communication are allocated in both managerial and operational sides in order to support activities of development of product and product chain. The collaboration might be extended to outside of the company. For instance, operational teams may need to record and answer relevant enquiries about products, and to transfer to product developers if there are technical issues from stakeholders (customers and consumers) which could influence product options.

(4) Knowledge building

The 'knowledge building' is an interactive and collective sub-system involved in various stages and functional areas of the C-POEMS, which is usually represented as an environmental information system. In Chapter 1, research found that SMEs need more sufficient support for environmental information and knowledge especially for long-term improvements. Information and knowledge can be the source for the environmental culture of an organisation alive. In this respect, the C-POEMS model is particularly concerned about this issue. The 'knowledge building' stage has a notion beyond a functional aspect of general environmental information management, and extends corporate philosophy towards environmental changes in culture, employees' attitude, innovative mindset, etc.

During the data collection associated with the environmental information system of the existing POEMS models, very few documents were found. Therefore, it is hard to draw up a clear outline of the information system of the C-POEMS model. However, some POEMS models suggested and emphasised a few elements associated with an environmental information system. Based on this, the C-POEMS model has constructed the 'knowledge building' stage with two main categories; 'information system (PR14)' and 'documentation preparation (PS15)'. The 'information system' handles the design and management of information systems in relevant functional areas such as environmental profiling of product or product chain. The 'documentation' focuses on communication (e.g., information provision) with interest groups inside and outside a company. For instance, customers or other stakeholders (e.g., insurance company, local authorities, or the public) may require a company to disclose the information of its environmental performance. For this, the company needs to identify what levels or formats of environmental information are requested by the different stakeholders. Internally, employee concerns about environmental issues are also increasing. Responding to this, information regarding the problems and opportunities involved in tracking the environmental performance of a company needs to be provided to the employees.

(5) Evaluation/continuation

According to the result of analysis 3 in the exploratory research (Chapter 3), the elements of the 'evaluation' and 'continuation' stage take place in different steps depending on the POEMS models. Thus, it is difficult to define the position of the elements in these two stages. It means that the boundary between the elements of the 'evaluation' and 'continuation' is not explicit and justified so far. Regarding this, the C-POEMS model allocates the relevant elements of the both stages into a single territory, so that they can be collectively dealt with and performed seamlessly.

The aim of the ‘evaluation/continuation’ of the C-POEMS model is to review and assess the results and procedures of the C-POEMS work (e.g., strategies, improvement of products, performance, etc.). Ideally, the result of the evaluation would be the basis for further development and continuation. From the analytical review of the existing POEMS models, five key areas can be drawn up including monitoring, evaluation, documentation, routinisation and continuation. For instance, improved products, and the procedure and performance of the C-POEMS projects are monitored and evaluated. In the documentation step, after a project is accomplished, data is gathered in particular product-related areas and provided to other parties who request it. Collaboration must take place and the information should be modified so as to reach the various users. Furthermore, the integrated performance of the C-POEMS projects with existing systems (e.g., quality control and environmental management) is regarded as a ground for a company to continuously carry on environmental improvements, and to coordinate new measures of the C-POEMS with traditional management systems.

4.2.3 Elements

In addition to the 42 key elements derived from the exploratory research, some key elements are decomposed and more relevant elements are added. As a result, the preliminary C-POEMS model has 137 elements overall (see below where each element is numbered in Table 4.2). In the table, the 42 key elements are highlighted. In particular, the elements in PS1, PS2, PS11 and PS12 are critical in POEMS. Most elements are described fairly plainly. The following section explains several examples among these elements.

Table 4.2: Contents of the C-POEMS model: main stages, categories and elements

Stage	Category	No.	Elements
Diagnosis	PS1: Drivers review	ps1n1	Legislation
		ps1n2	Customers
		ps1n3	Stakeholders
		ps1n4	Competitors
		ps1n5	Market opportunities
	PS2: Product profiling	ps2n6	Legal compliance
		ps2n7	Environmental impact
		ps2n8	Environmental cost
		ps2n9	Environmental benchmarking/position
	PS3: Company profiling	ps3n10	Economical capability
		ps3n11	Technical capability
		ps3n12	Management capability
		ps3n13	Staff ability
		ps3n14	Share norm/value
		ps3n15	Environmental awareness
		ps3n16	Expertise support
		ps3n17	Communication-internal
		ps3n18	Communication-external
		ps3n19	Cooperation-internal
		ps3n20	Cooperation-external
		ps3n21	Corporate culture
Plan	PS4: Managerial approach	ps4n22	Establish business policy
		ps4n23	Establish business strategies
		ps4n24	Establish project objectives
		ps4n25	Establish innovation targets
		ps4n26	Identify related areas
		ps4n27	Establish procedures
		ps4n28	Establish network
		ps4n29	Establish systems
		ps4n30	Prioritisation (strategies, activities)
		ps4n31	Communication/co-operation
		ps4n32	Mutual agreement-internal
		ps4n33	Mutual agreement-external
	PS5: Operational approach	ps5n34	Resource allocation-human
		ps5n35	Resource allocation-finance
		ps5n36	Resource allocation-technique
		ps5n37	Allocation-responsibilities, authorities
		ps5n38	Supporting system
		ps5n39	Knowledge building-management
		ps5n40	Knowledge building-environment
		ps5n41	Knowledge building-supply chain
		ps5n42	Knowledge building-market
		ps5n43	Knowledge building-best available technique
		ps5n44	Integration with existing asset & system

Stage	Category	No.	Elements
Plan	PS6: Market & sale	ps6n45	Establish strategy-marketing
		ps6n46	Establish strategy-sale
		ps6n47	User/purchaser guidelines
		ps6n48	Environmental certificates
	PS7: SCM (Supply chain management)	ps7n49	Sustainable purchasing plan/guide
		ps7n50	Decision-making-suppliers/products
		ps7n51	Check communication
		ps7n52	Check cooperation
Implementation	PS8-a: Managerial side of cooperation with:	ps8a53	Project team
		ps8a54	Managerial & operational team
		ps8a55	Whole department
		ps8a56	Suppliers
		ps8a57	Customers
		ps8a58	Shareholders
		ps8a59	NGOs
		ps8a60	Other stakeholders-authorities, public etc
		ps8a61	Questions guide for customers cooperation
	PS8-b: Managerial side of communication with:	ps8b62	Establish formal interface
		ps8b63	Establish eco-design support
		ps8b64	Project team
		ps8b65	Managerial & operational team
		ps8b66	Whole department
		ps8b67	Suppliers
		ps8b68	Customers
		ps8b69	Shareholders
		ps8b70	NGOs
		ps8b71	Other stakeholders
		ps8b72	Record & answer enquiries related to product
	PS9: Operational side	ps9n73	Trace options for improvement
		ps9n74	R&D of chosen alternatives
		ps9n75	Decision-making of best alternatives
	PS10: Product development	ps10n76	Check design for environment (DfE) requirements
		ps10n77	Development of DfE concept
		ps10n78	DfE implementation
		ps10n79	Sustainable option validation
		ps10n80	Decision-making best alternative
	PS11: CP (Cleaner production)	ps11n81	Energy
		ps11n82	Material
		ps11n83	Toxicity
		ps11n84	Health & safety
	PS12: SCM (Supply chain improvement)	ps12n85	Education of customers/suppliers
		ps12n86	Improvement of information management
		ps12n87	Support suppliers' declaration
		ps12n88	Recheck efficient communication
		ps12n89	Recheck efficient co-operation
	PS13: Marketing	ps13n90	Market introduction
		ps13n91	Eco-design after-sale plan
		ps13n92	Environmental information to customers
		ps13n93	Check additional market-related issues

Stage	Category	No.	Elements
Knowledge building	PR14: Information system	pr14n94	General investigation/information
		pr14n95	Environmental information
		pr14n96	Market information
		pr14n97	Management information
		pr14n98	Technical information
		pr14n99	Chain information
		pr14n100	Social information
		pr14n101	Test/methods of measurements
		pr14n102	Information availability
		pr14n103	Collect supplementary data
	PS15: Documentation	ps15n104	Define precondition of documentation
		ps15n105	Build-up base for documentation
		ps15n106	Supply documentation of product environmental impact
		ps15n107	Supply documentation for product opportunities
Evaluation and continuation	PS16: Monitoring	ps16n108	Product/service monitoring
		ps16n109	Project/process monitoring
		ps16n110	Review strategies/targets
		ps16n111	Check DfE, process, performance
		ps16n112	Feedback from customers/stakeholders
		ps16n113	Check environmental work & initial ambition
		ps16n114	Check communication
		ps16n115	Check co-operation
		ps16n116	Check firm’s other activities
	PS17: Evaluation	ps17n117	Product requirements
		ps17n118	Product performance
		ps17n119	Product legal compliance
		ps17n120	Product other aspects
		ps17n121	Project & activities
		ps17n122	Internal & external communication & co-operation
		ps17n123	Use of tools & methods
		ps17n124	Data sources, data collection methods, data quality
		ps17n125	Market response
		ps17n126	Environmental benefits
		ps17n127	Cost effectiveness/benefits
		ps17n128	Social benefits
	PS18: Documentation	ps18n129	Product related information
		ps18n130	Co-operation with stakeholders
		ps18n131	Modification for various use
	PS19: Routinisation	ps19n132	Setup further action plan/timeframe
		ps19n133	Preparation of new project
		ps19n134	Integration/coordination of new requirements & existing system
	PS20: Continuation	ps20n135	Prioritisation of resources & feedback for new target
		ps20n136	Possible change of policy, objectives & other elements in system
		ps20n137	Consistency of principles/procedures

Internal and external mutual agreement (ps4n32 and ps4n33) means that relevant players inside and outside the company share the vision of the environmental improvement, agree the responsibilities, and promise active involvement in required performance. Internally, top management support must be ensured and externally stakeholders and suppliers need to communicate and cooperate together during a C-POEMS project.

Integration with existing assets and systems (ps5n44) entails that in the 'plan' stage the C-POEMS model utilises existing systems such as EMS standards or IT systems. Many authors already point out the benefits of the current environmental standards that provide a structure for the usage of appropriate resources, the assignment of responsibilities and the continuous evaluation of practices and processes (Brezet and Rocha, 2001). Evidence has shown that the companies active in eco-design often establish a part of EMS and have more confidence to proceed with further improvement by incorporating EMS and eco-design (Van Hemel, 1999, cited by Brezet and Rocha, 2001).

Erlandsson (2006) provides an example of using existing IT systems in a firm. According to the author's survey, the company that participated in the research already had an information system partially covering environmental information such as waste, raw material use and environmental steering document. However, the author observes that there was an insufficient level of detail in the information system of the case, because the financial system did not cooperate with the environmental information management. For instance, when the environmental coordinator inquired about the information relating to their supplied products, they could only find the suppliers' names, dates and amounts, rather than detail descriptions of environmental aspects of the products (Erlandsson, 2006). In this regard, the C-POEMS model is designed to complement this shortage of collaboration and synergy between functional units, by collective management in the ‘knowledge building’ stage. Existing information systems of a company can be the base for establishing further systems of environmental information.

Establishment of a formal interface (ps8b62) means that during the ‘implementation’ stage the project team may need to have regular meetings, information exchanges, or progress reports with other relevant departments. The formal interface aims to prevent isolation of the project, and derive the best decision as required in the performance.

4.3 Development of a diagnosis template

4.3.1 Procedure of formulation of a diagnosis template

A diagnosis template aims to demonstrate an example of component use of the C-POEMS model, and how a diagnostic approach can be realised in a C-POEMS application. Before the formulation of a diagnosis template, some key points need to be considered. In terms of scope and contents, a diagnosis template needs to cover important elements or categories to discover the main drivers of environmental improvements (e.g., legislation compliance, internal pressure, market demand, etc.). In terms of format, a diagnosis template should have a self-applicable format (e.g., checklist, description, etc.) for data collection, and the result of the diagnosis must be translated within the C-POEMS framework by clarifying focal areas for improvements, which means being independently applicable and integrated into the C-POEMS model.

This research has taken two steps in developing a diagnosis template. First, a preliminary template has been formed. Second, the form could be finalised only after validation of the C-POEMS contents in primary research. A diagnosis template aims at identifying focal areas of a C-POEMS project, which is closely related to the basic form of correlation and prioritisation aspects of the C-POEMS model, as illustrated in Figure 4.7. However, the correlation between the categories or the elements, and prioritisation of the elements or categories are still not identified yet. Also, additional elements of the 'drivers review (PS1)' may be suggested in the confirmatory survey (primary research). Therefore, primary research needs to be implemented first, which will verify the preliminary structure and contents of the C-POEMS model and define the correlation and prioritisation of elements and/or categories. The result of the primary survey would help alter and refine the diagnosis template. In each following two sections, this chapter will present both the preliminary scope and contents of the diagnosis template, and the final altered template.

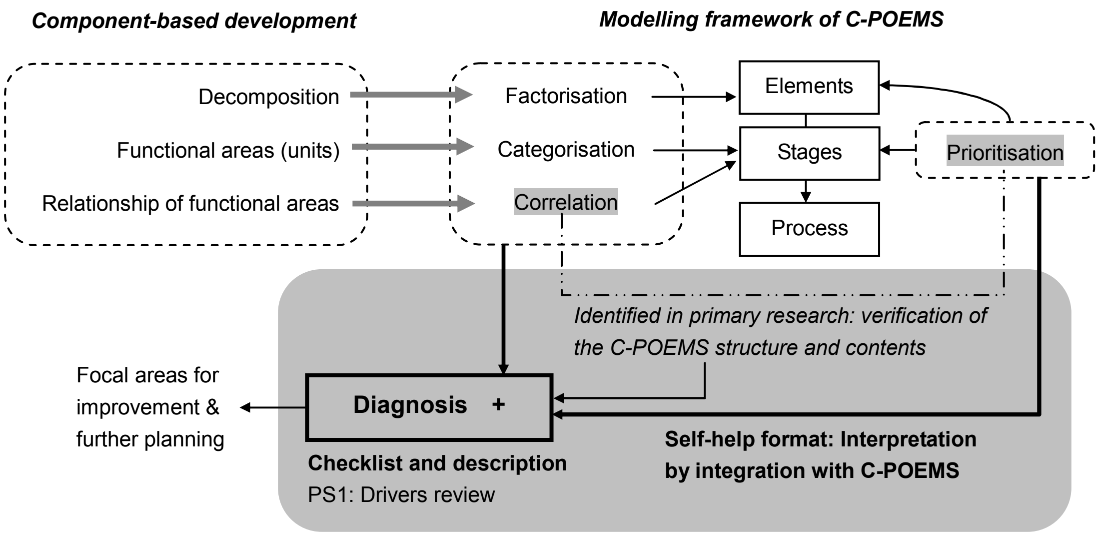


Figure 4.7: Integration mechanisms of a diagnosis template with the C-POEMS model

4.3.2 Preliminary scope and contents of a diagnosis template

Several issues are considered for the selection of a component among three categories (PS1, PS2 and PS3, see Table 4.2) in the 'diagnosis' stage. Firstly, the main environmental drivers for SMEs in the background study (see Chapter 1.1.2.2) are legislation and policy compliance, and customer and consumer demand. These elements are mostly in the 'drivers review (PS1)'. Secondly, the two cases (SWOT analysis and AIDA model) of the POEMS models in the exploratory research has appeared to lack in the approach to general environmental issues and focused instead on specific issues such as the environmental profiling of particular sectors, or upon POEMS itself (where most effort is made for advertising POEMS). The elements of the 'drivers review (PS1)' cover the general environmental issues. In this regard, this research focuses on the 'drivers review (PS1)' in the 'diagnosis' stage of the C-POEMS for developing a preliminary diagnosis template.

To design detailed contents for a diagnosis template, the three propositions in the exploratory research (see Table 3.6 in Chapter 3) are considered: (1) start with general issues such as identifying a company's main drivers or interests and focus areas, (2) perform as applicable self-help format for new users or the ones unfamiliar with environmental issues, and (3) integrate the diagnosis with the POEMS or tailoring POEMS (C-POEMS in this case).

For the proposition (1), the contents of a diagnosis template need to cover the general environmental concerns, main drivers and barriers. Drivers most especially need to be identified in areas requiring legislation compliance, customers' or stakeholders' demands, and market competitiveness. Detailed guidelines are presented in Table 4.3, which clarify problems related to the environmental issues of a company. As mentioned before, prioritisation of and correlation between categories or elements are not defined at this stage of this research. Therefore, a confirmatory survey that validates the contents and structure of the C-POEMS model should discover the aspects most in need of prioritisation and correlation. Then, a diagnosis template can be elaborated to include interpretation of application results within the C-POEMS framework.

Table 4.3: Guideline for contents and format in developing a preliminary diagnosis template

Scope	**Contents**	**Data collection method**
Company information (basic)	Company size, employee number, turnover, business areas, market type, main customers	Checklist and/or description
Environmental documentation	Subject, document title, format, completion	Checklist
Main drivers and barriers		
Awareness	Environmental issue in general & legislation	Checklist and/or description
Legislation	Impending legislation	Checklist
	Legislation compliance and preparation	Checklist
	Difficulties in legislation compliance	Description
	Legislation impact on business	Checklist
	Reason of legislation of impact	Description
	Disadvantages of legislation compliance	Description
	Benefits of legislation compliance	Description
	Barriers to compliance	Description
Market division	B2B, B2C, or both	Checklist
Customers (B2B)	Customers' awareness	Checklist
	Customers' pressure	Checklist
	Customers' concerning areas	Description
	Customers' requirements	Checklist and/or description
	Company's reaction	Checklist
	Customers' feedback methods	Description
Consumers (B2C, market) & competitiveness	Environmental influence on the market	Checklist
	Market pressure	Checklist
	Company's reaction	Checklist
	Market advantages from environmental improvement	Checklist
Man barriers	Main barriers	Checklist
	Clarification of barriers (specific details, potential solution, responsibilities, etc.)	Description

A format of the diagnosis template is related to the proposition (2). This research has adopted a checklist and a description of a self-help questionnaire with which companies can easily collect relevant data and briefly recognise problems. A company may obtain the information mainly from the environmental management division. In this process, a huge effort is not necessary.

In terms of the proposition (3), the result of a diagnosis can be interpreted within the C-POEMS framework. With this interpretation, individual companies may be able to design their own C-POEMS project. However, considering the fact that POEMS itself is new and unfamiliar to many SMEs, it may be difficult for SMEs to design a C-POEMS project by themselves. Therefore, intervention of expert(s) or trainer(s), who understands the interpretation of diagnosis result and has professional experience to be able to elaborate the interpretation of the diagnosis result on planning a further C-POEMS project, may be required. The details are searched through the prioritisation and correlation analysis in the confirmatory survey presented in Chapter 6.

4.3.3 Final format of a diagnosis template

The contents of a diagnosis template outlined in the initial guideline can be changed after the primary research if the survey results would supplement more elements in the 'drivers review (PS1)'. This section presents the altered version of the diagnosis template. For example, 'internal drivers' such as employees' awareness of environmental issues was recommended by the participants in the questionnaire and interview survey (see Table 6.3 in Chapter 6.1.2). Thus, this element is included in the template.

The final contents of the diagnosis template composed here comprise three parts;

awareness, main drivers and barriers. A company can answer to the questions in each part either by checking or describing them. In the first part, awareness of environmental issues may be discovered in questions about general environmental drivers, recognition of specific environmental issues and awareness of relatively new environmental legislations. A second part requires in-depth information about the major environmental drivers of a company, and sub-questions to be asked to the company including legislation drivers, internal drivers, consumer and market demands, and customer pressure.

A third part is added in order to develop a company's or person's own view about any hindrance to environmental improvements. This part has two steps, choice of barriers and in-depth discussion about the choice. It is ideally taken on with other relevant or interested people in the organisation. However, it may sometimes discourage a person from taking part in the diagnosis template by expressing an opposite opinion against the organisational orientation. Thus, initial encouragement to involve other people may not be necessary. The diagnosis template for the 'drivers review' category in the 'diagnosis' stage of the C-POEMS is named as '1Da', and the detailed contents are described in Appendix G.

4.4 Integrative implementation of C-POEMS and diagnosis template

The implementation process of the C-POEMS model basically goes through five stages (diagnosis, plan, implementation, knowledge building, and evaluation/continuation). However, project implementation can vary depending on the result of the diagnosis that is integrated with and influences the rest of process. For instance, a company can use the template 1Da in order to briefly identify general issues the company faces, and then translate the diagnosis result by using C-POEMS prioritisation and correlation map that will be pre-defined through a primary research (see Figure 6.3 in Chapter 6). As a result, prior and focal areas are identified and a C-POEMS project can be generated. Considering the fact that the C-POEMS model has a broad scope and planning a project requires understanding of complex elements of the C-POEMS, experienced person would intervene during the translation of diagnosis result and design of project.

In terms of general process of C-POEMS implementation, the scope of each stage in a C-POEMS project may be different. For example, in Figure 4.9, the 'diagnosis' stage, using the diagnosis template, aims to *delineate* issues and customise the C-POEMS model for a company's situation and needs. Theoretically, the diagnosis template is integrated with the C-POEMS model by identifying problems and focal areas of the company. The identified issues are reflected into planning stage that establishes product policy, objectives, target, strategies, or project plan, etc. Hence, the company may become dealing with more specific issues and scope.

During the 'implementation' stage, the company implement a C-POEMS project that solves the problems identified. Thus, the scope of the project areas delineated throughout the 'diagnosis' and 'plan' stages is likely to be sustained. The 'knowledge building' stage aims to gather and share environmental information among the actors. The *accumulated* information covers all previous stages, which the scope is vastly extended not only to the focal areas but also to all relevant issues. In the 'evaluation/continuation' phase, the outcome needs to be monitored and assessed, which include the project as well as organisational performances. Thus, the scope could be beyond the focal areas.

The results of monitoring and assessment are documented and *disseminated* throughout the organisation. As a result, the scope of this process would be considerable to the full extent of affecting and engaging various employees. Finally, the 'routinisation/continuation' is to *embed* the achievements of the project and the following activities in the existing system, and to take a further action that identifies a new project and establishes a plan for this. The scope would be again focused on particular areas. The company can either proceed with a new project based on the previous one, or return to the diagnosis step. This whole procedure of C-POEMS is ideally iterative in a continual development cycle.

Knowledge building																			
Diagnosis			Plan				Implementation							Knowledge building		Evaluation & continuation			
PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8a	PS8b	PS9	PS10	PS11	PS12	PS13	PR14	PS15	PS16	PS17	PS18	PS19/20
ps1n1	ps2n6	ps3n10	ps4n22	ps5n34	ps6n45	ps7n49	ps8a53	ps8b62	ps9n73	ps10n76	ps11n81	ps12n85	ps13n90	pr14n94	ps15n104	ps16n108	ps17n117	ps18n129	ps19n132
ps1n2	ps2n7	ps3n11	ps4n23	ps5n35	ps6n46	ps7n50	ps8a54	ps8b63	ps9n74	ps10n77	ps11n82	ps12n86	ps13n91	pr14n95	ps15n105	ps16n109	ps17n118	ps18n130	ps19n133
ps1n3	ps2n8	ps3n12	ps4n24	ps5n36	ps6n47	ps7n51	ps8a55	ps8b64	ps9n75	ps10n78	ps11n83	ps12n87	ps13n92	pr14n96	ps15n106	ps16n110	ps17n119	ps18n131	ps19n134
ps1n4	ps2n9	ps3n13	ps4n25	ps5n37	ps6n48	ps7n52	ps8a56	ps8b65		ps10n79	ps11n84	ps12n88	ps13n93	pr14n97	ps15n107	ps16n111	ps17n120		
ps1n5		ps3n14	ps4n26	ps5n38			ps8a57	ps8b66		ps10n80		ps12n89		pr14n98		ps16n112	ps17n121		Ps20n135
		ps3n15	ps4n27	ps5n39			ps8a58	ps8b67						pr14n99		ps16n113	ps17n122		Ps20n136
		ps3n16	ps4n28	ps5n40			ps8a59	ps8b68						pr14n100		ps16n114	ps17n123		Ps20n137
		ps3n17	ps4n29	ps5n41			ps8a60	ps8b69						pr14n101		ps16n115	ps17n124		
		ps3n18	ps4n30	ps5n42			ps8a61	ps8b70						pr14n102		ps16n116	ps17n125		
		ps3n19	ps4n31	ps5n43				ps8b71						pr14n103			ps17n126		
		ps3n20	ps4n32	ps5n44				ps8b72									ps17n127		
		ps3n21	ps4n33														ps17n128		

Figure 4.8: Preliminary format of the C-POEMS model with 5 stages, 20 categories and 137 elements

Key elements

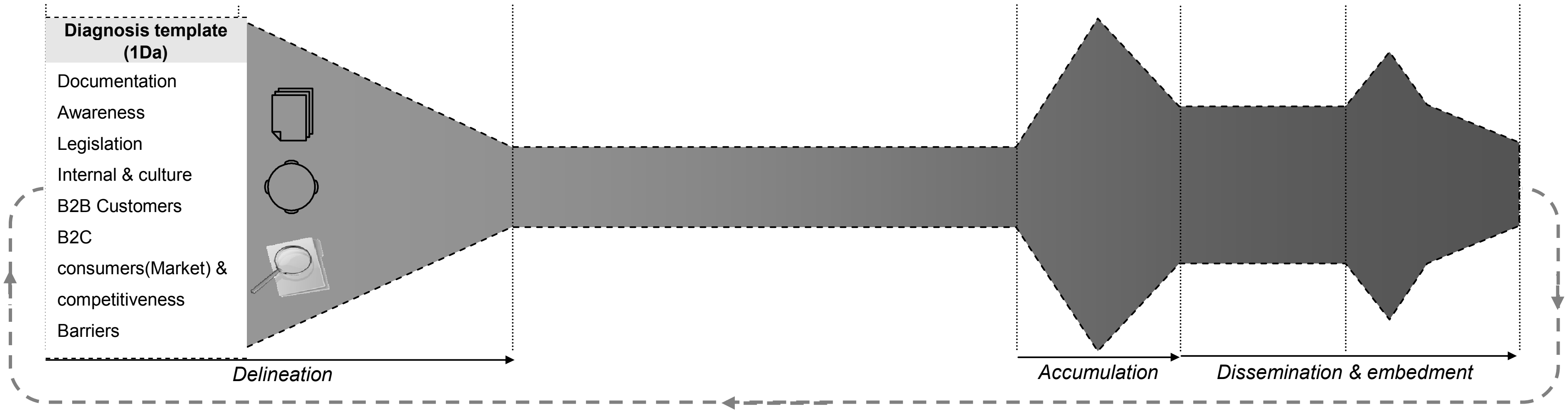


Figure 4.9: Integrated form of the C-POEMS model with the diagnosis template 1Da

Chapter 5 Hypotheses and methodology

This chapter is comprised of two parts – hypotheses and methodologies. Each part of them is divided into two sub-sections corresponding to the C-POEMS model and diagnosis template. The hypotheses are the key principles for formulating the basic form of the C-POEMS model and the diagnosis template. The methodologies as a confirmatory research introduce methods that enable to verify the hypothetical assumptions.

5.1 Hypotheses

5.1.1 Hypothesis framework of the C-POEMS model

In Chapter 1, based on the background mechanisms surrounding SMEs in environmental issues, two sets of research questions were raised about POEMS. As seen in Figure 5.1, the first set of research questions was responding to the mainstream principles of environmental product policy and regulation, and was answered in the literature study of POEMS. Literature study found that POEMS could be a promising tool to encompass the requirements of the mainstream principles. However, the usability of the tool in SMEs was still questionable as depicted in research question set 2 in Figure 5.1. Thus, the further research problems from the second set of research questions have been developed into six issues that were examined in the exploratory research of the existing POEMS models. From the exploratory research, four propositions for the further development of POEMS were suggested in Chapter 3. In order to improve the feasibility of POEMS in SMEs, a conceptual C-POEMS model was developed based on the propositions in Chapter 3 and the component-based modelling theory in Chapter 4.

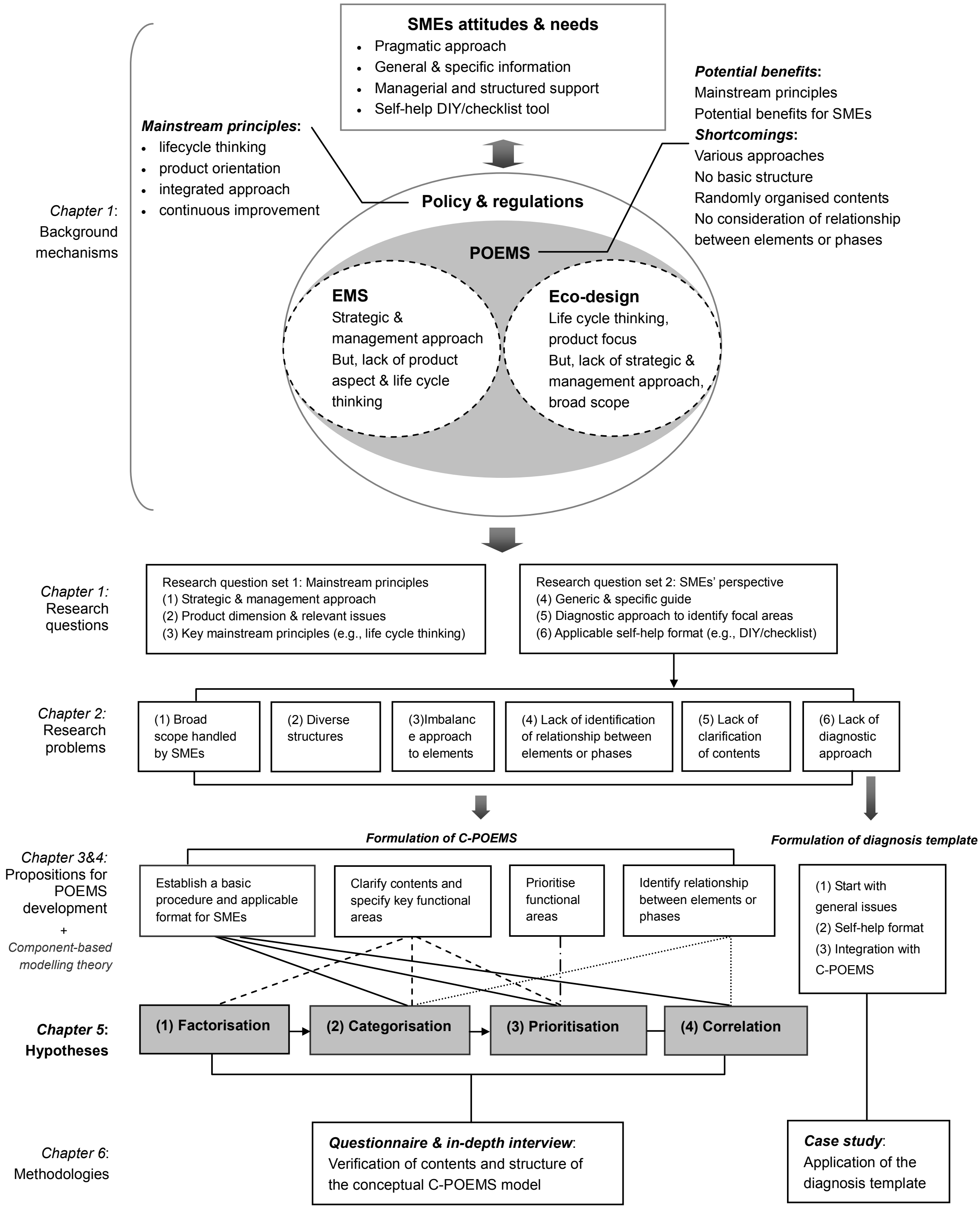


Figure 5.1: Hypotheses framework for development of the C-POEMS model

A conceptual C-POEMS model was established in three ways; by a breakdown of the existing POEMS system into components and elements (factorisation), re-arrangement and re-categorisation of the elements into main stages (categorisation), and initial prioritisation of key elements (prioritisation). The relationship between the categories or elements also needed to be identified (correlation). These are the hypothetical assumptions for formulation of a preliminary C-POEMS model summarised as follows:

(1) ***Factorisation*** of systems and activities of POEMS to elements

(2) ***Categorisation*** of the elements into functional areas or units

(3) ***Prioritisation*** of the categories and/or elements

(4) ***Correlation*** of the categories and/or elements

5.1.2 Hypothesis framework of the diagnosis template

The research question (5) in Chapter 1 was whether POEMS has any diagnostic approach for identifying focal areas for environmental improvements. This research question was examined through the two cases (SWOT analysis and AIDA model) of the existing POEMS models in the exploratory research in Chapter 3. This exploratory research found that there was a need to develop a diagnostic method that both achieves the benefits and overcomes the shortcomings of the two cases (see Table 3.5 in Chapter 3). In the conclusion of the exploratory research, the following three aspects (see Table 3.6 in Chapter 3) were suggested as hypothetical assumptions for the development of a new diagnosis template.

(1) Starting with general issues such as identification of a company's main drivers or interests and focus areas

(2) Finding an applicable self-help format for SMEs, new users or the ones unfamiliar to

environmental issues

(3) Integration with POEMS or tailoring POEMS (C-POEMS in this study)

In Chapter 4, the contents and format of a diagnosis template were designed, which included general information about environmental issues, in particular motivations, awareness, barriers, etc. The diagnosis template adopted a format of simple checklists that a company can easily conduct by itself. Also, the interpretation of the result was discussed, and raised the question of how the diagnosis can be integrated with the C-POEMS. For this, correlation and prioritisation of the elements and categories must be investigated and defined through primary research. Figure 5.2 describes the evolution of the research questions and problems into hypotheses as principles for the development of a diagnosis template.

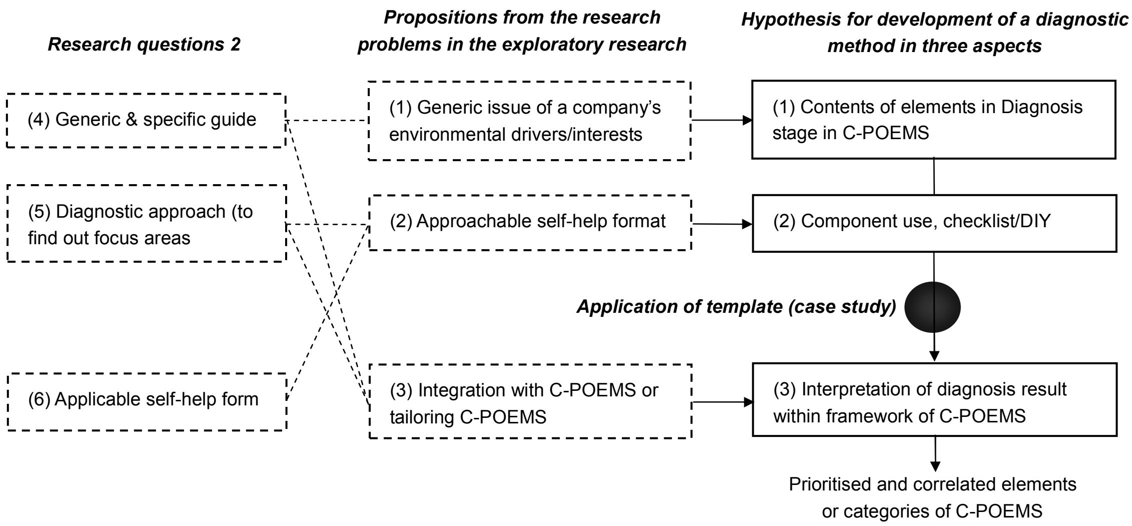


Figure 5.2: Hypotheses framework for development of the diagnosis template

5.2 Methodology

5.2.1 Semi-structured questionnaire and interview

5.2.1.1 Aim and subject

The formulation of the conceptual C-POEMS model follows the four hypothetical assumptions; (1) factorisation, (2) categorisation, (3) prioritisation, and (4) correlation. This primary research aims to verify the initial contents and structure of the preliminary C-POEMS model, and gain in-depth information related to the model. The core subjects requiring validation are summarised as follows:

- For hypothesis (1) factorisation and (2) categorisation, the relevance of the elements and appropriateness of their allocation to corresponding categories must be verified. There is neither a definitive model of POEMS nor environmental management tools that have the characteristics of POEMS. Thus, no tools or methods may be able to verify the conceptual C-POEMS model. Also, C-POEMS has a much broader scope and the elements have complex issues to be examined, which is not helped by a distinct lack of experts in this field and the time constraints on research.
- For hypothesis (3) prioritisation, this study initially defined important elements from the 42 key elements. However, this was based on the secondary research that analysed the frequency of the elements appearing in the existing POEMS model. Besides, there is no information about the important categories of functional areas or units. The initially prioritised elements and/or categories need to be verified and detailed through primary research.
- Hypothesis (4) correlation is intended to identify relationships between the elements or

categories of functional areas/units of the C-POEMS model. Relationships between the elements or categories can have complex features in practice. In this regard, this study proposed to define at least a basic correlation between the elements or categories. However, no existing models have considered this aspect. Therefore, correlation between the elements or categories must be identified through primary research.

This study employed a semi-structured questionnaire and in-depth interview to be given to high-profile experts in this field. These methods aimed at testifying the initial elements and their categorisation of the C-POEMS model. The research methods were selected because a questionnaire primarily serves for the purposes of drawing accurate information from the respondents, providing a standard format on which comments or opinions can be recorded, and being able to facilitate data processing (Hague, 1993). In-depth interviews were conducted to encourage participants to fully discuss topics in an unconstrained environment (Blumberg *et al*. 2005). The validating subjects of the hypotheses are represented as a fixed format of the elements and categories of the C-POEMS. Through a questionnaire survey, the participants would either confirm the format or not. Also new issues in the development of POEMS, such as the prioritisation of the elements or categories, can be discussed by the participant experts through the use of in-depth interviews. The validating subjects of the primary research and corresponding methods are summarised in Figure 5.3.

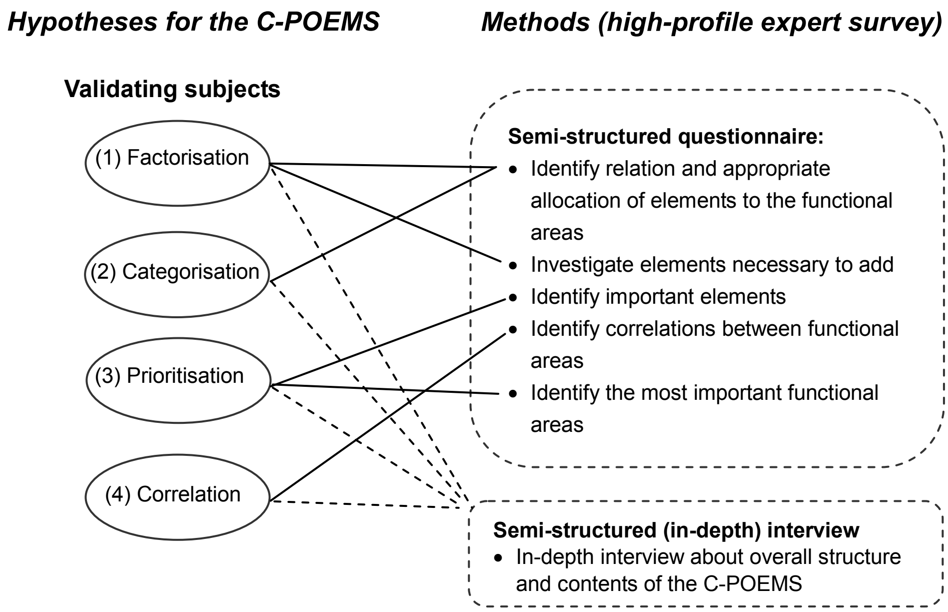


Figure 5.3: Validating subjects of hypotheses for the C-POEMS model and methods

5.2.1.2 Selection of participants

POEMS generally has a very wide scope of areas and involves a variety of activities. Additionally, POEMS is a relatively new field that even the basic concept of integration EMS and product dimension (e.g., by eco-design) is still under development. Thus, only few people in the environmental area might understand POEMS. Regarding this, participants in the survey must have in-depth knowledge about all relevant issues of EMS and product aspects of environmental improvements as well as how they can both be incorporated together. In this respect, this study carefully selected high-profile experts who have had a general experience of environmental management for reasonably long periods of time, have sufficient knowledge about recent trends in environmental policies and regulations, and are involved in various functional areas of corporate environmental business. During the process of selection, EU-based experts were involved and advised on the selection of appropriate participants. Finally, 18 participants worldwide were chosen and an enquiry with brief explanation of the survey and POEMS were sent to them. Among them, 12 persons replied and consented to take part in the survey. The participants were spread out geographically from Belgium, Demark, Germany, Italy, Japan, Korea, Switzerland to the UK.

5.2.1.3 Survey format and material

Data type

The format of the questionnaire and the in-depth interview is divided into three type of data collection as follows:

(1) Nominal data:

In identifying the relation of each element within a certain category of the C-POEMS model, nominal data type is suitable to obtain a more precise answer by simply questioning whether the elements are 'relevant or not relevant' ('appropriate or inappropriate') to their corresponding categories. This data type applied to the subject 1 and 2 of the hypotheses (see Figure5.3). It also applied to the association of the participants' job with the elements of the C-POEMS model. The reason for investigating the association of the participants' job with the elements is to identify whether the participants are influenced by their current work, and whether they answer the questions objectively (i.e., not based on subjective perceptions that could occur when participants have a close relation to certain subjects).

(2) Ordinal data:

In identifying the correlation and prioritisation of the elements or categories, ordinal data is appropriate. For example, the participants can rate the importance (prioritisation) of each element or category (subject 3 in Figure5.3). They can also rate the degree of closeness in relationship between categories (subject 4 in Figure5.3).

In terms of rating the importance of the elements or categories, it is significant to avoid a mistake in the measurement of participants' rating scales, and to allow them to make a good judgement. However, according to the literature (Blumberg, Cooper and Schindler, 2005), there is often a case in which rating errors such as 'leniency', whether it is negative or positive, could occur by which a person could give a higher score when the candidate has close knowledge or relations to a certain subject (in this study, a functional area or the elements belonging to it). A rating scale of measurement is advised to have more points in the scale (*Ibid.*).

Beside, the broad scope of the C-POEMS contents would increase the possibility that participants find it hard to give consistent and fair judgement. In order to obtain reliable data for the validating subject (3) prioritisation, this research divided questions in two ways. First, the participants can separately rate the importance of each element, and, second, they also see the elements collectively and select the most important categories. The results of each approach can be compared and derive priority areas in common so that more reliable data of prioritisation can be obtained.

In terms of identifying correlation between categories, ordinal data type employed a rating system with shorter space of scale because the participants can express their opinion less ambiguously as they directly compare a pair of two subjects about the degree of their closeness of correlation.

(3) Description:

During the verification of the elements, the participants might want to add more elements and provide additional comments about the structure and contents of the C-POEMS. With respect to this, the question format was designed for the respondents to be able to describe their additional opinion for the subjects and more detailed information about prior areas, and have an in-depth discussion through face-to-face and on-line interviews.

Question structure

Deciding the degree of question and response structure, two types of measurement question are utilised, classification questions and target questions (structured or unstructured) (Blumberg, Cooper and Schindler, 2005). Classification questions are usually related to demographic variables that allow respondents' answers to be grouped so that patterns are revealed and can be studied (*Ibid.*). In this survey, classification questions are applied to identify detailed information about the participants such as the type of organisation, the size of the organisation, professional areas, and how long they have worked in their present job.

Target questions state the investigative questions of a specific study, and can be designed to be structured questions (namely, closed questions with a fixed set of choices) or unstructured questions (called open-ended questions without limiting responses but providing a frame of reference for a participants' answer) (*Ibid.*). The research conducted by this study employed a semi-structured questionnaire with three types of questioning that participants were required to answer. Some questions required a set of choices, from which the participant must select one among given options and describe more information and their opinions on the question.

Closed questions were applied to identify the size of organisation, interviewees' associations with the categories and elements of the C-POEMS model, appropriateness of the elements to the corresponding categories, degree of importance of each element, and correlations between categories. Open-ended questions are designed to investigate work experience and additional elements that the participants would like to input. The combination of closed and open-ended questions was asked to the participants about a type of organisation and professional areas. These questions refer to the single-option variable in terms of response format in 'closed questions' and the scales are different depending on the type and complexity of a question as addressed in the section about data type.

In-depth interviews encourage participants to share as much information as possible in an unconstrained environment in which an interviewer needs to use a minimum of prompts and guiding questions (*Ibid.*). Due to the fact that the C-POEMS model has such a large scope to consider, the participants might be distracted during the procedure and the value of data could be affected by that. In order to reduce the exhausting nature of the procedure, the questions were designed by simplifying the target questions as far as possible and delivering a clear message about the main subjects. At the same time, the in-depth interviews were conducted to gather additional information through further discussion with the participants about the prior categories chosen by them and additional information of the C-POEMS contents in general. For this, the topical direction with guiding questions was provided to promote the discussion and elaboration by the participants.

Material provided

A questionnaire and interview form was finally produced and given to the participants. The contents and basic format of this research were the same for both groups, but for convenience the on-line participants were provided with slightly different answer sheets to fill out. Overall the survey format was comprised of three main sections (see the details in Appendix C). The first section presented an introductory part including a guide for interviewees, a cover letter, and element descriptions. The second section explained the background of this research project and the C-POEMS model under investigation. The Third section presented the main target questions of the questionnaire and interview. The final section provided answer sheets. The main section of the questionnaire and in-depth interview was divided into four groups.

(1) Interviewees' information:

The first four questions asked to participants to describe the type of organisation they worked for (Question 1), the size of their organisation (including the number of employees) (Question 2), the professional areas in which they have experience (Question 3), and how long they have worked in their present job (Question 4). It aimed, therefore, at identifying participants' expertise and experience.

(2) Participants' association with the elements and categories of the C-POEMS model:

All interviewees were questioned about the areas of their work most related to the given elements of the C-POEMS model (Question 5). The results were also compared with other questions, which could show that the participants were not influenced by their work, and answered the questions objectively.

(3) Contents and structure of the C-POEMS:

The interviewees were asked about relevance or non-relevance (appropriateness) of the elements to the corresponding categories (Question 6). Also they were required to add any other elements that believed should be included into the C-POEMS (Question 7). These two questions (Q6 and Q7) were designed to verify the factorised contents of the C-POEMS model by which screening and checking the right positions and appropriateness of the elements.

Participants were asked to rate each element regarding its importance for the successful implementation of environmental strategies (Question 8). This question (Q8) was designed to uncover the elements that could be generally important to environmental improvements, and thus to prioritisation. Finally, the participants were questioned to indicate what correlations they believe pertained between categories (Question 9). This question (Q9) aimed at defining the correlation between the categories so that those functional areas/units and/or the elements in the correlated categories presented in similar groups can be handled collectively.

(4) In-depth interviews of additional opinions and detailed information about the important categories chosen by the participants:

The participants were given two questions which presented categories that are of the most importance for companies to adopt environmental strategies and implement improvements. They were asked to choose their top five important categories (Question 10), and in-depth discussion was conducted with individuals about the chosen issues (Question 11). This result was compared with Question 8. Thus, the individual importance of elements from Q8 and collective importance of elements from Q10 could be compared so that reliable data be derived in order to define the priority areas of the C-POEMS model.

Table 5.1: Questions of semi-structured questionnaire and interview

(1) Interviewees' information	Q1	What type of organisation do you belong to?
	Q2	How may employees within your organisation?
	Q3	What are the main areas of your occupation?
	Q4	How long have you worked in your current position?
(2) Interviewees' association with functional areas	Q5	What are the most related areas to your work? (choose as many elements as related to your main profession) (use the answer sheet A)
(3) Contents and structure	Q6	What would you think inappropriately categorised (allocated) or unrelated elements to the categories? (mark as many as elements in the case) (use the answer sheet A)
	Q7	Please add if you think that there are elements omitted in each category. (use the answer sheet A)
	Q8	Please indicate how important the elements are in terms of successful implementation of environmental strategies in companies. (1 unimportant, 3 neither unimportant nor important, 5 very important) (use the answer sheet A)
	Q9	Please indicate correlations between categories. (3 highly correlated, 2 medium, 1 poorly correlated, 0 no correlation) (use the answer sheet B)
(4) In-depth interview	Q10	Please choose 5 of the most important categories (functional areas/units) when companies adopt environmental strategies and implement environmental improvement. (use the answer sheet A)
	Q11	Free discussion about the subjects in Q10. (for online interviewees, please explain the reason on the answer sheet A)

5.2.1.4 Procedure

Before conducting the questionnaire and interviews, a pilot test was implemented.

Feedback from the test was reflected to alter the first format of the correlation question and answer sheet. After minor change to the formulation of the questions, a set of questions was provided to individual participants. The participants in the UK took part in this research via face-to-face survey while people in other continents used an on-line route. As some participants' requested, individual participants were given time to comprehend the preliminary structure and contents of the conceptual C-POEMS model before they responded to the survey. If necessary, separate presentations also took place at a participants' organisation, and materials were provided for the on-line interviewees when requested. During the survey, the participants were provided additional materials and opinions for a total of five months. The two answer sheets filled in by the participants were sorted out according to the topics, and re-organised for the quantitative analysis. The respondents interviewed face-to-face allowed the tape-recording of the whole procedure of the survey. Hence, all the discussions and interviews were tape-recorded and transcribed.

5.2.1.5 Analytical methods

This research employed two analytical methods: descriptive analysis, and multidimensional scaling (MDS). Descriptive analysis was applied to the raw data processing of most questions. MDS was used particularly in the analysis of correlation data. With the conjunction of these methods, a rank order method was also used. For computation and data processing, SPSS and MS Excel have been employed. The procedure of analysis consists of several steps, including data preparation to edit the collected raw data such as detect errors and omissions, coding and pre-coding the data by assigning numbers and symbols for statistical analysis, data entry, and analysis of the data.

Descriptive analysis

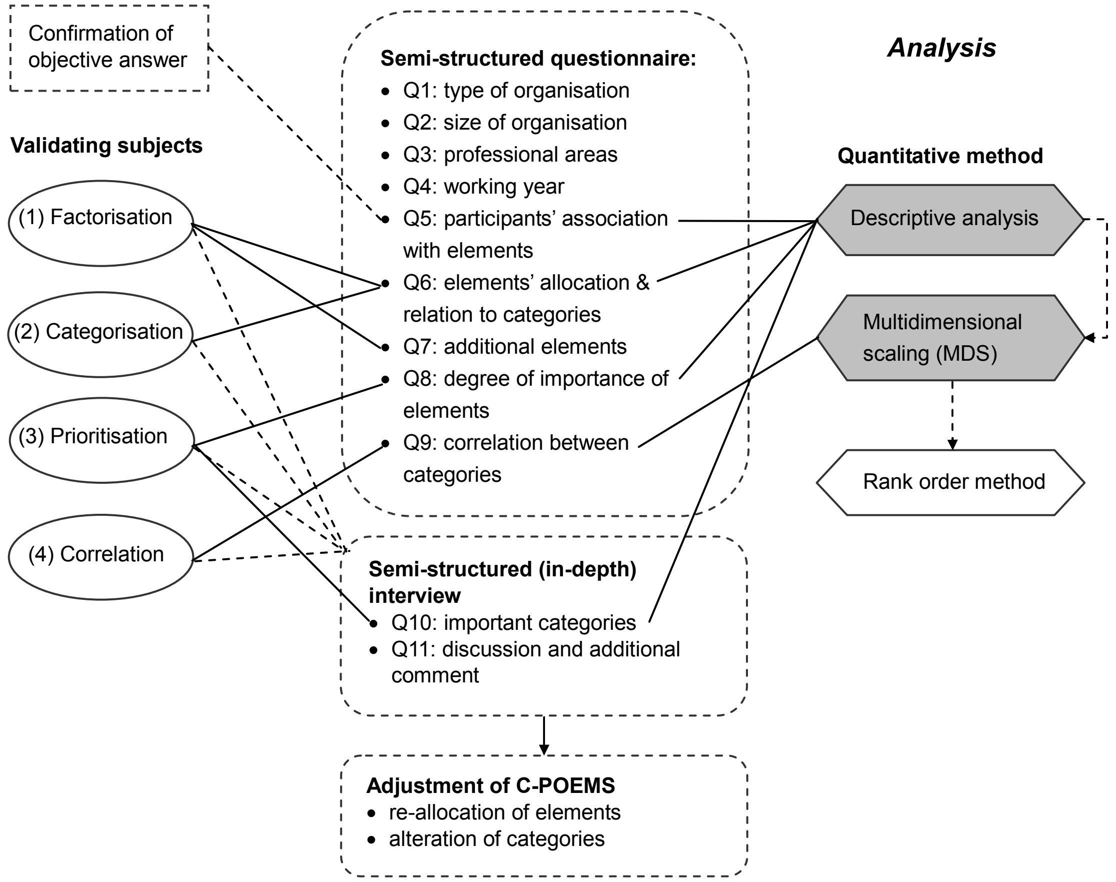


Figure 5.4: Relationship between analytical methods and survey questions linked to validating subjects of hypotheses for the C-POEMS model

Descriptive statistical analysis is normally used in data cleaning (e.g., error detection, missing data checks, etc.), and the development of sufficient knowledge to be able to describe the set of data (e.g., the characteristics of the sample such as location, spread and shape) (Blumberg, Cooper and Schindler, 2005; Pallant, 2005). There are a number of ways to obtain the descriptive analysis such as *Frequencies*, *Descriptive* or *Explore* (Pallant, 2005). The descriptive statistics show optional values, selected by an operator, such as minimum, maximum, mean or standard deviation of the body of data. This research widely applied the descriptive analysis to firstly analyse most raw data from the questions. In particular, mean values (obtained by first processing the raw data) were used later for additional analyses of other methods such as rank analysis and multidimensional scaling (MDS). The corresponding questions that employed descriptive analysis are illustrated in Figure 5.4.

Multidimensional scaling (MDS)

Multidimensional scaling (MDS) is designed to discover meaningful underlying dimensions that allow the researcher to explain observed similarities or dissimilarities (distance) between investigated objects (StatSoft, 2003). In MDS, one may analyse any kind of similarity or dissimilarity matrix in addition to correlation matrices, while in factor analysis the similarities between objects (variables) are expressed in the correlation matrix. In general, MDS is used to arrange objects (variables) in a space with a particular number of dimensions so as to reproduce the observed distance, which results a research to be able to explain the distances in terms of underlying dimensions (*Ibid*.).

In MDS, two-dimensional solutions certainly have the virtue of simplicity and may, in many cases, provide an easily understood basis for gaining insight into complex proximity data; consequently they are, in many situations, likely to be the solutions of most practical importance (Everitt. and Rabe-Hesketh, 1997). In the interpretation, MDS methods generally allow the researcher to ask relatively unobtrusive questions (e.g., how similar is brand A to brand B) and to derive from those questions underlying dimensions without the respondents ever knowing what is the researcher's real interest (StatSoft, 2003). It results in indicating of variables as data sets and of which variables (C-POEMS categories) are close to which ones.

Analysing data by ranking between values (e.g., means) of variables is simple and widely used in many cases. The values derived from the two methods above are ranked and compared so that a degree of relevance and/or similarities of objects (i.e., elements or categories) can be identified.

5.2.2 Case study

5.2.2.1 Aim and subject

In implementing a diagnosis template as a component of the C-POEMS model, this study conducted additional case studies. These case studies aimed to demonstrate how a component-based application of the C-POEMS model might work and to validate the hypotheses for development of a diagnosis template. The following subjects need to be highlighted in the results of these case studies. Firstly, the general environmental issues of main drivers surrounding the participant companies needed to be explored when the diagnosis template was used. This information should be, secondly, translated within the framework of the C-POEMS model by using a prioritisation and correlation map. Thirdly, the result of the interpretations should be able to help the participant companies determine focal areas and/or design further projects (in particular through modification of the C-POEMS with relevant elements).

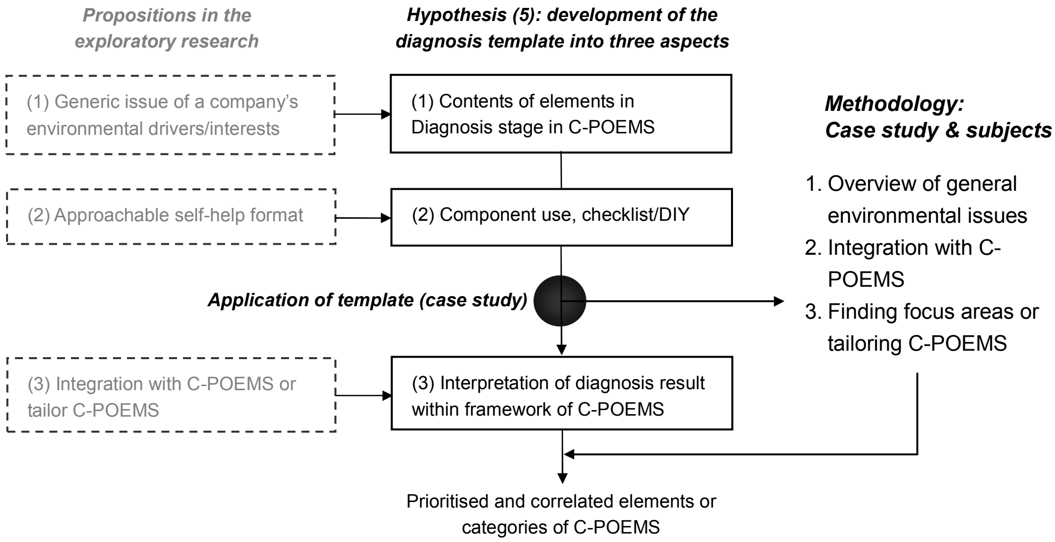


Figure 5.5: Validating subjects of hypothesis for the diagnosis template and method

5.2.2.2 Selection of participant companies

The choice of participant companies is based on the size of company such as employee number (European Commission standard; less than 250). However, it was difficult to find small companies in this project. Thus, relatively large companies were included in the case studies, with company or company units of around 500 employees. This research initially selected three companies in the UK that were interested in environmental improvements and had partly implemented some elements of C-POEMS such as EMS certification or relevant technology R&D. Since first contact with the companies, one organisation (company A) expressed participation in the case study. After a case study with company A was conducted, two more international companies took part in. One is located in Europe (company B) and the other is in Asia (company C). Therefore, three companies participated in the case studies.

Three companies are from different sectors such as the manufacturing sector (company A), telecommunication services (company B), and the oil and gas industry (company C). Two companies (A and C) mostly supply their products or services to other large enterprises or business customers (business-to-business markets). One firm (company B) has a direct relationship with the end consumers (Business-to-consumer market). All companies belong to large organisations in different countries, but two company units are constituted of less than 50 employees while one manufacturer has around 500 employees.

5.2.2.3 Survey format and material

The format of diagnosis template 1Da is made up of two types of data collection; checklists and descriptions. Respondents can answer the questions by simply checking the given options or describing detailed information or opinions. Questions are designed to lead participants from an overview of an issue to in-depth or specific subject of the issue, which participants can then develop into discussions. Materials provided to the companies included descriptions of the C-POEMS model and the case study survey, and diagnosis template 1Da.

As explained before, template 1Da consists of three parts; awareness, main drivers and barriers. Before applying the diagnosis template to the companies, basic information about the participant companies was asked by which company information section was placed before template 1Da and requested specific information of company size, business area, market type, main market and main customers. In this section, the companies were also asked to check specifications of environmental documentation such as document title, subject, existence, format and completion. The following section considers the role of template 1Da as a main diagnosis component that a company can use by itself (see Appendix G).

5.2.2.4 Procedure

The procedure required for the case studies with the three companies was slightly different depending on the location of the companies. For example, the whole procedure of the project with company A took place by a face-to-face interview as it was housed in the UK whereas the other two companies preferred to take the on-line route. The basic procedure involved preliminary work, implementation, analysis and interpretation, and then feedback to the companies. In the preliminary work, information about the C-POEMS model and its implementation framework, diagnosis template and survey method was provided. In addition, general information of the participant companies such as current environmental activities, and available staff or department involved were gathered and shared through presentations and meetings with staff in different departments. This information also included products or environmental tools. Then, diagnosis template 1Da was implemented and the answers were analysed and interpreted within the C-POEMS framework. The result was finally provided to and discussed with individual company with guidance for further work. During this discussion as well as the whole procedure, feedback from the participant companies was observed and received.

Chapter 6 Result and discussion

Chapter 6 presents the results and principal findings of the primary research. The first section explains the survey results corresponding to the subjects of the hypotheses for the C-POEMS model. This result is reflected to amend the preliminary C-POEMS and produce a final form of the C-POEMS model with prioritisation and correlation map. The second part discusses the outcome from which the diagnosis template (1Da) is tested in three companies. The diagnosis result of each case is interpreted according to the hypothetical assumptions for the diagnosis template.

6.1 Semi-structured questionnaire and interviews

This section presents the result of the questionnaire and in-depth interviews. First, participants' expertise and detailed information of current jobs (Q1 to Q4), and association of their job with the C-POEMS elements (Q5) are described. Second, the analysis result of the survey for validating subject 1 and 2 (factorisation and categorisation), which clarifies the right categories of the elements, is explained by investigating unrelated or inappropriately categorised elements (Q6). Also, the validating subject 1 is more flourished by which the participants input additional elements (Q7). Third, validating subject 3 (prioritisation) is defined in two ways: the degree of importance of elements within each category (Q8), and prioritisation of categories (Q10). Fourth, validating subject 4 (correlation) is explained, which is defined by the participants (Q9). Finally, in-depth discussion on the most important categories chosen by the respondents is summarised (Q11).

6.1.1 Participants' profile and association with C-POEMS elements

Basic information and profile of participants

Participants were asked about their detail information including current job areas, work year, etc. in question 1 to 4. Average work experience of the current job is 7.4 years. It shows that the participants have sufficient experience in various areas in this field, which is described in Table 6.1. Although a few of the participants have only been in their present jobs for a relatively short period of time, they had been involved in relevant fields such as quality management in the past. It was considered preferable to gather opinions of experienced professions in the survey because they have good knowledge of organisational systems and business process in the way that the POEMS affects business process management in the environmental domain.

Table 6.1: Profile of participants

No.	Work year	Profile
P1	2	• This participant is a supply chain expert and researcher in a multinational brand of consumer and IT products. • Although the years of work in the organisation appears relatively short, s/he has been involved, for a reasonably long time, in a diverse range of multi-disciplinary research areas including social science as well as engineering based research, and published and presented reasonably amount of work.
P2	1.5	• This participant is working in a broad scope of environmental areas such as legislation and policy compliance, sustainable business and management, and technical consultancy (e.g., LCI, LCA, LCC, LCM etc.) etc. • S/he also has been involved in a large scale and amount of national and international projects including UNEP, SETAC and German government. • This person is a member of advisory group of European Commission, and member of the editorial board of leading international journals of environmental science. • This person also an executive director of a consulting company based in the EU and has gained business-related awards. • Although the work years with in the present organisation appear relatively short, this person has been involved in the environmental area for a considerably long time.

P3	3.5	• This participant is an environmental technologist and expert in broad areas, and working for a multinational company that has a huge range of suppliers. • In particular, s/he is specialised in SCM and LCA and thus has sufficient knowledge about SMEs as s/he supports and coordinates suppliers by training and developing tools, providing information of legislation and policy, and so on. • This person has been involved in various international projects of, for example, UNEP, SETAC and European Commission in relation to environmental information database. • S/he also has sufficient understanding of the areas of eco-design, POEMS, and so on. • This person also has presented in a variety of conference, seminar, or symposium etc. mainly targeting professional and business groups.
P4	1	• This participant is a quality and environmental manager in a medium-sized company that produces IT equipment especially data storage and test equipment etc., and is one of the major suppliers for a world-leading IT brand. • S/he has been working as specialist in quality management and is involved in environmental management too. • This person has a sufficient experience on EMS certification and eco-design.
P5	8	• This participant is a managing director of an electronic and electrical manufacturing company, as a second or third tier supplier, that supplies components to worldwide. • The company is strongly influenced by new environmental legislations, and thus s/he has been dealt with various issues in relation to the legislations. • Since late 1990s, the company has implemented environmental tools such as eco-design and the person has been deeply involved in environment-oriented business practices.
P6	3	• This participant is an electronics sector specialist and technical expert who support companies to comply with new environmental legislations. • This person provides various strategic advice including legislation, CSR (corporate social responsibility), carbon management etc. • S/he have worked for an international company as an environmental project manager and is now a principal consultant in an environmental consulting company providing expert services from technical support to training. • This person has been involved in various research groups and presented professional information. • This person is also a legal compliance contributor in one of the leading international environmental news magazines, and a member of legislation technology team of UK DTI.
P7	1.5	• This participant is an eco-product and system expert in an advanced research group and covers broad range of environmental information specialised in legislation and policy, and technical guide of supply chain, LCA, logistics, cleaner production etc.
P8	20	• This participant is an expert in EMS standards, and a member of ISO TC 2007/SCI Working Group 2. • This person has been involved in various research projects in national and international level including European Commission and UK DTI. • This person has also widely published books and papers targeting commercial audiences particularly in SMEs. • S/he is a member of chief editor of leading journals in the environmental business field.
P9	13	• This participant is working for environmental consulting company for a long period of time, and involved in technical areas including LCA/LCC/VE/SCEM, CDM (CO_2), eco-design, green marketing, etc. • This person has been widely engaged in business and research projects of environment, and has

		published papers for such as SETAC.
P10	11	• This participant is a researcher and lecturer in environmental field such as life cycle engineering, eco-product development, etc. • S/he has been involved in various research projects including eco-efficiency of eco-design endorsed by European Commission, and large public corporations, etc. • This person has been published many papers and presented at various conference, seminar, or symposia.
P11	4.5	• This participant is working for a multinational consumer product brand that produces electronic and electrical products; supporting environmental planning and environmental technique of products. • This person has organised and been involved in research groups within the relevant field. • S/he has sufficient knowledge about corporate environmental performance and strategic approach using various tools.
P12	20	• This participant is a manager of a division of a multinational corporation that is actively involved in industrial ecology. • This person has tremendous experiences in terms of corporate management and technical support, and progressively integrated new schemes of environment. • S/he has been particular supporting the company in LCA, legislations (WEEE, RoHS, REACH), technical improvement or availability, etc.

Most respondents were from industry and two from academia. Seven persons were working for multinational corporations or SMEs as environmental managers, and three are environmental consultants dealing with various types of environmental subjects. A person was in R&D department on supply chain system in the environmental department of a multinational company. Not only have the experts in SMEs provided an insight of SMEs but also the people from multinational corporations did so as their jobs involve close cooperation with SME suppliers such as support and education of SMEs. Thus, practical advice could be obtained from both groups (for detail information, see Table D1 in Appendix D).

Most experts were working in more than two specialised areas in this field. The main expertise of the participants was related to environmental management in general including EMS standard certification, corporate social responsibility (CSR), supply chain management (SCM), and information management (e.g., environmental key performance indicators (E-KPIs)). More than half of the people were directly associated with the new environmental legislations (e.g., WEEE, RoHS, REACH, EuP) and environmental product policies (i.e., IPP, etc.). About 8 persons were involved in technical guides about, for example, hazardous materials, electronics manufacturing, life cycle inventory (LCI), life cycle assessment (LCA), life cycle costing (LCC), life cycle management (LCM), cleaner production (CP), end-of-life treatment (EoL), and so on. Two people replied as specialists in environmental product development including eco-design and eco-labelling. However, most participants' job were found to have an association with eco-product development (for detail information, see Table D2 in Appendix D).

Participants' association with elements and categories

Question 5 asked the participants to identify the level of association of their job with the elements of the C-POEMS model. The average of related elements to their work was 62.42 out of 137 elements, which may mean that the respondents were associated with a large scope of environmental issues in their job. The respondent who was the most frequently involved in various areas in her/his work chose 130 elements. The association of the respondents' job with the elements can be divided into four groups:

(1) Group 1 (two respondents): an extreme case of multi-task involved in more than 100 elements

(2) Group 2 (three respondents): a fairly large scope of areas related to their work between 60-100

(3) Group 3 (five respondents): the greatest number of respondents answered between 30 and 50

(4) Group 4 (two respondents): a relatively small number of areas related to their work between 1 and 29

Group 3 has the greatest number of respondents who had different records in their present job or company type. This implies that the chosen elements and/or categories were not particularly affected by the participants' working years, present job or company type. Group 1 had two respondents who indicated they had similar work year and similar size and type of companies. However, the small size of the sample was too limited to enable to draw any further conclusion of the relationship of work year or size and type of firm with their choice of elements.

The categories most commonly related to the respondents' job assessed, by comparing the mean value of each category, were 'cleaner production (PS11)', 'product profiling (PS2)' and 'supply chain management (SCM) (PS12)'. Other elements such as 'information system (PR14)', etc. were significantly involved in their business too (for detail information, see Table D3 in Appendix D). In terms of the association of the elements, between 8 to 10 respondents replied that their work was closely and frequently involved in these elements; 'legislation' (in the 'drivers review (PS1)'), 'legal compliance' and 'environmental impact' (in the 'product profiling (PS2)'), and 'internal communication' (in the 'company profiling (PS3)') (for detail information, see Table D4 in Appendix D). However, most of the elements chosen by the respondents in group 3 are shown across various categories of the C-POEMS model. This means that the participants are involved in a variety of activities in different functional areas or units of the C-POEMS model.

To summarise, the result shows that most respondents are involved in various areas covered in POEMS, which means that they well acknowledge the concept of POEMS. The main areas of the categories and elements of the C-POEMS model that the participants are most strongly related to their current job can be specified as: product and production-related environmental activities (production might be related to environmental costs and impacts); compliance with environmental regulation in product and production; and information and knowledge.

6.1.2 Validating subject 1 and 2: Factorisation and categorisation

Preliminarily factorised and categorised elements of the C-POEMS model are judged and adjusted by the expert participants (Q6 and Q7). The result of question 6 shows that 8 out of 12 respondents have agreed the original contents, which the elements are relevant and accordingly allocated to the corresponding categories of functional areas or units. However, four people selected 13 elements as inappropriately allocated or unrelated to the corresponding categories. Twelve elements amongst 13 were chosen as unrelated to the corresponding categories, which are described in Table 6.2. Apart from these elements, there were no further suggestions of which categories and elements should be reallocated.

Table 6.2: Elements inappropriate and unrelated to the corresponding categories

Categories		Elements	P1	P2	P9	P11
PS1	Drivers review	Customers				√
PS3	Company profiling	Share norm/value		√		
PS6	Market & sale	User/purchaser guidelines	√			
		Environmental certificate			√	
PS8a	Managerial aspect 1: co-operation	Whole department				√
		Shareholders				√
		Question guide for customers cooperation				√
PS8b	Managerial aspect 2: communication	Whole department				√
PS9	Operational aspect	Trace option for improvement				√
		R&D of chosen alternatives				√
		Decision-making of best alternative				√
PS14	Information system	Environmental information (LCA data update)				√
		Chain information				√

In question 7, four respondents proposed 14 additional elements which are summarised in Table 6.3. One person expressed disagreement with the element, 'environmental certificate' in the 'market and sales (PS6)' ('plan' stage), and made the suggestion to divide the element into 'organisational certificate (e.g., ISO 14001)' into the 'managerial approach (PS4) ('plan' stage), and 'product certificate (e.g., eco-labelling) into the 'product development (PS10) ('implementation' stage). The person indicated that the reason for this is that eco-labelling is occasionally used for marketing but has more relation to the build-up of internal and external communication, and could be a part of guidelines for environmental product development. Another respondent addressed the opinion that 'user/purchaser guide' in the 'market and sale (PS6)' ('plan' stage) was in the wrong category and thus reallocated it into the 'supply chain management (PS7)' ('plan' stage). As most respondents confirmed the initial contents and structure of the C-POEMS, there is no need for a large scale of alteration of the form. However, the additional suggestions are reflected to refine the C-POEMS model, as a fairly minor alteration.

Table 6.3: Additional elements

Category	Additional elements
PS1 Drivers review	Continuous improvement (i.e., internal driver to improve environmental performance)
PS2 Product profiling	Variation for national differences
PS3 Company profiling	Corporate culture: staff age & sex, worker's capability etc.
PS4 Managerial side	Championing of approach
PS5 Operational side	Cross-functional team
PS6 Market & sale	Environmental certificate can be separate: Organisational certificate (ISO 14001) to PS4; Product certificate (eco-labelling) to PS10. Eco-labelling is occasionally used for marketing but it has more relation to internal and external communication build-up.
PS8a Managerial aspect 1: cooperation	Cross-functional team

PS8b Managerial aspect 2: communication	Manufacturer has significant influence by residents. So build-up relationship with residents needs to be an independent requirements rather than dealing within the stakeholder group.
PS10 Product development	Add 'social aspect' (e.g., children labouring) DfE focuses on the environmental issues unlike DfE has expanded to sustainability including social issues. It needs to be specific.
PS11 Cleaner production	Irrigation, industrial waste, waste water
PS12 SCM (Chain improvement)	Legal contract Formalise expectation
PS13 Marketing	Working relationship
PS17 Evaluation	Life cycle assessment of improved products Environmental impact assessment of improved products Assessment of products' function

6.1.3 Validating subject 3: Prioritisation

Validating subject (3) is about prioritisation of the categories and/or elements. Two different questions were asked to the participants. Question 8 was intended to select the degree of importance of the individual element within its corresponding category. Question 10 was designed to choose the five most important categories. In order to compare results between participants, descriptive statistics were used to analyse both sets of answers. Firstly, the mean values of the variables (elements) from question 8 were obtained (see Appendix E), and they were then compared and ranked. Some categories have more elements that are highly rated, for example: 'drivers review (PS1)', 'product profiling (PS2)' and 'company profiling (PS3)' in the 'diagnosis' stage; 'managerial approach (PS4)', 'operational approach (PS5)' and 'supply chain management (PS7)' in the 'plan' stage; and 'product development (PS10)' in the 'implementation' stage. The details are presented in Table 6.4. The result shows that most participants consider the 'diagnosis' and 'plan' stages as the most significant areas for environmental improvements.

Table 6.4: Important elements and their corresponding categories

Category			Element	Mean value
PS1	Drivers review	ps1n1	Legislation	4.75
		ps1n2	Customers	3.92
		ps1n3	Stakeholders	3.83
		ps1n4	Competitors	3.92
		ps1n5	Market opportunities	4.17
PS2	Product profiling	ps2n6	Legal compliance	3.83
		ps2n7	Environmental impact	3.46
		ps2n8	Environmental cost	3.50
		ps2n9	Environmental benchmarking/position	3.33
PS3	Company profiling	ps3n10	Economical capability	3.46
		ps3n11	Technical capability	3.21
		ps3n12	Management capability	3.38
		ps3n13	Staff ability	3.00
		ps3n17	Communication-internal	3.08
		ps3n19	Cooperation-internal	3.08
		ps3n21	Corporate culture	3.08
PS4	Managerial approach	ps4n22	Established business policy	3.00
		ps4n23	Established business strategies	3.33
		ps4n24	Established project objectives	3.21
		ps4n28	Established network	3.00
		ps4n30	Prioritisation (strategies, activities)	3.08
		ps4n31	Communication/cooperation	3.42
		ps4n32	Mutual agreement – internal	3.17
PS5	Operational approach	ps5n34	Resource allocation-human	3.58
		ps5n35	Resource allocation-finance	3.33
		ps5n36	Resource allocation-technique	3.33
		ps5n37	Allocation-responsibilities, authorities	3.33
		ps5n40	Knowledge building-environment	3.17
		ps5n44	Integration with existing asset & system	3.04
PS6	Market & sale	ps6n45	Establish strategy-marketing	3.00
PS7	SCM	ps7n49	Sustainable purchasing plan/guide	3.04
		ps7n50	Decision-making suppliers/products	3.25
		ps7n51	Check communication	3.17
		ps7n52	Check cooperation	3.00
PS10	Product development	ps10n76	Check DfE requirements	3.50
		ps10n77	Development DfE concept	3.42
		ps10n78	DfE implementation	3.50
		ps10n79	Sustainable option validation	3.13
		ps10n80	Decision making best alternative	3.25

The second method of validating the subject (3) (prioritisation) was to ask that participants to choose five the most important categories. About half of the participants chose ‘drivers review (PS1)’ and ‘product profiling (PS2)’ in the ‘diagnosis’ stage, ‘product development (PS10)’ in the ‘knowledge building’ stage, and ‘evaluation (PS17)’ in the ‘evaluation/continuation’ stage (see right section in Table 6.5). The important categories in the second analysis were ranged fairly broadly, while the first analysis has shown that most participants gave more attention to the first and second stages (diagnosis and plan).

Table 6.5: The result of ‘descriptive statistics’ on the degree of importance of elements and categories

Question 8: Degree of importance of elements			Question 10: Degree of importance of categories		
Rank	**Category**	**Average of mean value**	**Rank**	**Category**	**No. of respondents**
1	PS1	4.12	1	PS1	7
2	PS2	3.53	1	PS10	7
3	PS 10	3.36	2	PS2	6
4	PS 7	3.11	2	PS17	6
5	PS 5	3.08	3	PS4	5
6	PS 4	3.00	4	PS3	4
7	PS 3	3.00	4	PS5	4
8	PS 6	2.75	4	PS7	4
9	PS 9	2.64	4	PR14	4
10	PS 8b	2.51	5	PS11	3
11	PS 13	2.51	6	PS6	2
12	PS 17	2.51	6	PS9	2
13	PS 11	2.46	6	PS13	2
14	PS 16	2.30	6	PS16	2
15	PS12	2.20	6	PS18	2
16	PS 8a	1.99	6	PS20	2
17	PR14	1.89	7	PS8a	1
18	PS 20	1.86	7	PS8b	1
19	PS 19	1.83	7	PS12	1
20	PS 15	1.79	7	PS15	1
21	PS18	1.72	8	PS19	0

Two results were compared according to the degree of importance so that the common categories of significant functional areas/units and elements were discovered. This result is illustrated in Table 6.5. Before the comparison, the average mean values of the elements within each category were calculated because each category has different number of elements. On the left section in Table 6.5, the list of categories is described in order of collective importance of its belonging elements. On the right section, the categories are ranked according to the degree of importance. The common categories considered as significant from both analyses were 'derivers review (PS1)', 'product profiling (PS2)', and 'product development (PS10)'. Therefore, a company may need to pay more attention on these categories of functional areas/units. Also, the elements that fall into these categories can be firstly considered as key requirements when implementing a C-POEMS project.

6.1.4 Validating subject 4: Correlation

For validating subject 4 (identification of correlation between categories), the respondents were asked to give a rate to a pair of categories regarding their close relationship or degree of interaction (Q9). Analyses of correlation between categories were carried out in two ways that attempt to identify frequency and closeness of interrelation between categories. In the first analysis of frequency, descriptive statistics were used and the mean values of variables (categories) are simply compared and ranked. The second analysis of closeness employed multidimensional scale (MDS) that shows similarity and dissimilarity between variables. Combining the two analyses, this research produced core categories of the C-POEMS model. The details are explained bellow.

(1) Descriptive statistics:

To identify the frequency of correlation of each category with other categories, a descriptive command was conducted, and a mean value of correlation degree of each category was drawn up. Then the means of each variable (category) were simply ranked and compared to each other. The result shows which variables are frequently related to others. It allows us to assume that the greater the degree of correlation of some variables (categories) with others, the more likely they were to be dealt with as core issues than less correlated ones. This judgement could also apply to the elements within the priority categories, which those elements are considered as important. This data were then compared with the result of the validation subject (3), so that more substantial elements can be clarified and confirmed. The result shows that some categories such as PS10, PS14, PS4, etc. have relatively close relationship with other categories as described in Table 6.6. However, the differences between the mean values are not largely distinguished. Thus, it is hard to tell the superiority of the relatively highly ranked categories as seen in coloured areas from 1 to 5 ranks in Table 6.6. Nonetheless, this result can be compared with following MDS analysis in order to make a more reliable judgement on correlation.

Table 6.6: The result of 'descriptive statistics' about highly correlated categories

Question 9			
Rank	**Categories**		**Mean value**
1	PS10	Product development	2.26
2	PR14	Information system	2.19
3	PS4	Managerial approach	2.13
4	PS17	Evaluation	2.13
5	PS8b	Managerial aspect 2: communication	2.12
6	PS7	Supply chain management (SCM)	2.12
7	PS12	Chain improvement	2.09
8	PS8a	Managerial aspect 1: co-operation	2.05
9	PS16	Monitoring	2.04
10	PS9	Operational aspect	2.04
11	PS20	Continuation	2.03
12	PS13	Marketing	2.03
13	PS1	Drivers review	1.99
14	PS19	Routinisation	1.96
15	PS2	Product profiling	1.96

16	PS5	Operational approach	1.95
17	PS18	Documentation	1.94
18	PS15	Documentation preparation	1.94
19	PS11	Cleaner production	1.92
20	PS6	Market & sale	1.89
21	PS3	Company profiling	1.88

(2) Multidimensional scaling (MDS):

The second analysis of correlation between categories used multidimensional scaling (MDS) to identify closeness (similarity) in correlation between categories. This approach is different from the forgoing method. The purpose of the MDS analysis in this research is to explore which categories are close together as a group by reducing them all into the domain or bigger clusters. By doing so, similar categories can be dealt with effectively and collectively by sharing or using data.

Approximately five clusters were identified as similarity groups seen as dotted circles in Figure 6.1. Small and thick circle lines can be considered as core issues as they are closely positioned to most elements within their cluster. For instance, PS9 (operational aspect) has the shortest distance with PS18 (documentation), PS15 (documentation preparation), PS16 (monitoring) and PS4 (managerial approach). The elements in PS9 (operational aspect), such as ‘trace options for improvement’, ‘R&D of chosen alternatives’, and ‘decision-making of best alternatives’, may need to be considered more importantly in the ‘plan’ stage when establishing a policy and strategy of a C-POEMS project. Subsequently, follow-up activities in the operational side (PS9) in the ‘implementation’ stage should be monitored (PS16) and the data from the monitoring must be included in the environmental documentation (PS15 and 18). PS4 (managerial approach) in the ‘plan’ stage and PS8b (managerial side of communication) in the ‘implementation’ stage are the closest categories, which may mean that objectives and targets in the 'plan' stage need to be consistent along the implementation of the project by supporting eco-design or increasing communication among project team and operational and management team.

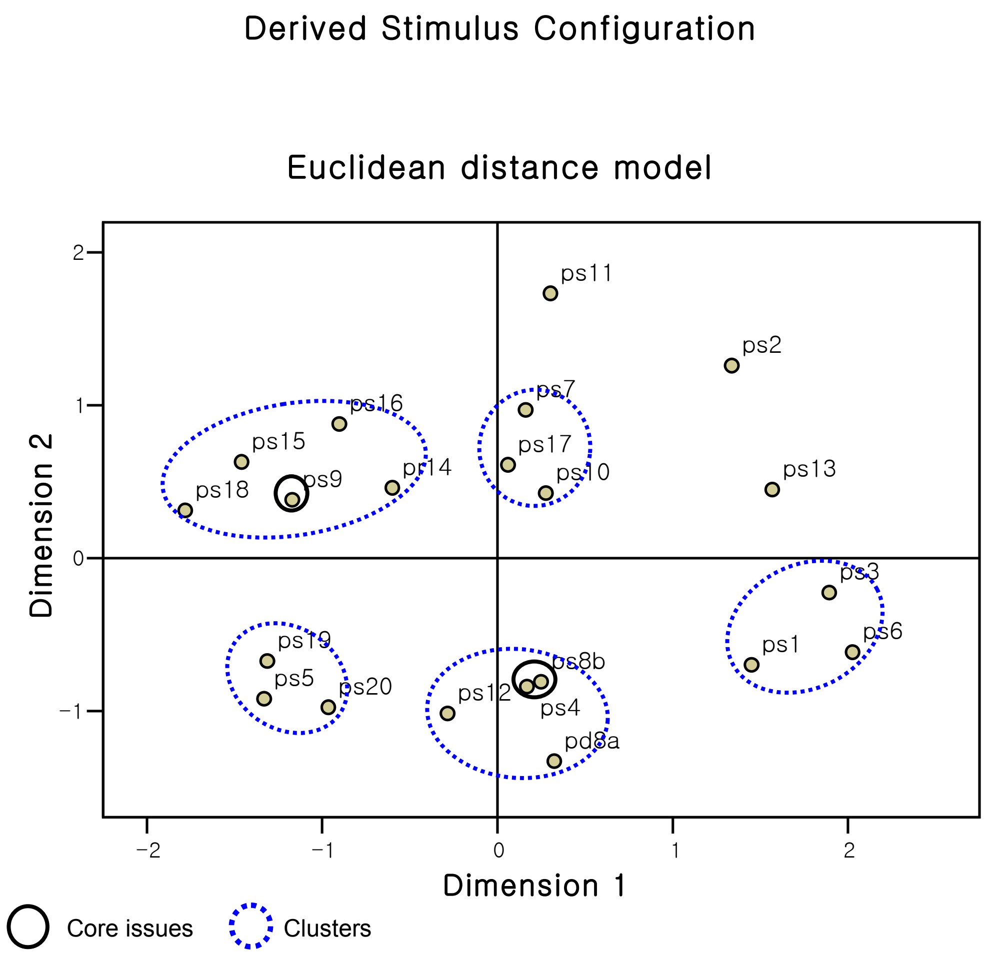


Figure 6.1: Two-dimensional solution from non-metric scaling of similarities or dissimilarities of correlations between categories

On the other hand, PS2 (product profiling), PS11 (cleaner production), and PS13 (marketing) in the 'implementation' stage are found to be more independent categories. This result may mean that the elements in these categories are likely performed with less involvement of or interaction with the elements of other categories. However, it is not a definitive answer to be able to apply to all elements in these categories because some required actions to fulfil a certain element in these categories might involve the elements in other categories such as production (PS11) or supply chain management (PS7). For instance, assessment of environmental impacts of a product (in PS2) requires information from other parties of the product chain, for instance, environmental impact assessment of materials or components supplied from second or third-tier suppliers. Besides, the assessment data of environmental impacts of a product (in PS2) is often used for developing an environmental product. Therefore, some elements of PS2 can have a close relationship with other categories such as PS7 (supply chain management), PS9 (product development) or PS11 (cleaner production). In this regard, the participants may have answered the correlation between categories according to their more collective perception.

(3) Combination of the two results

The result of the descriptive analysis (degree of each category's correlation with the rest of ones) was combined with the result of MDS (categories clustered based on the similarities). Figure 6.2 presents a graphical image of the correlations between categories. In both analyses, PS4, PS8b and PS17 showed close relationships with other categories, which can be 'core issues' as seen in Figure 6.2. In particular, these categories have close characteristics with many other categories. For instance, MDS analysis revealed that PS9 (operational aspect) in the 'plan' stage has similar characteristics of PR14 (knowledge building), PS16 (monitoring), and PS18 (documentation) in the 'evaluation/continuation' stage.

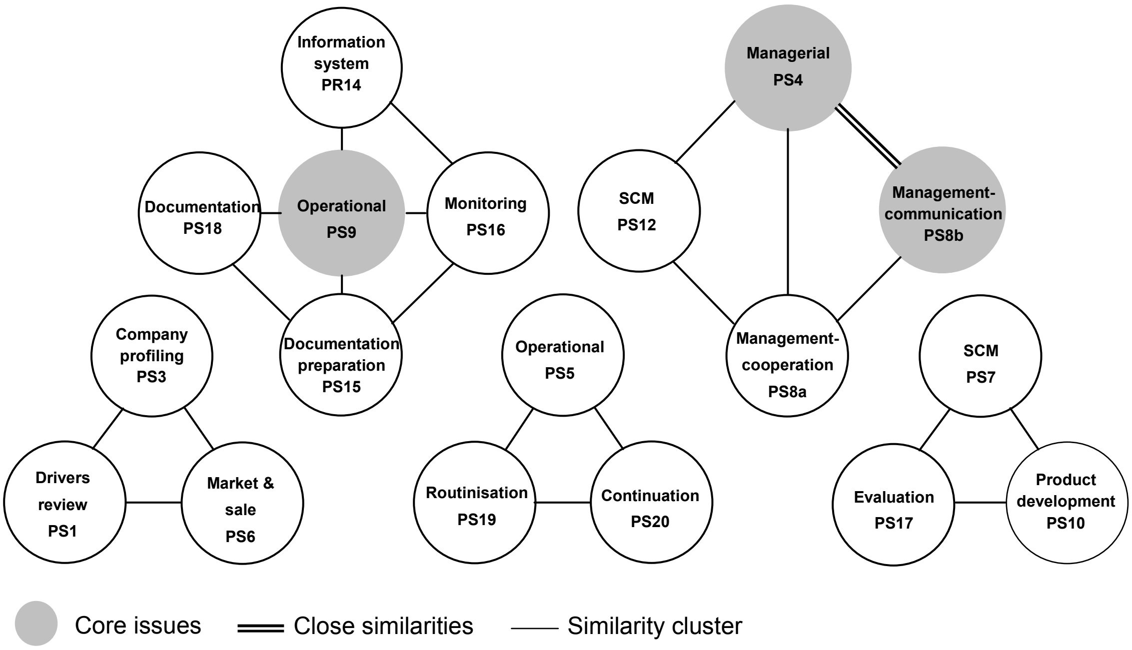


Figure 6.2: Relationships between categories of the C-POEMS model

PS4 (managerial aspect) in the 'plan' stage and PS8b (communication of management approach) in the 'implementation' stage seem to have extremely close relationship as depicted in Figure 6.1, and both received the higher marks in the descriptive analysis too in Table 6.6. This may means that successful implementation of a C-POEMS project depends on how to handle the elements in managerial aspect such as establishment of environmental strategies and objectives, and that these elements are determined by active communication between participants in the organisation through, for example, formal interface among cross-functional team. PS10 (product development) that received the highest mark in the descriptive analysis is closely related to PS7 (supply chain improvement) in the 'implementation' stage, and PS17 (evaluation) in the 'evaluation/continuation' stage. This may imply that the environmental impact assessment of the improved product needs to be checked along and supported by the supply chain.

To summarise, the categories in the clusters were considered collectively. The core issue categories need to be handled as prior areas in a C-POEMS project. This analyses data is reflected to produce a final form of the C-POEMS model with prioritisation and correlation map.

6.1.5 In-depth interviews

The five most important categories were chosen by the respondents in response to question 10. In question 11, the respondents were asked to discuss further the chosen subjects through in-depth interviews. Table 6.7 is the summary of the main discussions and most suggestions that most contributed to producing the final model.

Table 6.7: Summary of in-depth interviews regarding the five most important categories

	Category	No. of respondents	Discussion
PS1	Drivers review	7	The high level driver of strategies must be the initial driver of the environmental effort, since strategies include technical, managerial and communication.
PS2	Product profiling	6	As a hardware product development and manufacturing company this drives much of our environmental thinking.
			Required for preparing environmental barrier. Need to quantify the potential environmental impacts. Need to quantify the amount of money spent for environment. Simply say, "No input, no output". Furthermore, social aspect is to be involved.
PS3	Company profiling	4	Capability today vs. tomorrow is clearly a driver of strategies.
PS4	Managerial approach	5	No additional comment
PS5	Operational approach	4	Related to but stronger than PS4: the management decisions need to be translated into resource allocation, otherwise nothing will happen.
PS6	Market & sale	2	
PS7	SCM (Supply chain management)	4	SCM is ultimately to be a tool for Sustainable purchasing
PS8a	Managerial aspect 1: co-operation	1	No additional comment
PS8b	Managerial aspect	1	No additional comment

	2: communication		
PS9	Operational aspect	2	PS 9 and 10 (and others) are about actually 'doing' the environmental improvements, and hence form the core of any system.
PS10	Product development	7	Currently DfE is in style. However, we are to consider the social aspect as well. Seeking for DfS is expected to be a good strategy for not only upcoming EuP but also sustainability.
PS11	CP (Cleaner production)	3	In our case, this subject has a greater influence on employee and customer perception than it does measured environmental impacts.
			Cleaner production is now considered as basic requirement in the era of environmentally conscious product oriented society. Therefore the four sectors consisting of cleaner production should be met.
PS12	SCM (Chain improvement)	0	No additional comment
PS13	Marketing	2	Unless we do work out on the marketing, our newly produced environmentally friendly product or system would finally make a deficit. In this sense, marketing is so important.
PR14	Information system	4	The need for technical and legal knowledge is critical in managing environmental aspects of our business. Strategies for building knowledge and communicating it throughout the supply chain are very important, followed by using it of course, but clearly the building part comes first. Knowledge building should be considered in entire life cycle if it is potentially developed for central database. Our company has not yet reach this level but certainly work together closely with our suppliers.
PS15	Documentation preparation	1	No additional comment
PS16	Monitoring	2	If one doesn't know whether you go in the right direction or not, management will (unluckily) never keep supporting this activity.
PS17	Evaluation	6	Decisions around the progress of the environmental effort are dependent on evaluation of current performance, in terms of legal compliance and of measured waste and product characteristics.
PS18	Documentation	2	No additional comment
PS19	Routinisation	0	No additional comment
PS20	Continuation	2	Many times, it stops after a pilot project. Continuation is of extreme importance.

6.1.6 Conclusion and final form of the C-POEMS model

The participant experts overall agreed with the initial form of elements and categories, which verified the hypothesis (1) factorisation and (2) categorisation for development of the C-POEMS model. The participants provided their opinions in terms of prior areas and correlation between categories. Through the analyses of the responses, hypothesis (3) prioritisation and (4) correlation of categories and elements were defined. They also provided additional information related to contents and structure. Overall results led to improvement of the detail contents and structure of the preliminary C-POEMS model. About ten more elements were input and some original elements were divided into two categories. For example, some experts mentioned that the social aspect in eco-product development became important and thus the eco-design concept needed to be extended to design for sustainability (DfS). Also a growing aspiration of employees to corporate environmental performance was held to be an important driver in initial stage of a C-POEMS project. Hence, 'internal driver' was also supplemented. As a result, 148 elements of the final form of the C-POEMS model were generated, re-allocated and re-numbered as described in Appendix F. (element numbers in following sections indicate new ones).

In relation to prioritisation and correlation, this research produced pre-defined prior categories and elements. This was established by comparison of the results of validating subject (3) and (4) described in Table 6.8. In the table, there are four sections representing the results of validating subject (3) and (4). In the comparison between Q8 (degree of importance of elements) and Q10 (degree of importance of categories), PS1 (drivers review), PS2 (product profiling), and PS10 (information system) are the commonly important categories in both elements and categories. Therefore, the elements in these categories need to have a special attention.

On the right two sections in Table 6.8, correlation of categories shows different perspectives. PS4 (managerial approach) are highly rated in both frequency of involvement and similarity of attributes with some other categories. PR14 (information system) and PS10 (communication in managerial aspect) are relatively more correlated with other elements, and each of them is positioned in a similarity cluster.

Based on the comparison of validation subject (3) and (4), this research firstly defined which categories are more important and correlated to others. After this, the analysis data of validating subject (3) was reflected to clarify more considerably important categories. With this result, the elements in the relatively more important categories are divided into three groups: 'mandatory', 'important' and 'conditional', as described in Table 6.9.

The 'mandatory elements' means that a company should take into account of them as crucial parts of environmental improvement, for example, identifying legal compliance of products and customers' demands in the categories, 'drivers review (PS1)' and 'product profiling (PS2)'. The 'important elements' such as establishing environmental (product) policy and targets are also essential. However they are not necessarily must-do elements to be carried out in all cases of C-POEMS activities. The rest of the elements (not in the important categories) are categorised as conditional elements that are assumed to be considerable depending on strategies or targets of a project.

Table 6.8: Comparison of the results of prioritisation and correlation

Validating subject (3): prioritisation							Validating subject (4): correlation					
Q8: Degree of importance of elements				Q10: Degree of importance of categories			Q9: Descriptive analysis of correlation			Q9: MDS analysis of correlation		
Rank	Category		Average of mean value	Rank	Category	No. of respondents	Rank	Category	Mean value	Cluster	Category	No. of category
1	PS1	Drivers review	4.12	1	PS1	7	1	PS10	2.26		PS9	
2	PS2	Product profiling	3.53	1	PS10	7	2	PR14	2.19		PS15	
3	PS10	Product development	3.36	2	PS2	6	3	PS4	2.13	1	PS14	5
4	PS7	Supply chain management	3.11	2	PS17	6	4	PS17	2.13		PS16	
5	PS5	Operational approach	3.08	3	PS4	5	5	PS8b	2.12		PS18	
6	PS4	Managerial approach	3.00	4	PS3	4	6	PS7	2.12		PS17	
7	PS3	Company profiling	3.00	4	PS5	4	7	PS12	2.09	2	PS7	3
8	PS6	Market and sale	2.75	4	PS7	4	8	PS8a	2.05		PS10	
9	PS9	Operational aspect	2.64	4	PR14	4	9	PS16	2.04		PS5	
10	PS8b	Communication in managerial aspect	2.51	5	PS11	3	10	PS9	2.04	3	PS19	3
11	PS13	Marketing	2.51	6	PS6	2	11	PS20	2.03		PS20	
12	PS17	Evaluation	2.50	6	PS9	2	12	PS13	2.03		PS8b	
13	PS11	Cleaner production	2.46	6	PS13	2	13	PS1	1.99	4	PS4	4
14	PS16	Monitoring	2.30	6	PS16	2	14	PS19	1.96		PS12	
15	PS12	Chain improvement	2.20	6	PS18	2	15	PS2	1.96		PS8a	
16	PS8a	Cooperation in managerial aspect	1.99	6	PS20	2	16	PS5	1.95		PS1	
17	PR14	Information system	1.88	7	PS8a	1	17	PS18	1.94	5	PS3	3
18	PS20	Continuation	1.86	7	PS8b	1	18	PS15	1.94		PS6	
19	PS19	Routinisation	1.83	7	PS12	1	19	PS11	1.92		PS13	
20	PS15	Documentation (preparation)	1.79	7	PS15	1	20	PS6	1.89		PS11	
21	PS18	Documentation	1.72	8	PS19	0	21	PS3	1.88		PS2	

Prior categories in individual importance of either category or element

Prior categories in correlation (collective management in clusters)

Table 6.9: Elements (new numbered) in mandatory and important groups

Category		Element		Mean value
PS1	Drivers review	ps1n1	Legislation	4.75
		ps1n2	Customers	3.92
		ps1n3	Market opportunities	4.17
		ps1n4	Competitors	3.92
		ps1n5	Internal drivers of organisation	NA
		ps1n6	Stakeholders	3.83
PS2	Product profiling	ps2n7	Legal compliance	3.83
		ps2n8	Environmental impact	3.46
		ps2n9	Environmental cost	3.50
		ps2n10	Environmental benchmarking/position	3.33
		ps2n11	Social aspect	NA
PS3	Company profiling	ps3n12	Economical capability	3.46
		ps3n13	Technical capability	3.21
		ps3n14	Management capability	3.38
		ps3n15	Staff ability	3.00
		ps3n19	Communication-internal	3.08
		ps3n21	Cooperation-internal	3.08
		ps3n23	Corporate culture	3.08
PS4	Managerial approach	ps4n25	Established business policy	3.00
		ps4n26	Established business strategies	3.33
		ps4n27	Established project objectives	3.21
		ps4n28	Established innovation targets	2.88
		ps4n29	Identification of related areas	2.67
		ps4n30	Established procedures	2.92
		ps4n31	Established network	3.00
		ps4n32	Established systems	2.75
		ps4n33	Prioritisation (strategies, activities)	3.08
		ps4n34	Communication/cooperation	3.42
		ps4n35	Mutual agreement – internal	3.17
		ps4n36	Mutual agreement – external	2.58
		ps4n37	Organisational certificate (ISO 14001 etc.)	NA
PS5	Operational approach	ps5n38	Resource allocation-human	3.58
		ps5n39	Resource allocation-finance	3.33
		ps5n40	Resource allocation-technique	3.33
		ps5n41	Allocation-responsibilities, authorities	3.33
		ps5n44	Knowledge building-environment	3.17
		ps5n48	Integration with existing asset & system	3.04
PS6	Market & sale	ps6n49	Established strategy-marketing	3.00
PS7	SCM	ps7n53	Sustainable purchasing plan/guide	3.04
		ps7n54	Decision-making suppliers/products	3.25
		ps7n55	Check communication	3.17
		ps7n56	Check cooperation	3.00

PS8b	Managerial aspect1: cooperation	ps8bn66	Establish formal interface	2.42
		ps8bn67	Establish eco-design support	2.67
		ps8bn68	Project team (cross-functional team)	2.58
		ps8bn69	Managerial and operational team	2.67
		ps8bn70	Whole department	2.46
		ps8bn71	Suppliers	2.58
		ps8bn72	Customers	2.75
		ps8bn73	Shareholders	2.42
		ps8bn74	NGOs	2.17
		ps8bn75	Other stakeholders (build-up relationship with resident)	2.33
		ps8bn76	Record and answer enquiries related to products	2.58
PS9	Operational aspect	ps9n77	Trace options for improvement	2.54
		ps9n78	R&DE of chosen alternatives	2.63
		ps9n79	Decision-making of best alternative	2.75
PS10	Product development	ps10n80	Check DfS requirements	3.50
		ps10n81	Development DfS concept	3.42
		ps10n82	DfS implementation	3.50
		ps10n83	Sustainable option validation	3.13
		ps10n84	Decision making best alternative	3.25
		ps10n85	Product certificates (eco-labelling etc.)	NA
		ps10n86	Product declaration in chain system	NA
		ps10n87	Social aspect	NA
PR14	Information system	pr14n104	General investigation/information	2.00
		pr14n105	Environmental information (LCA data update)	2.17
		pr14n106	Management information	1.83
		pr14n107	Technical information	2.00
		pr14n108	Product chain information	1.83
		pr14n109	Market information	1.92
		pr14n110	Social aspect information	1.42
		pr14n111	Test/methods of measurements	1.92
		pr14n112	Information availability	2.08
		pr14n113	Collecting supplementary data	1.67

Mandatory group   Important group

To conclude, PS10 needs to be highly considered according to the importance of elements and categories as well as correlation with others. Thus, most elements in PS10 should be more heavily weighed than any of the other elements. However, some new elements added by the participants, such as ps10n85 (product certificates), ps10n86 (product declaration in chain system) and ps10n87 (social aspect) are not included in the mandatory group, as they were not approved in validating subject (3), but are included in the important group taking into account their potential in line with collective importance of PS10.

Although PS1 and PS2 are defined as important areas but have less interrelation with other areas, some elements in these categories have a strong influence to other categories such as PS10. For example, ps10n80 (eco-deign concept) are deeply connected with most elements in PS2 (product profiling) as well as some other elements in PS1 (drivers review) such as ps1n1 (legislation requirements), ps1n2 (customers) or ps1n3 (market opportunities). Therefore, the importance of both elements and categories defined in validating subject (3) also needs to be taken account as mandatory group regardless of correlation effect on other categories.

In validating subject (3), PS14 has received attention in both the descriptive and MDS analyses. Hence, the elements might have a potential to interact with the elements in such categories including PS9, PS15, PS16 and PS18. Therefore, those elements in these categories are considered in 'important group'. A similar case is PS4, in that this category has been found to have a relatively frequent relationship with other categories even though the mean value was marginally different from lower categories such as PS17 or PS8b. However, PS4 has an extremely close relationship with PS8b. Because of this, the elements of PS4 are categorised in 'important group' too. This judgement is applied to the core categories of the clusters in MDS analysis result including PS9 and PS8b.

Thus, overall 11 categories are considered in mandatory or important group. Some elements are described as core, which means that these elements can be collectively handled with other elements in the closely related categories. As a result, this research established a final form of the C-POEMS model with a prioritisation and correlation map illustrated in Figure 6.3. This final form will be used in the interpretation of analysis of the case studies with the diagnosis template.

6.2 Case studies

This section explains the outcome of the implementation of the diagnosis template 1Da in three companies. The diagnosis template 1Da was applied as a component of the C-POEMS model in order to demonstrate the feasibility of the template according to the hypotheses for development of the diagnosis template: (1) starting with general issues such as identification of a company's main drivers or interests and focus areas, (2) providing an applicable self-help format for SMEs, new users or those unfamiliar with environmental issues, and (3) integrating and/or tailoring C-POEMS. For hypothesis (1), the diagnosis template 1Da covers general issues of the environment surrounding companies. The applicability in the format of the template to hypothesis (2) was observed during the implementation of the template in the companies. Feedback from the companies and observation results are explained in each following section. In the interpretation of the diagnosis result, the prioritisation and correlation map of the final form of the C-POEMS model was used. Through this, focal areas of each case were found and a direction for further implementation of a C-POEMS project was suggested, which can provide an answer to hypothesis (3). Each case study consists of two parts: summary of diagnosis result describing general issues of each company (hypothesis 1), interpretation of the result and feedback (hypotheses 2 and 3).

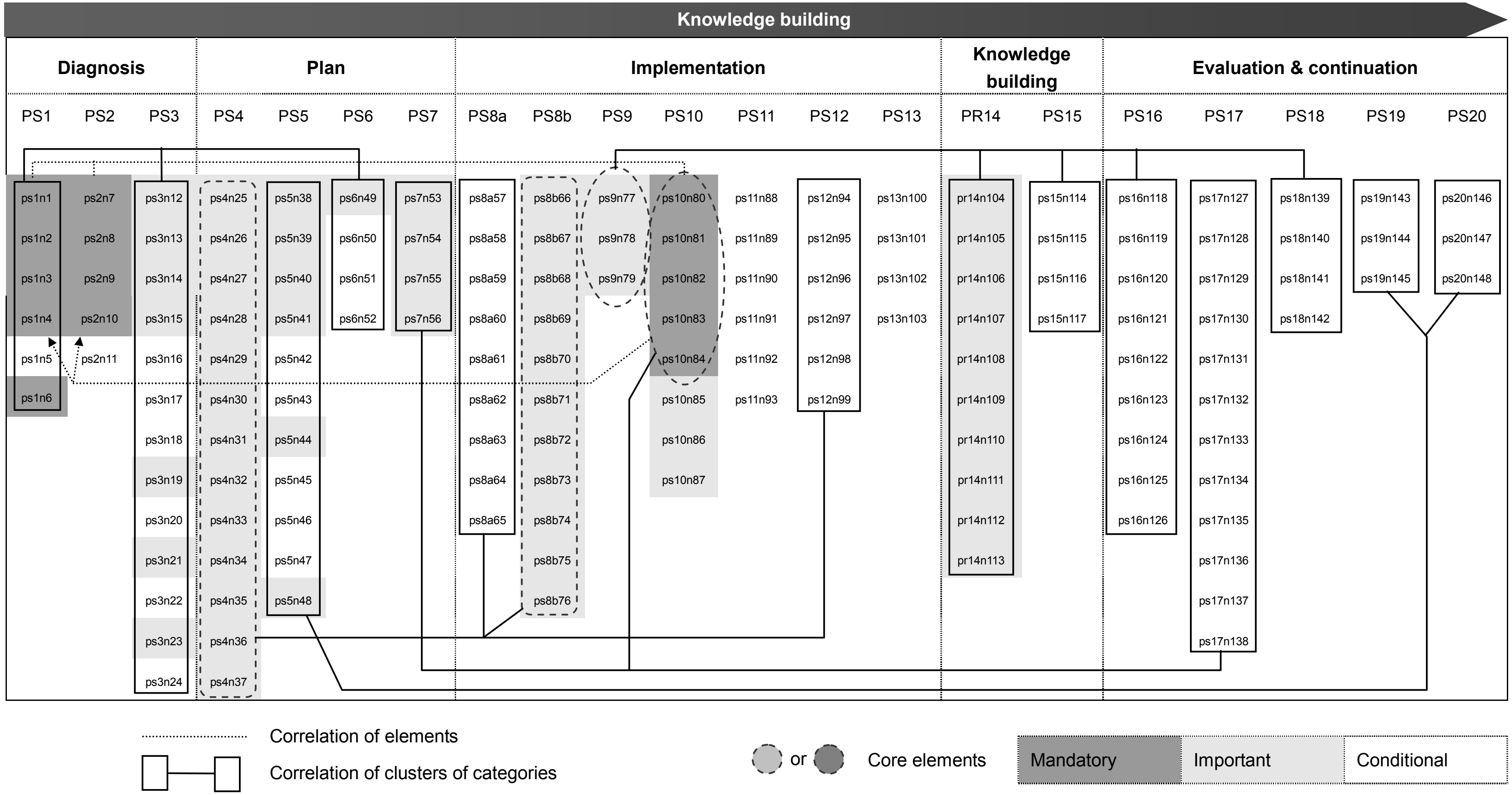


Figure 6.3: Prioritisation and correlation map of final format of the C-POEM model

6.2.1 Company A

Summary of diagnosis result

Company A can be categorised in medium to large sized enterprise that has overall 500 employees are in domestic company unit. This company produces IT equipment and supplies products to multinational IT branded companies. Since environmental product policy and regulations in Europe have been implemented and have had a particularly strong influence on electronic and electrical manufacturers, Company A has been actively involved in environmental improvements by adopting, for example, environmental management standards (e.g., ISO 14001) and technical development to comply with recent environmental regulations (e.g., WEEE, RoHS, EuP). This company has looked for further environmental innovation but feels it is difficult to find out a new direction.

According to the feedback from the template 1Da (see Appendix H), Company A has been aware of general environmental pressures such as legislation, customers' requirements, internal interest, market demand, etc. The respondent of Company A was fully aware of the recent legislations (i.e., WEEE, RoHS, EuP and REACH). In terms of main drivers, the template 1Da has four areas, i.e., legislation, internal drivers, customers, and market (including consumer and competitiveness). The first major driver for Company A was legislation compliance, which was directly influenced by the regulations as well as customers requirements. Most legislation in the list was engaged in the company's products. Especially technical aspects such as thermal management of equipments were main concerns with regard to customers and regulations.

Although the company recognised well enough the concept of EuP legislation, its response to the level of compliance with EuP was very obscure. For instance, the company expected that its current state of compliance with EuP would not cause any problem because EuP is a voluntary scheme at that moment and has not yet defined implementing measurements and specific requirements regarding environmentally relevant product characteristics. Therefore, Company A felt it was difficult to take particular actions for eco-design innovation until the legislation has a clear shape. This may also be partly due to the lack of experience and knowledge about eco-design in general coupled with the fact that most companies like Company A are more concerned about WEEE and RoHS than EuP.

A second driver for environmental improvements for the company was customer pressure, in particular, compliance with EU legislation as their customers' products are exported to EU market. Through various channels (e.g., communication in executive level, customer audits or view of ISO 14001 registering body), the company's customers expressed their concerns on general environmental information on products, requirements of product's environmental improvement, and environmental policies or performance.

An internal driver was also important for the company in order to encourage employees and orchestrate resources for environmental improvements. However, the centre of internal driver was mainly the environment-related departments (compliance dept., development dept. or procurement dept.) or executive levels (e.g., CEO, CTO), while other functional units or lower layers of hierarchy were far less aware of environmental issues. The company replied that there was no pressure from the end consumer market, but certainly from the business customer market. Company A considered that better performance of products and business in the environment would bring positive effect, for instance, improvement of corporate or brand image, potential market growth, product and service differentiation, market competition, and so on. It was especially felt that being a European company aware of and acting on EU environmental regulation, the company had substantial advantages over global competitors in other continents.

Finally, the main barriers in implementing environmental improvements were discussed. For the company, system and culture were the most difficult aspects, which often caused uncoordinated activities of several decisions throughout different units worldwide. Besides, the environmental policy of product improvements was not penetrated in the design department at all, which resulted in a lack of involvement of design parts that potentially limited technical solutions for environmental improvements to their products. A lack of tools was also mentioned, in particular a lack of structure in use of tools. For example, there was not enough information about technical support of software especially eco-design tools for EuP compliance and benefits from business cases of eco-design, which could support the design department. Instead, the company has only used some software mainly related to WEEE or RoHS directives, for checking the status of compliance with the legislations. More information and details are summarised in Appendix H.

Interpretation and feedback of diagnosis result within C-POEMS framework

The information of the template 1Da can be integrated with the C-POEMS framework. In this process, each case study has two main steps that, first, translate the information of individual companies replied to the template 1Da, and, second, apply the information obtained to the prioritisation and correlation map of the C-POEMS. As a result of the second step analysis, focal and prior areas are identified and a C-POEMS project can be designed. The conductor of this research has intervened to interpret the diagnosis results, and elaborate a project plan for individual companies.

In the case of Company A, firstly, the result in terms of main drivers is compared with the prioritisation and correlation map (see Figure 6.3). The company highlighted legislation, customers and internal pressures as key drivers, described as the top-left boxes in Figure 6.4. According to the interpretation of the answers within the C-POEMS map, the main drivers have a close relationship with PS3 (company profiling in the 'diagnosis' stage) and PS6 (market and sale in the 'plan' stage). Also, some elements of PS2 (product profiling in the 'diagnosis' stage) and PS10 (product development in the 'implementation' stage) are associated with the drivers. Hence, four categories (PS2, PS3, PS6 and PS10) were initially counted as relevant areas (correlation categories), illustrated as boxes in the middle section in Figure 6.4.

Secondly, according to the C-POEMS map, the correlated categories to the main driver elements are directly or indirectly influenced by other categories such as PS10 and PS7, PS10 and PS17. Therefore, overall 52 elements can be considered for Company A initially. Among them, about 17 elements are found to be mandatory or important that the company should prioritise, described in prioritisation element boxes in the meddle section in Figure 6.4. In line with these, thirdly, in order to clarify more significant (focal) areas for Company A, the main barriers that the company described need to be considered. Hence, more important problems such as internal issues are taken into account while the external barriers such as landlord charge (finance resources) are disregarded for further project development. Internal issues discussed are, for example, a lack of awareness and involvement of product development team in environmental activities of the company.

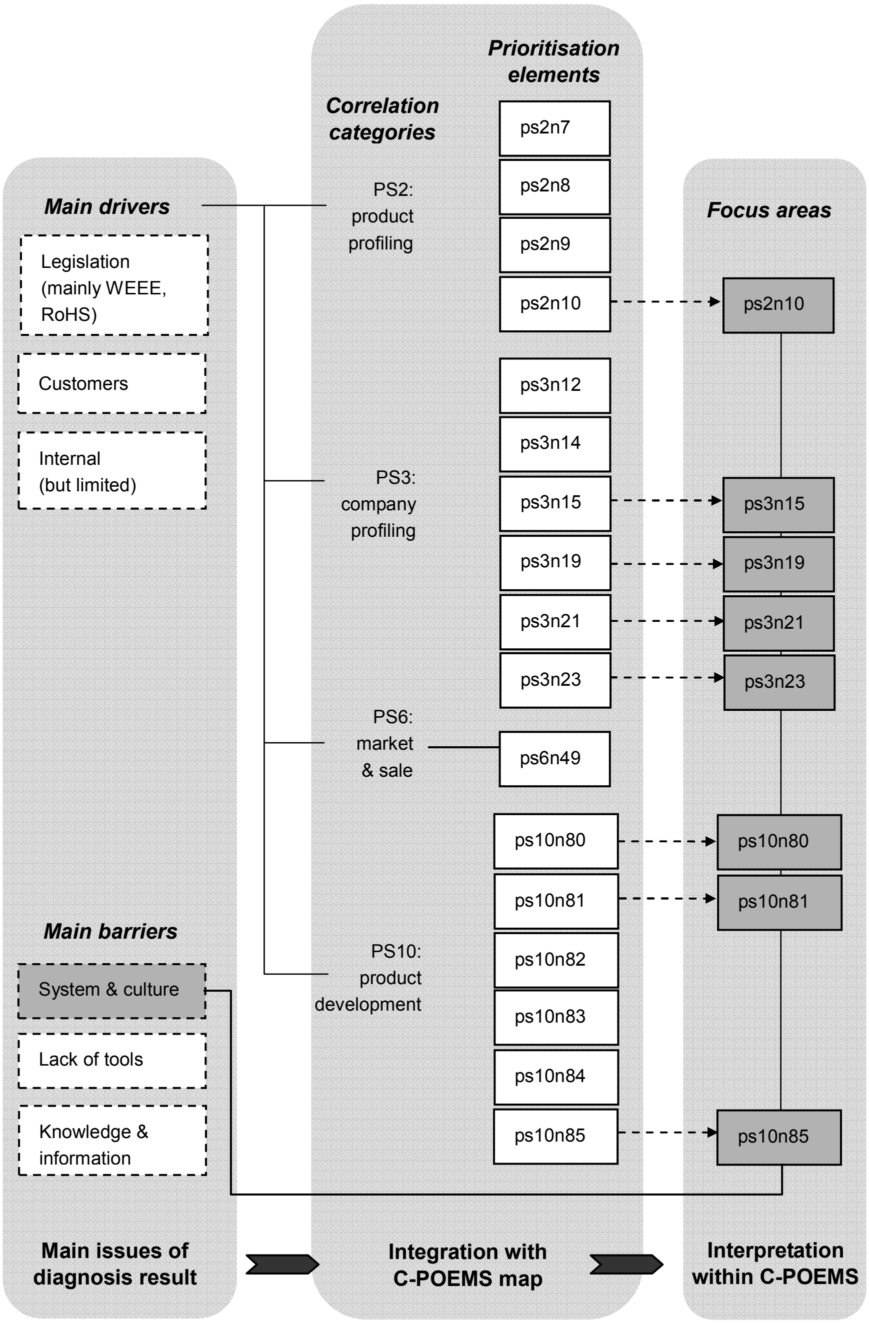


Figure 6.4: Focus areas for Company A (for indication of number, see Appendix F)

Combining the company's own view of its internal barriers and the translation of diagnosis result with the C-POEMS map, following focal areas, as seen in the far right section in Figure 6.4, are finally drawn up; ps2n10 (environmental benchmarking/position), ps3n15 (staff capability), ps3n19 (internal communication), ps3n21 (internal cooperation), ps3n23 (corporate culture), ps10n80 (check DfS requirements), ps10n81 (development of DfS concept), and ps10m85 (product certificates, e.g., eco-labelling).

Based on the interpretation of the diagnosis result and professional experience of the research conductor, Company A was advised to develop a strategic structure with the focus elements to implement a C-POEMS programme. The project aims to increase corporate culture and staff capability in the environmental aspect. Also, the elements of the chosen focal areas are strategically allocated. For example, the structure of the programme has three pillars each representing, environmental benchmarking, product certification and DfS activities, which could increase environmental motivation by giving responsibilities and objectives of the C-POEMS project to relevant departments and individuals. Sharing corporate environmental policy and common goals might strongly affect the design department and interdepartmental communication and cooperation especially when environmental issues are aligned rather than isolated with company profits such as compliance with customer requirements. Regarding this, the marketing department can play an important role by undertaking a research of benchmarking products and providing the design department with the resultant information. Likewise, the environmental or compliance departments could share, with the design or other departments, information about a product environmental certification and its requirements strongly related to the main drivers. The information of environmental benchmarking and requirements of product certification could then be the basis to produce eco-design requirements and develop a concept by the design department.

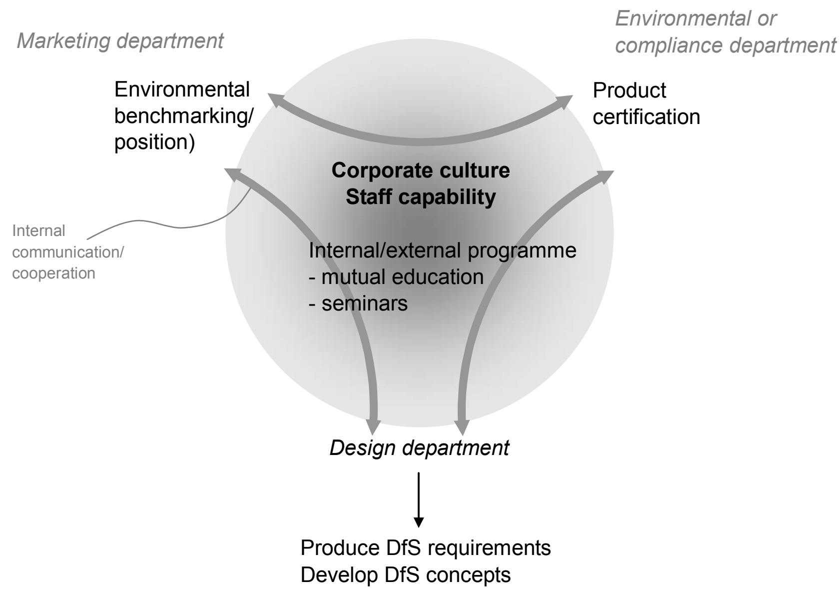


Figure 6.5: Three-pillar structure for implementing a C-POEMS project for Company A

After the result of integration and interpretation of diagnosis template 1Da within the C-POEMS framework, Company A decided to develop an education programme for the product development departments especially the product engineers. Through the further work, the company expected to establish a foundation for proactive environmental performance and preparation for full compliance with EuP legislation in the future. Overall feedback of the company was fairly positive. Firstly, participants did not have any particular difficulties in using the template. Secondly, the C-POEMS model with the prioritisation and correlation map contributed to streamline a project onto the focal areas. This was the most positive aspect of implementing the C-POEMS model for Company A, which allowed the users to clarify and convince themselves to persuade the ones who were not actively involved in the environmental issues.

6.2.2 Company B

Summary of diagnosis result

Company B provides a telecommunication service to end consumers. Not only the parent company but also all company units have not considered environmental issues widely. Thus, environmental documentation was not found. Nevertheless, the participant in Company B replied that there are potential challenges in legislation compliance, internal drivers, and customers' requirements. The main concern for the company was energy consumption of telecommunication equipment, which they may need to consider in terms of environmental procurement and maintenance of equipment. The respondent of the company recognised well enough the recent environmental product legislations although none of the legislations were associated with the company's business. Hence, legislation compliance and impact to their business were hardly considered. Cost savings through reducing energy consumption might be the only driving force for the company.

Some employees in the company expected that environmental improvement, even if it is minor sacrifice, could bring positive outcome such as better image of the company which is significant for its operation. Despite environmental concerns on a personal level, there was no policy or potential consideration of the environment at company level. Besides, the company perceived that its activities had very little environmental impacts. Therefore, internal drivers hardly affected corporate environmental policy. In terms of customer and market pressure, the company has replied that there was no noticeable pressure at all. However, potential advantages in the market through environmental improvements were expected, for instance, improvement of corporate and brand reputation, market competitiveness, potentially new business opportunities, etc.

The company described the major barriers including a lack of knowledge and information, a limitation of finance resources, a lack of management skills and support, and system and culture. Environmental information especially about potential market reward could motivate the company for environmental improvement. However, the respondent of Company B addressed a lack of financial support on the market research. In addition, little understanding of CSR (corporate social responsibility) and the environmental aspect in management were also stated as bottleneck. Allocation of the appropriate person to deal with the environmental area and training employees were suggested as solutions for this problem. In a corporate culture and system, there was no real incentive for environmentally conscious performance, which might be also related to a lack of awareness of environmental issues in particular executive level. Increasing attention and information throughout the organisation are necessary. In brief, the company only expected few benefits such as financial rewards and company image, which could be potential drivers.

Interpretation and feedback of diagnosis result within C-POEMS framework

The main drivers for Company B are outlined as financial aspect and company image. Apart from the financial benefit that is important elements in PS2 (product profiling), company image is not directly considered as a major driving force in the 'diagnosis' stage of the C-POEMS model. However, company image could influence other aspects such as customers, market opportunities or competitiveness. Most barriers raised above have a close relation to the lack of awareness of environmental issues and lack of financial support.

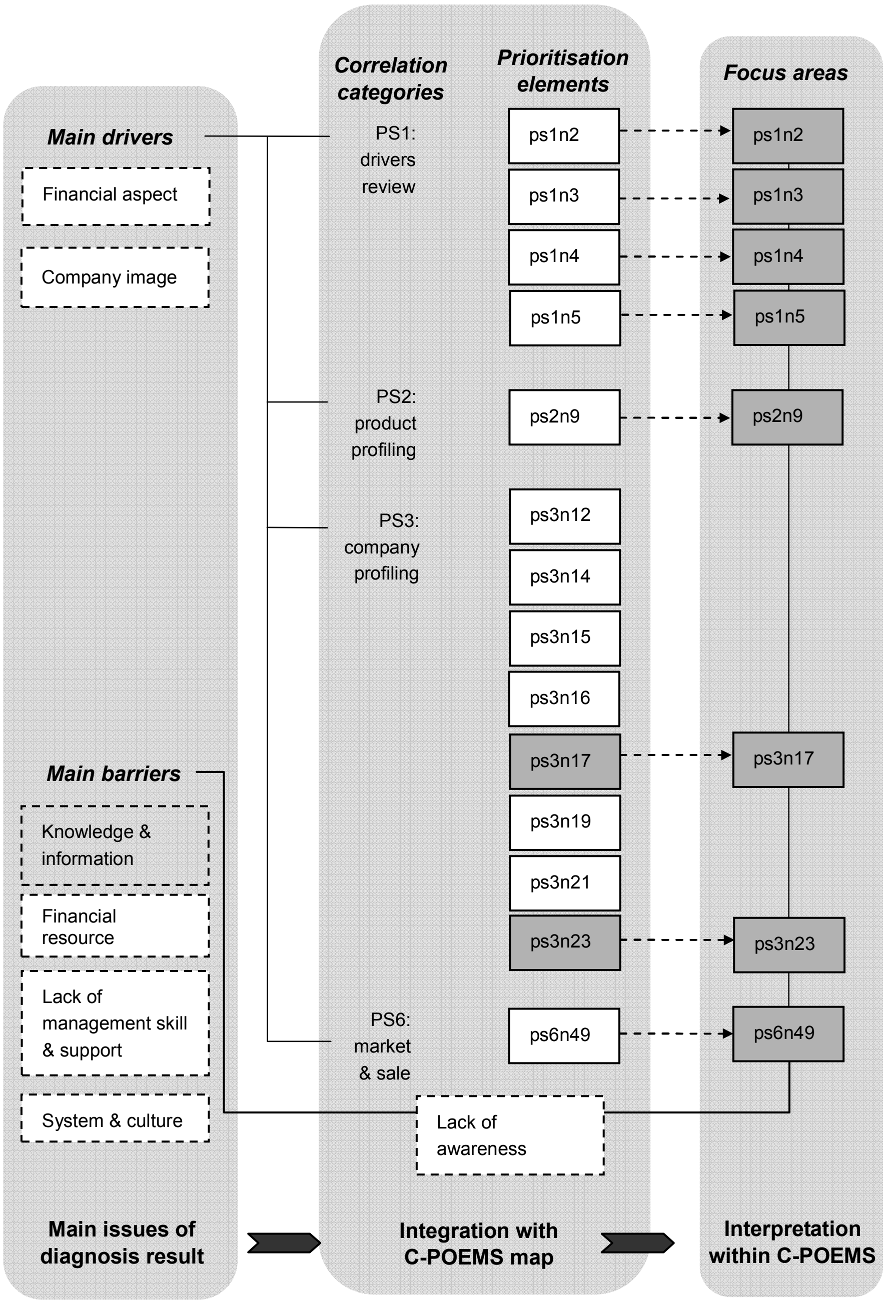


Figure 6.6: Focus areas for Company B (for indication of number, see Appendix F)

The result of diagnosis template 1Da (elements of drivers and barriers) was also applied to the prioritisation and correlation map of the C-POEMS model. As legal compliance is not the main issue for the company, it was excluded from the interpretation of the result. Improving company image is potentially associated with consumer appeal, market opportunities or competitiveness. In addition, cost saving through environmental improvements can be a determinant. Thus, PS1 and PS2 are considered as prioritisation groups. These two categories have correlations with PS3 (company profiling) and PS6 (market and sale). Hence, four categories including PS1, PS2, PS3 and PS6 are initially counted as relevant areas, illustrated as middle section in Figure 6.6.

According to the prioritisation and correlation map, some elements are more influential to the two main drivers (i.e., financial rewards and company image). For instance, company image is likely to be associated with consumer, market and competitiveness. With respect to the main barriers, four issues are all related to environmental awareness and corporate culture. In the prioritisation categories, following elements were considered as focal areas including: ps1n2 (customer), ps1n3 (market opportunities), ps1n4 (competitors) and ps1n5 (internal drivers) – in PS1; ps2n9 (environmental cost) – in PS2; ps3n23 (corporate culture) – in PS3; and ps6n49 (marketing strategy) – in PS6.

As Company B does not have any particular pressure and has most concerns on the advantages in the financial aspect and company image, identifying benefits rather than threats could be more effective to motivate the company. In this regard, a C-POEMS project aims to increase awareness by searching possible benefits from environmental improvements for the company. In this regard, successful cases from other organisations, preferably same sector, could draw some attention. Company B was suggested to implement a two-step simulation project described in Figure 6.7. This project needs to cover the issues defined as focus areas in the far right section of Figure 6.6.

As a first step, a case study may need to focus on most attractive aspects for Company B such as company image linked to consumer appeal, market opportunities, or competitive advantages. Company B can be simulated through the role models of the case study so that potential benefits can be estimated. Ideally, the marketing department would conduct this project.

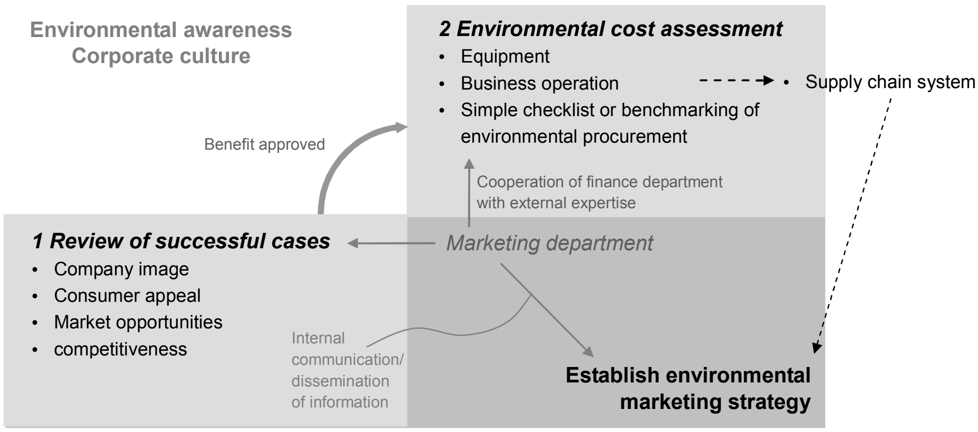


Figure 6.7: Two-step simulation project for Company B

Once the company witnesses the potential benefits, an abridged assessment and/or analysis of environmental costs can take place. A scope of the assessment/analysis could be one or all of these subjects; equipments, business operation and/or benchmarking of environmental procurement – the most interest areas for the company. If necessary, the finance department of the company may be able to collaborate with external experts. Any proof of cost savings would likely extend the scope toward the supply chain system. Outcomes of the two-step project should be disseminated throughout the company and the information needs to be shared. Thus, the whole procedure of the project can be a stepping-stone to increase environmental awareness and change corporate culture. In the overall observation and feedback, the company did not have problems using the template. However, the sector of Company B has recognised that there are no huge threats and profits from environmental issues. Therefore, the C-POEMS model would not be immensely useful for those sectors.

6.2.3 Company C

Summary of diagnosis result

Company C provides products and technologies of production and processing in the oil and gas industry. The business areas of its major customers have a broad range from large household appliances to IT and telecommunication equipment. The major market is where the company supplies process equipment and technologies, and manufacturing facilities and systems, etc. in relation to oil and gas supply. Company C replied that they have no environment-related documents.

Any products or operations by this company (including parent company) are not involved in any regulations described in the template 1Da, but constrained by local environmental regulations such as reduction or removal of BTEX (benzene, toluene, ethyl-benzene, and xylenes) and VOC (volatile organic compound) in the production process. The company perceived compliance with environmental regulations as slightly negative as perhaps a burden for their business.

In terms of an internal driver, there was no particular department or person that deals with environmental work. But, at a personal level, environmental concerns were noticed.

However, collaboration with other departments or support for environment-related activities was sceptical. This may be due to the fact that the company does not run any facilities or factories that directly create environmental impacts. Besides, the customers are not aware of environmental issues and do not pressure the company at all. These might be the reasons why this company does not consider environmental aspects now or in the near future of its business. Internally, the company was concerned about reducing the use of paper, and externally emission and cost for total operation or maintenance of unit/system, as well as the health and safety of products from customers' viewpoint. Company C indicated that the market has been more sensitive to environmental issues than business customers. Nevertheless, direct pressure from the market does not exist.

Regarding the main barriers for environmental improvements, a lack of financial, time, and human resources and tools were selected. For example, the company has been facing more demand from investors or clients to spend more capital on environmental improvements. However, a substantial shift of business towards sustainability may not be possible for the company as the industry as a whole has been known as the major source of environmental pollution and resource depletion. In line with this, if environmental issues were fully involved in this industry, the respondent expected that the business would collapse due to the fact that alternative energy sources and technologies have not been fully developed to be able to replace the conventional ones. Regarding this, the respondent stressed that government should put more effort into supporting the industry in developing environmentally sound technologies.

Interpretation and feedback of diagnosis result within C-POEMS framework

Even though there was no a strong driving force for environmental innovations for Company C, maintaining compliance with local regulations, using less materials in the working environment, or making a gradual effort to reduce emissions and cost in the operation and maintenance of units/system could be a challenge for the company. Thus, the major environmental drivers for the company are defined as local regulation compliance, and reduction of environmental impacts and costs from a life-cycle perspective. Thus, PS1 and PS2 are relevant categories in a C-POEMS project for the company. In terms of the main barriers, most problems mentioned are related to the financial or external issues such as government support. The financial problems in the environmental aspect are considered in the cost savings. A lack of time was addressed in that the respondent regarded it as a part of business management. Financial and time issues are more closely related to the existing system rather than environmental issues. Hence, the main barriers are not fully considered in prioritisation of the elements.

Applying the result to the prioritisation and correlation map, most elements of PS1 and PS2 are included in the prioritisation elements. PS1 has correlations with PS3 and PS6. Some elements of PS2 may have a relation to PS10 as seen in Figure 6.3. Therefore, overall five categories are considered as the correlation categories that each has prioritisation elements illustrated in Figure 6.8. Among the elements of the prioritisation groups, more important elements associated with the main drivers are considered as focal areas, that include ps1n1 (legislation compliance) in PS1, and ps2n7 (legal compliance), ps2n8 (environmental impact), and ps2n9 (environmental cost) in PS2.

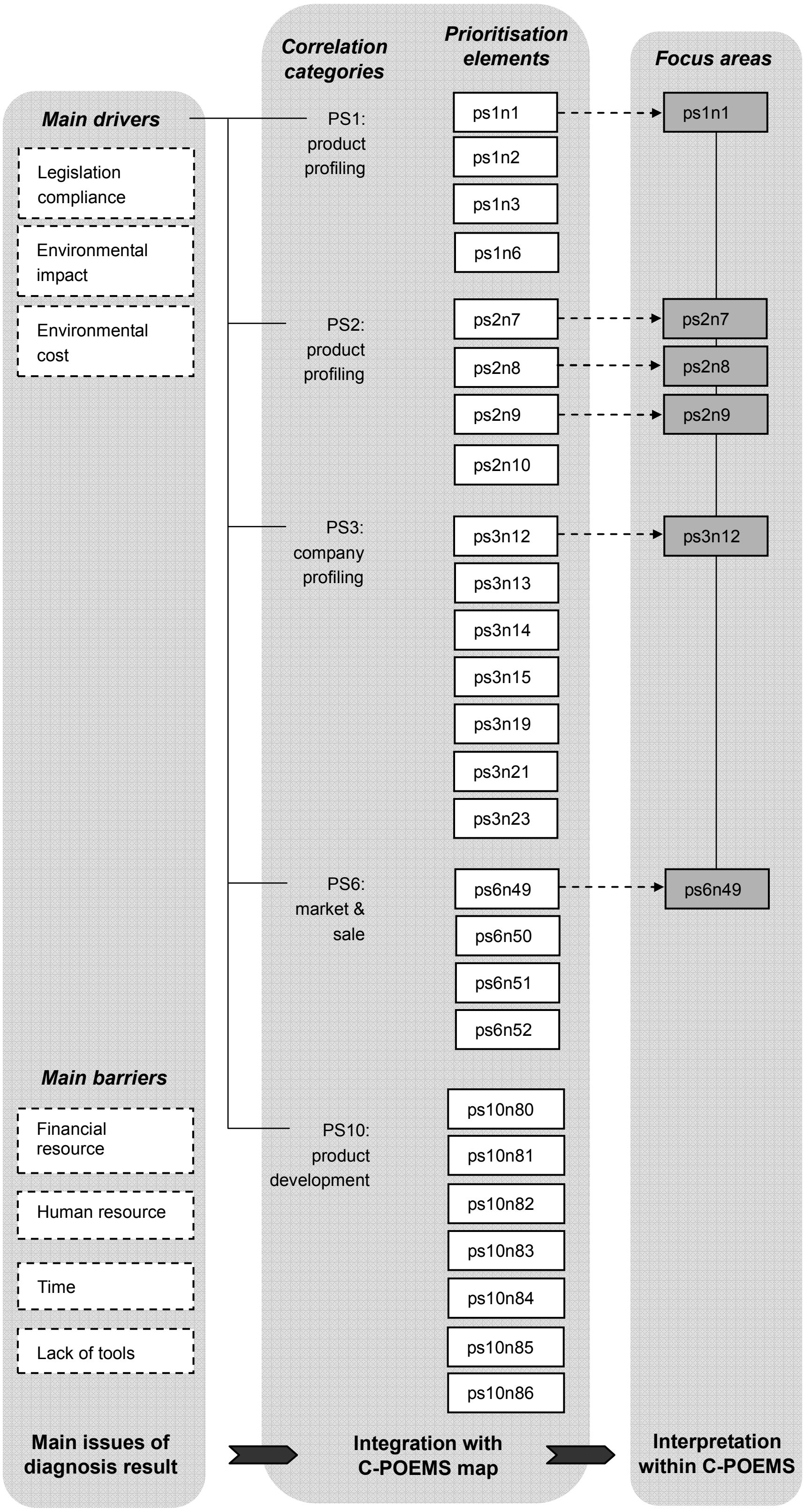


Figure 6.8: Focus areas for Company C (for indication of number, see Appendix F)

Based on the diagnosis result, Company C was advised to implement an environmental assessment of its products and operation in life cycle, as seen in Figure 6.9. The assessment also includes an environmental cost assessment. This company needs to consider compliance with local regulation for the potential market or more improvement beyond standard compliance in order to keep a good relationship with local regulators. The outcome of the environmental assessment can be considered when developing sustainable technologies and financial benefits can be returned to re-investment in R&D if any cost savings occur. General feedback of the company shows that its environmental concerns and actions are only apparent where they are directly related to company business. Despite the easy use of the template and perceptive guidance of the C-POEMS, some contents of the template (e.g., WEEE, RoHS, EuP directives), which were irrelevant to the company business, could not be particularly useful.

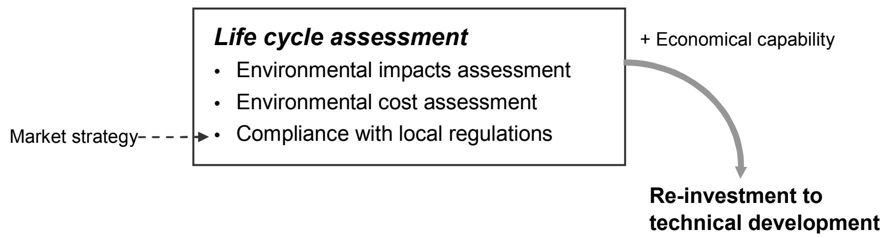


Figure 6.9: Life cycle assessment of products and operation for Company C

6.2.4 Conclusion

In the case studies of the diagnosis template 1Da, three subjects of the hypotheses for development of the diagnosis template were suggested that: (1) identify general environmental issues of main drivers, barriers, etc. surrounding the participant companies, (2) are applicable for SMEs, new users or those unfamiliar with environmental issues, and (3) integrate and translate the information within the C-POEMS framework in order to discover focal areas or to design a further project.

For subject (1), the implementations of the diagnosis template provided a chance for the participant companies to get an overview of their general environmental issues and performance. However, as the contents of the legislation part in the template focus on manufacturing in particular electrical and electronic sector, other sectors (e.g., service-oriented area of Company B) may have a limitation in utilising the template. This result might be because the POEMS as well as C-POEMS were developed in response to the product-oriented environmental policies and legislations that have been more focused on electrical and electronic products than other sectors including service areas. In terms of subject (2), most companies replied that the format of the template was fairly simple to implement. The procedure of using the template did not require extra effort for the companies. However, the analysis and interpretation within the C-POEMS framework might require intervention of experts who have knowledge about the C-POEMS or equivalent subject areas. Nevertheless, the pre-defined prioritisation and correlation map was helpful to clarify focus areas for the companies and to plan for further action, which are responded to the subject (3).

To conclude, overall initial aims and subjects of the diagnosis template are demonstrated. With respect to the potential benefits of implementing the diagnosis component of the C-POEMS model, positive results have been gained particularly from the manufacturing company. However, the diagnosis template needs to be developed in which users can fully utilise the C-POEMS model, without any extra help, particularly in translating diagnosis result within the C-POEMS framework to designing a further work.

Chapter 7 Conclusion

This chapter presents a summary of research results and provides recommendations for further work.

7.1 Contributions of the research

Strategic management support that lessens the environmental impacts of products and product chains is crucial in the product-orientation of the mainstream principles of environmental product policies and regulations. However, the shortcomings of existing tools (i.e., EMS and eco-design) and their lack of support for SMEs have been raised. Regarding this, POEMS has been introduced as a promising method to bridge the gap between EMS and eco-design, and overcome their shortcomings. However, a lack of methodological development and support for SMEs has been found in the existing POEMS models. With this background situation, this research aimed at developing a new model called component-based POEMS (C-POEMS), which can be applied to SMEs and encompasses the mainstream principles of environmental product policies and regulations.

This research developed a potential standardised model of C-POEMS in its contents and structure (i.e., stages of process, categories of functional areas/units, and elements) as well as diagnosis template as a component-based application. Through the primary research, the contents and structure of the C-POEMS model were approved and the diagnosis template comprising the categories in 'drivers review' stage was tested in medium and small-sized companies which showed appropriateness of component-based application of the diagnosis template. The results proved the research hypotheses developed from the initial research problems. This research has contributed important information to the environmental management field, and, in particular, the C-POEMS model has advantages for industry, which are summarised as follows:

Methodological development of POEMS:

1. The procedure of formulating C-POEMS produced valuable debates in terms of the existing POEMS models. Arguments concerning the existing POEMS models, suggestions and analytical information in this research will be helpful for further research in the POEMS field.
2. Development of the C-POEMS model improved POEMS by providing clear contents and a solid structure with defined stages and categories of functional areas and units, while at the same time sustaining the flexible format of a modular structure.
3. This model has a diagnostic approach that allows SMEs to identify relevant environmental elements without necessitating the full effort involving in going through a variety of environment-related issues in the first place. Also, the combined application of the diagnosis template with the C-POEMS model opens a possibility that this tool can be used as component. The C-POEMS model represents a benefit in both provision of generic contents and the identification of focal areas.

Applicable tool for SMEs comprising mainstream principles:

4. This research enhances an opportunity to explore to what extent SMEs can develop their environmental performance and how to initiate environmental projects. The C-

POEMS model is composed of a modifiable structure to adjust its contents for individual companies' own specific situations and levels of ambition. Regarding limited assets and resources of SMEs, this model has assisted in isolating the core factors required for environmental improvement and an effective approach. Therefore, this tool is particularly helpful for SMEs.

5. The C-POEMS model has pre-defined prioritisation and correlation of elements and categories of functional areas. Therefore, users can identify the central problems and collectively deal with them. Successful application of the C-POEMS model leads not only to environmental benefits but also to potential opportunities for improving business operations that companies usually pursue. Environmental tools need to be flexible and easy to apply especially for small enterprises. In this respect, the C-POEMS model can be incorporated into SMEs that are not constrained by major financial problems.

7.2 Limitation of the research

This section summarises several limitations of this research.

1. The C-POEMS model was developed from the existing POEMS method which is still underdeveloped. Hence, due to the broad scope of a product-oriented environmental approach, a variety of activities may not be encapsulated in the existing POEMS models. A lack of development and information relating to POEMS in general hampers the clarification of activities and terminologies. Therefore, the C-POEMS contents may miss some important factors, or the use of terminology may result in obscurity. Therefore, developing user-friendly and standardised terms will be a future challenge.

2. Most POEMS-related techniques are polarised into either those that focus on technological improvement (e.g., LCA) in the product dimension or those concentrated on environmental management (e.g., EMS). Eco-design in the product dimension is relatively untouched. Thus, full integration of eco-design and environmental management side is hardly exploited. Therefore, it is difficult to define the relevant contents required for the integration within the C-POEMS.
3. An asymmetric situation still exists. For example, POEMS itself has such a broad view. Thus, maintaining the wide scope and at the same time focusing upon specific areas remains a difficulty, since these approaches are dilemma of harmonisation. In addition, there is an insufficient degree of consideration given to the format of existing POEMS. This is a pressing issue as the C-POEMS model is presumably the first attempt to define a useable self-help format for SMEs. Hence, more research needs to be conducted in order to find the format best suited to small businesses.

7.3 Suggestions for future work

To gain continued insights into these issues, future work needs to be conducted on the following areas:

1. Due to such a broad areas C-POEMS covers and limited time of research, this research mainly focused on ‘drivers review (PS1)’ categories for developing a diagnosis template. Hence, the rest of the categories of the C-POEMS remain as future work. Therefore, more templates of the key categories of functional areas need to be developed.
2. More work for ongoing maintenance of the C-POEMS model is necessary, which

correspond to and encompass the future development and changes of environmental product policies and regulations, and environmental technologies.

3. This research initially attempted a new approach that integrated a business process model (e.g., component-based architecture) and an environmental management model (POEMS). Methodological development of C-POEMS will be useful for further developing an implementation format – ideally a software format.
4. Considering the fact that the concept of the C-POEMS (also, POEMS) is new and unfamiliar to SMEs and has a broad scope to handle, intervention of professional experience is necessary particularly in the process of interpretation of diagnosis result, and planning a C-POEMS project for individual companies. However, the intervention will be diminished by future model development.

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Appendix A: Process or structure of 10 POEMS models in the exploratory research

(1) Four-steps POEMS

Review	**1. Product-specific environmental review** • identification of environmental impacts/aspects • review of DFE organisation and capabilities • review of the product development process • market investigation
Plan	**2. Responsibilities and procedures** • definition of roles, responsibilities and authorities for product development • establishment of policies, objectives and targets • revision of the procedures for staff involved in product development and other product-related activities
Implementation	**3. DFE projects** • development of environmentally compatible products with competitive price, performance and quality standards.
Evaluation	**4. Audit/Evaluation** • revision of existing procedures and products aiming for continual improvement

Figure A.1: Four-steps POEMS (Ammenberg and Sundin, 2004a)

(2) POEMS integrated with SWOT analysis

Demonstration project of SWOT

1 Investigation of sectoral SWOT
- implement environmental profile of the recycled products of the sampled companies
- gathering information about the characteristics and possibilities of utilisation of recycled plastics
- relate the activities of recycling business to environmental agreement between government and companies

2. Interpretation of opportunities
- interpret environmental analysis to opportunities (e.g., improve images) of the plastics recycling industry (sectoral level)
- find new markets and strengthen their competitiveness in the market (company level)

3. Transfer of knowledge to the actors of the plastics chain
- aiming at the strategy where most environmental gain can be realised
- all information and knowledge gathered spread to designers and plastics processing companies

4. Sector specific POEMS implementation
- opportunities developed for the sectoral level are translated to and applied at the company level

Review

Step 2: Preliminary investigation
- preliminary investigation of the company by tailoring the general SWOT analysis to the companies → ***A demonstration project***
- setting up an environmental profile of the product
- selection of interest fields

Plan

Step 1: Project objectives & team
- definition of roles, responsibilities and authorities for product development
- establishment of policies, objectives and targets
- revision of the procedures for staff involved in product development and other product-related activities

Implementation

Step 3: Execution
- finding additional information on environmental or market related issues
- setting up a programme of requirements for new product development, or new market initiatives

Step 4: Checking and improvement
- searching for alternatives
- making a selection of the best alternative for improvement
- conducting a (small) feasibility study of the chosen alternative

Step 5: Embedding
- set up action plan and time frame for further actions that have to be taken
- preparing the production
- preparing the market introduction
- evaluating the project and set-up POMES or integrate new requirements in other management systems

Evaluation

Figure A.2: POEMS integrated with SWOT analysis (Baas, 2002)

(3) POEMS developed from PDCA cycle

Review **Plan**	**1. Plan** • set up product policy • set up objectives • products' environmental profile (LCA, LCC) • organisational review • existing management structure for eco-design • legal requirements • stakeholders' & customers' demands • market opportunities • review tools (EMS, eco-design etc.) • set up objectives & target (managerial/operational) • develop database (information building)
Implementation	**2. Do:** Implement product development process • discover improvement options • verify improvement options • mutual agreement for implementation • integrate with existing environmental/quality management systems (routinisation) • define details eco-design steps by guidelines (for supporting designers and technical consultation of materials, other information and experts) • product development
Evaluation **Continuation**	**3. Check and Act** • review and evaluate the product improved, processes, project • change policy, objectives, other elements of POEMS • set up direction for future work • commitment for ongoing improvement

Figure A.3: POEMS developed from PDCA cycle (Brezet and Rocha, 2001)

(4) POEM matrix modified from TQM

Review / Plan

1. System-technical organisation in operational level
- environmental information management systems
- control techniques; performance measurement
- budgeting

2. Social-dynamic organisation in operational level
- cross-functional consultation and communication
- increased environmental training
- motivation and commitment

3. System-technical organisation in strategic level
- shared norms and values (including environmental ones)
- employee empowerment
- ‘transformational’ leadership
- partnerships and integrated chain management (ICM)

4. Social-dynamic organisation in strategic level
- planning/strategic orientation
- vertical deployment
- formal interface management (internal and external)
- division of tasks and responsibilities (including environmental ones)

5. Core concepts
- continuous improvement
- cooperation and learning
- stakeholder focus

Figure A.4: POEM matrix modified from TQM (De Bakker, 2002)

(5) AIDA tool for tailoring POEMS

Preliminary work

1. Attention
- general communication to industrial SMEs

2. Interest
- information of potential benefits of POMES

3. Desire (checklist test)
- clarify the chances for a company

3. Desire (checklist test)

Proposition (question)	Expla-nation	agree	Dis-agree	Un-known
1. You know what the benefits of POEMS can be for your company				
2. Your customers ask questions about the environmental aspects/performance of your product				
3. Environmental aspects of your products are important for your company's image				
4. You are never surprised by new environmental legislation				
5. You have a quality or environmental management system				
6. Your competitors pay attention to the environmental aspects of their products				
7. Your workers are interested in the environmental aspects of your products				
8. There are labels available that communicate the environmental benefits of products in your market				
9. You are investigating the environmental impacts of your products				
10. You know what your customers do with your product				
11. You are familiar with the (production) processes of your suppliers				
12. You are planning to develop a new product or to re-develop an existing product				
13. You want to improve the quality of your product				
14. (Cost) Price is an important aspect of your product				
15. You are considering a change in the production technology				

4. Actions
- list of actions to give an idea on possible implementation of POEMS

Figure A.5: AIDA tool for tailoring POEMS (De Graaf, 2002)

(6) PEC combined with ICM

Plan	**1. Plan** • management decision on introduction of product-oriented environmental care • selecting a product to be used as a pilot • management decision on the choice of pilot project
Implementation	**2. Do** • Determining improvement projects for the product with the partners in the product chain • Choosing an improvement project with the partners in the product chain
	3. Check • Executing the improvement project and measuring the results
Evaluation	**4. Evaluate** • Management decision on whether product-oriented environmental care is of importance to the company • Evaluating the success of the improvement project

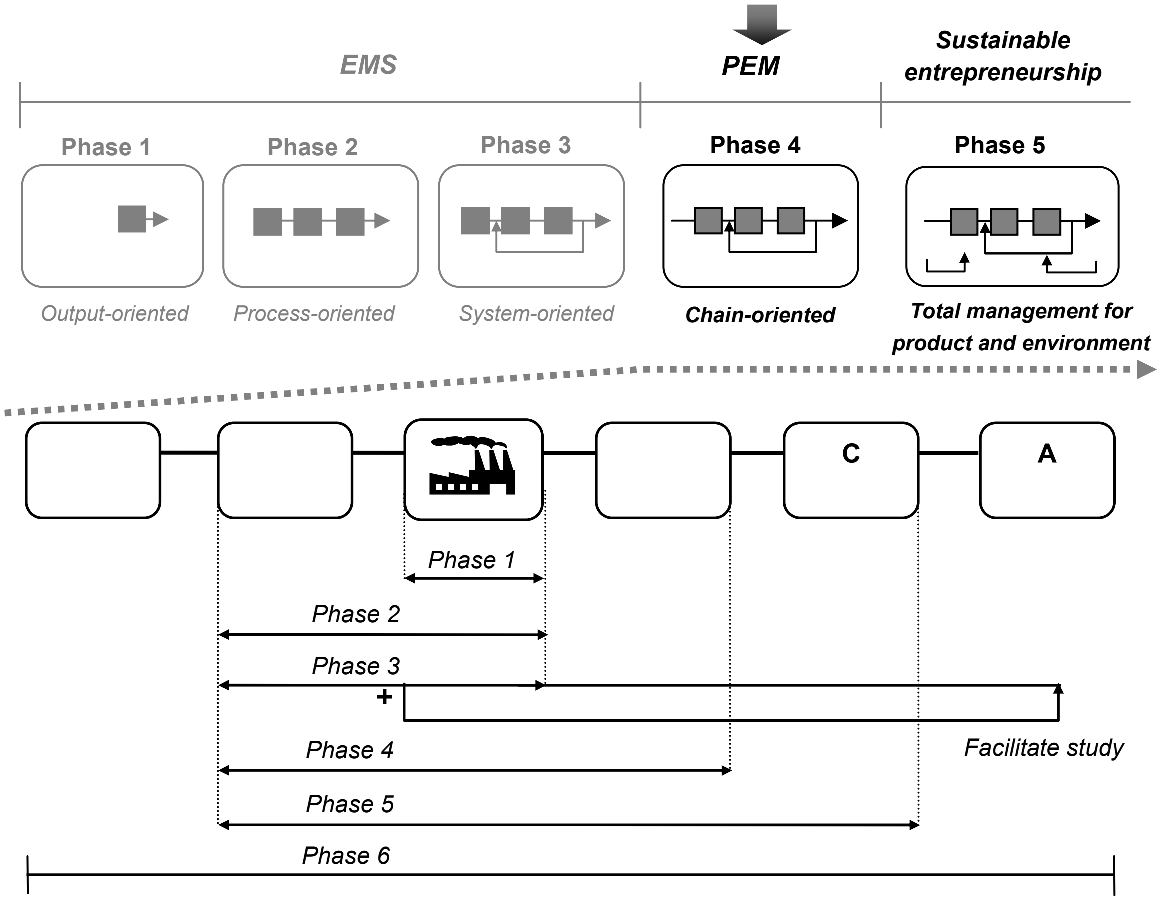


Figure A.6: PEC combined with ICM (Klinkers *et al*., 1999)

(7) Step-by-step PMZ model

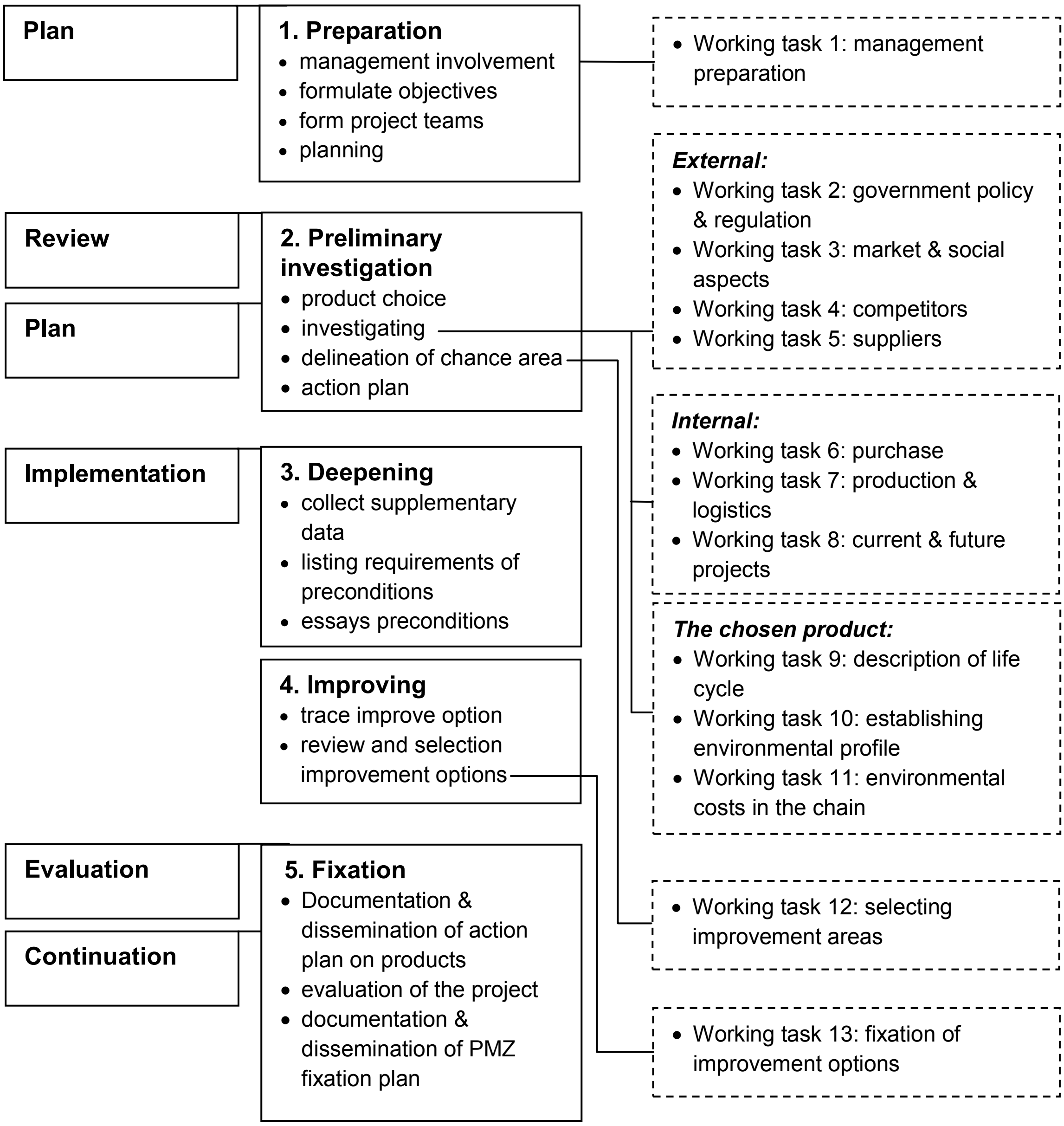


Figure A.7: Step-by-step PMZ model (CBM, 2002; Pinkse and De Graaf, 2002)

(8) Integrated approach of POEMS

Review

1. Environmental profile of products
- legal requirements
- environmental impacts in life cycle
- stakeholders' demands
- customers' demands
- opportunities
- provision of environmental information (supplied components, materials)
- LCA, LCC analysis
- establish E-KPI (comprehensive environmental performance indicators system)

Plan

2. Definition of objectives and targets
- define targets, objectives (managerial/ operational aspects)
- eco-design objectives and targets
- business strategy
- environmental product policy (stakeholders' view)
- generate and validate green options
- R&Ds

3. Managerial approach
- building capability and routine for eco-design implementation
- allocation of resources, responsibilities
- build expertise (tools, internal & external communication)
- incorporate the detail requirements/ elements above into eco-design activities/ projects
- set up process & methods in operation for continuous improvement

Implementation

4. Procedures of supporting eco-design
- set up procedure to support eco-design activities
- integrate in EMS and quality procedures
- allocate responsibilities, build up competence
- incorporate eco-design objectives, methodologies, tools into product development process (PCP) or other projects

Evaluation

Continuation

5. Review and continuation plan
- review and audit: POEMS, project, product, and management
- change policy, objectives, other elements of POEMS if necessary
- set direction for further improvement

Figure A.8: Integrated approach of POEMS (Rocha and Brezet, 1999)

(9) The Danish EPA POEMS programme

Review	**1. Reviewing and assessing environmental impacts** • you extend reviewing and assessment to include environmental impacts during the product's life cycle, including in any export markets. The scope and degree of detail will depend on your level of ambition for your product-oriented work. • you ensure that current and coming legislation relating to the product is included in the criteria for selecting significant environmental impacts.
Plan	**2. Environmental policy** • you describe the product-oriented work in your environmental policy statement
	3. Planning • your objectives and action plans cover the specific product aspects that you prioritise.
Implementation	**4. Implementation** • the management assigns responsibility and operation delegates tasks to the parts of the organisation that are affected by the product-oriented work. • you expand your purchasing and supplier control to ensure purchasing that corresponds to the chosen product-oriented work. • you train the employees in the aspects that are important for the product-oriented work. • you inform all the company's employees about the product-oriented work. • you include in your external communication information about proper use and disposal and about the production of the raw materials. • you supply documentation for the product(s)' environmental impacts. • you record and answer external enquiries concerning the product(s).
Evaluation	**5. Control and corrective** • your own internal control covers the product-action oriented work, including any requirements about using specific tests or methods of measurement.
Continuation	**6. The management's review** • the management prioritises resources so that the product-oriented work is maintained and expanded with new targets that are coordinated with the company's business strategy.

Figure A.9: The Danish EPA POEMS programme (Schmidt *et al*., 2002)

(10) Plan phase P-EMS for retail and manufacturing industry

Review

1. Environmental assessment of the product life cycle

[Basic methodology]
- LCA methodology

[Specific tools]
- Customised spread-sheet for summation of inventory data
- LCA software

[Possible data sources] - Internal processes:
- production administration;
- environmental records external processes;
- public databases;
- supplier questionnaires;
- customer questionnaires

2. Identification of environmental product improvement opportunities

[Basic methodology]
- Life cycle design methodology

[Specific tools]
- Life cycle design strategies and criteria
- Generic design tools

[Possible data sources]
- Information on new developments in processes, products and materials (industry associations, technical institutes)

Plan

3. Operational POEMS plan

[Basic methodology]
- Life cycle design methodology

[Specific tools]
- ABC prioritisation system for environmental improvement options

[Possible data sources]
- Information on new regulations and trends in customer behaviour

Figure A.10: Plan phase P-EMS for retail and manufacturing industry (Van Berkel *et al*., 1999)

Appendix B: Comparative positions of the key elements of 10 POEMS models

(1) Review stage

Figure B.1

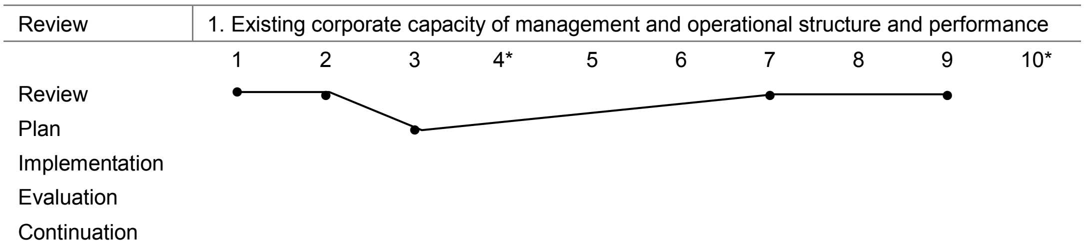
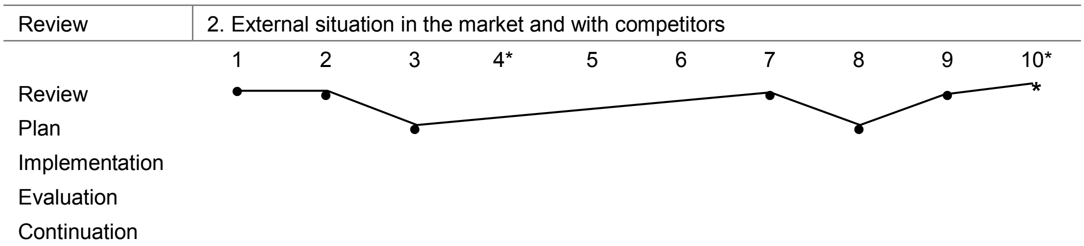


Figure B.2



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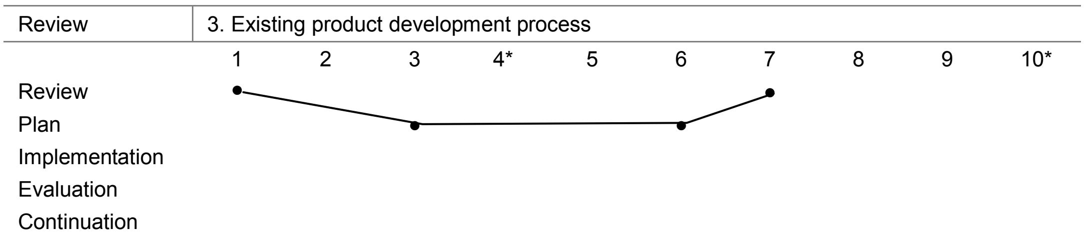

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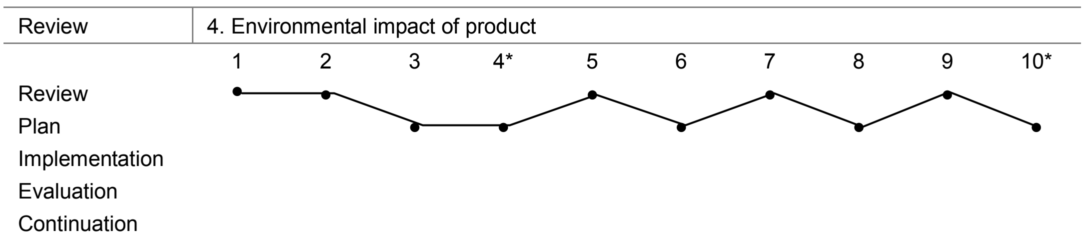

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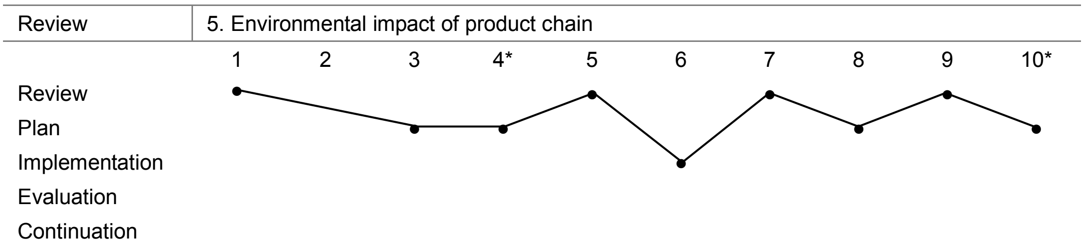

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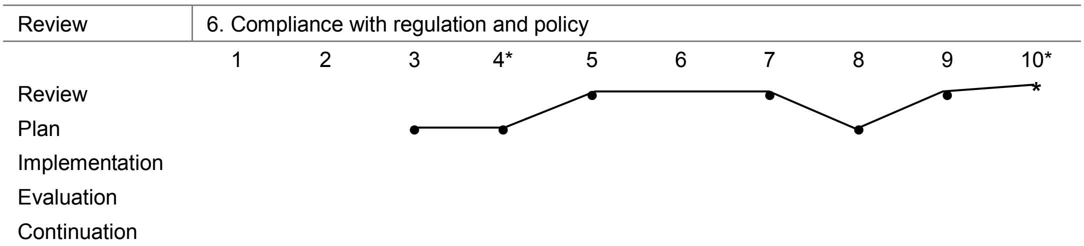

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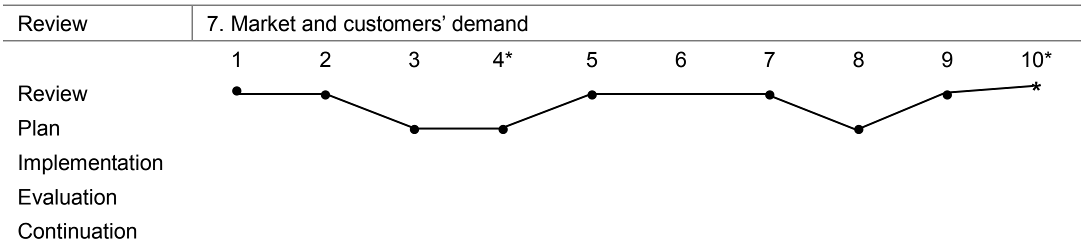

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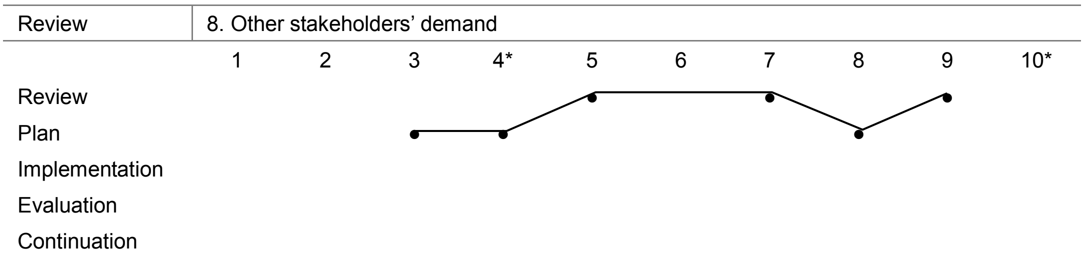

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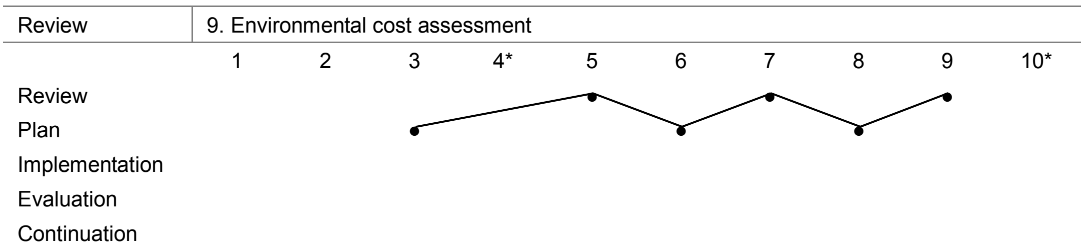
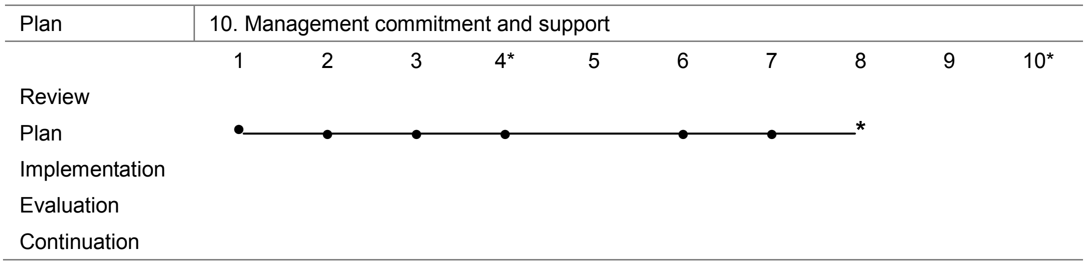


(2) Plan stage

Figure B.10



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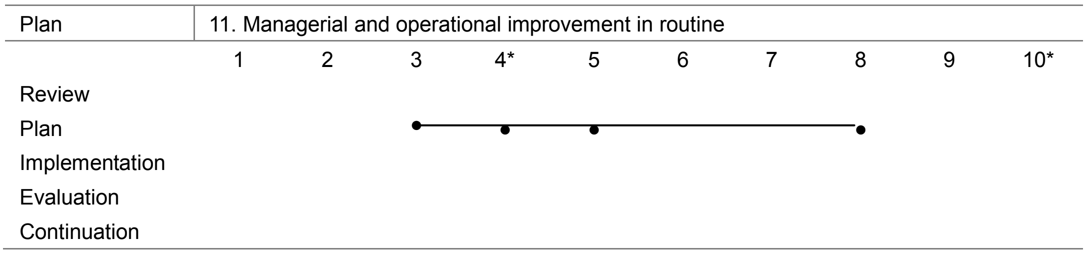

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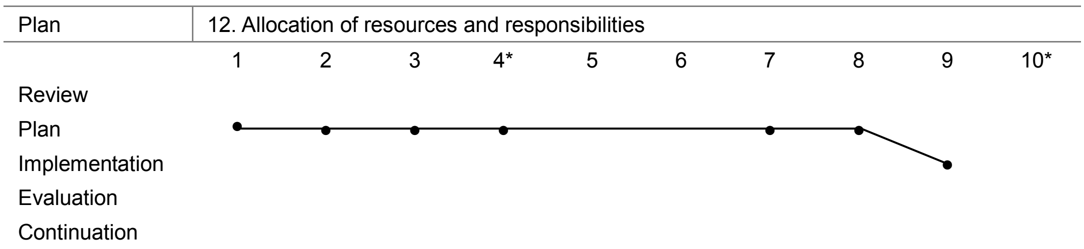

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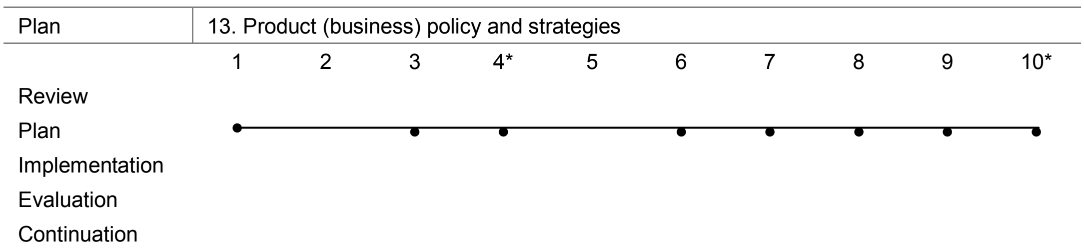

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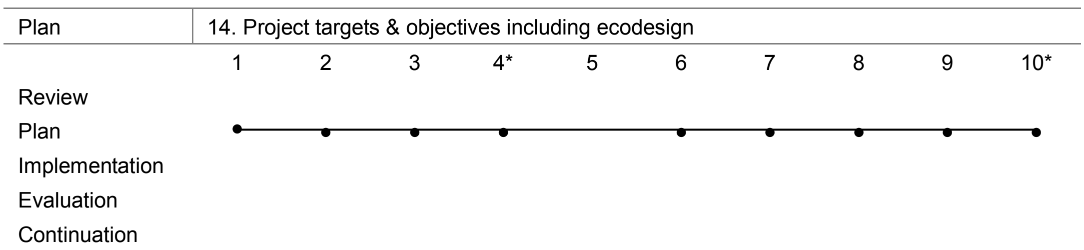

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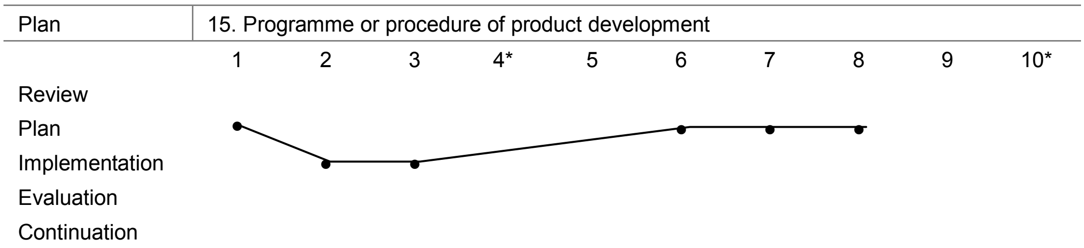

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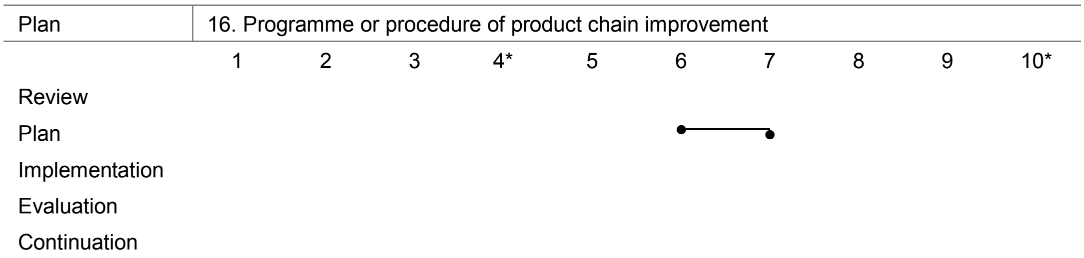

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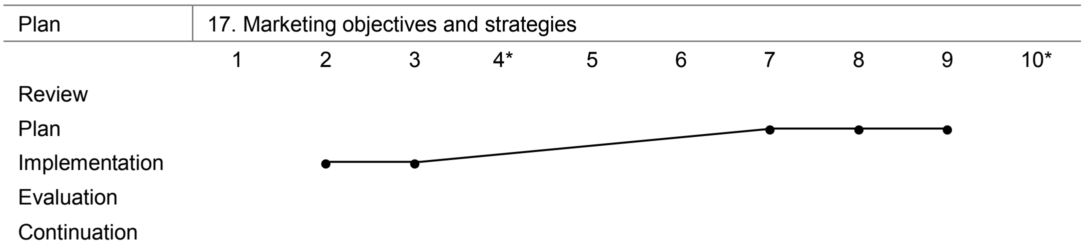

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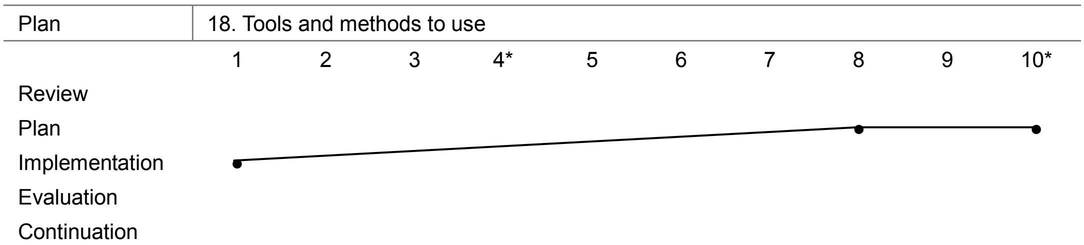

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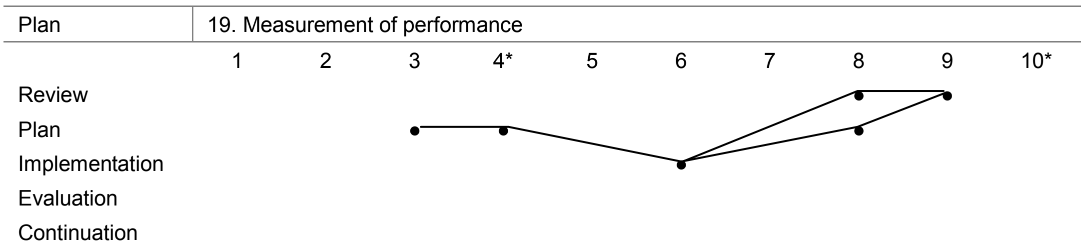

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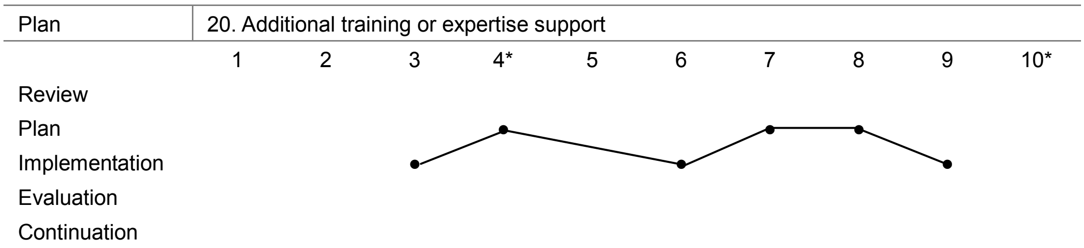

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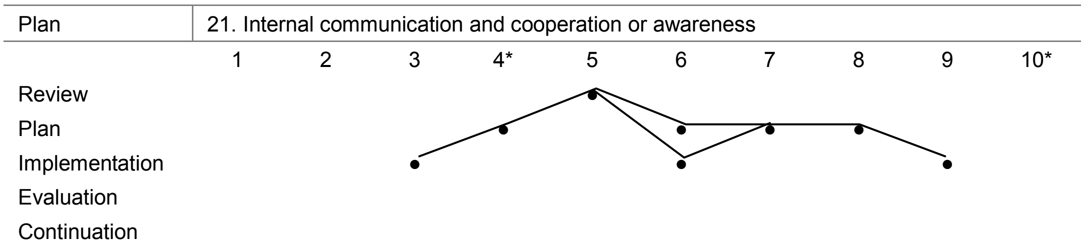

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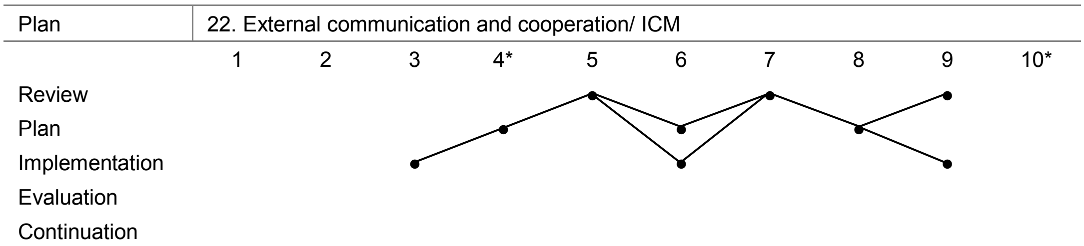

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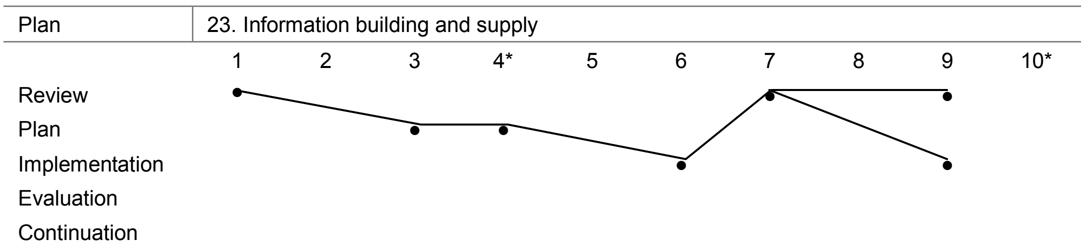
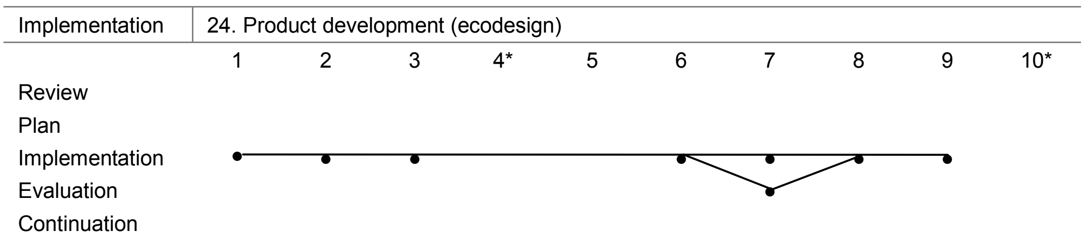


(3) Implementation

Figure B.24



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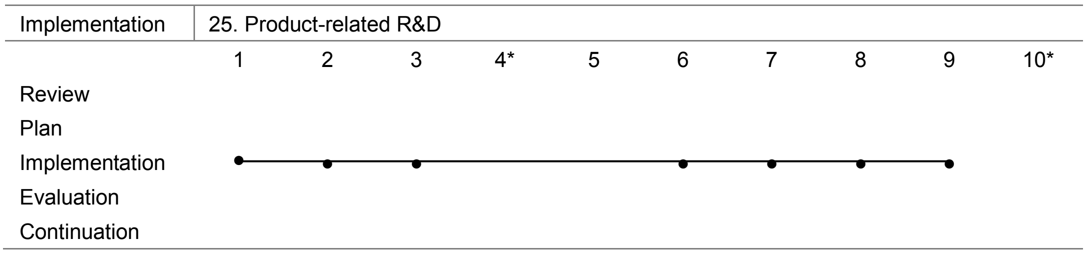

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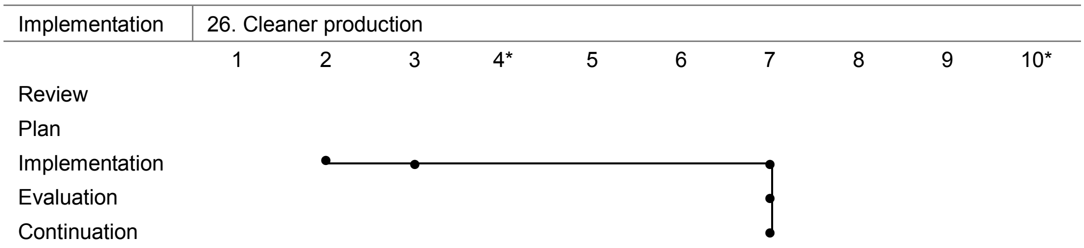

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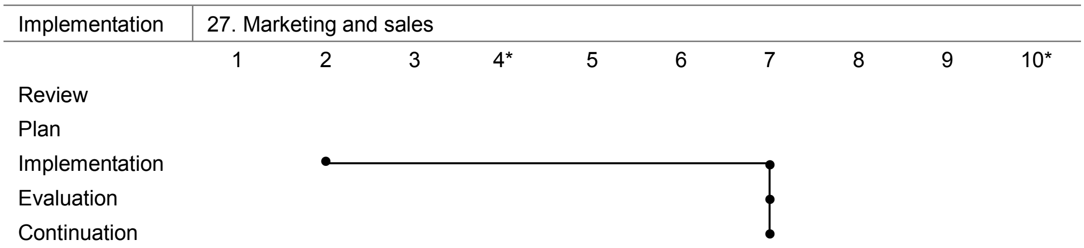

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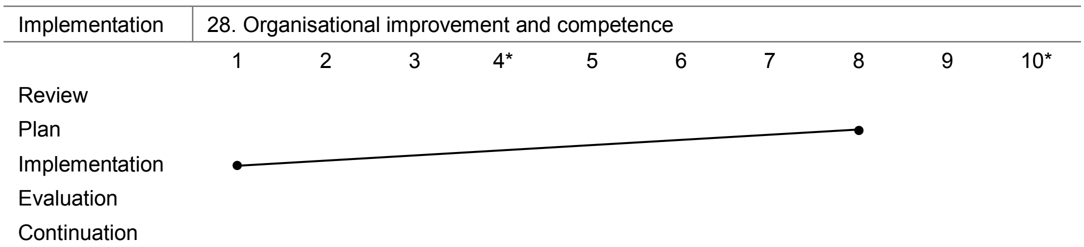

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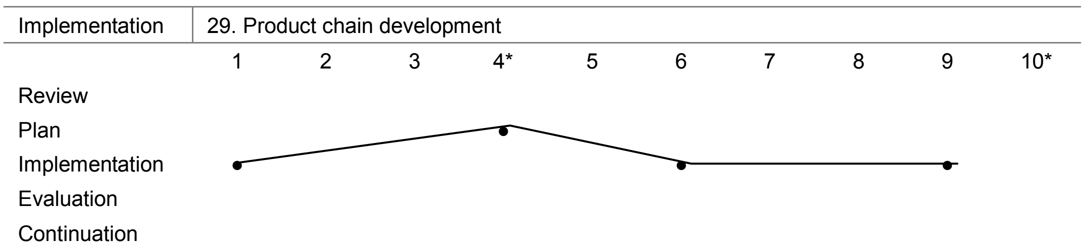

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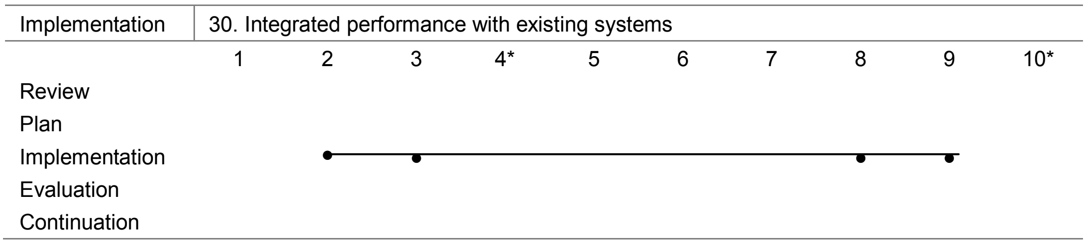
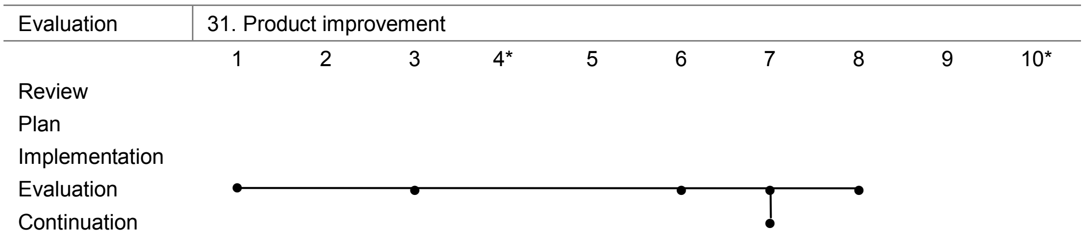


(4) Evaluation

Figure B.31



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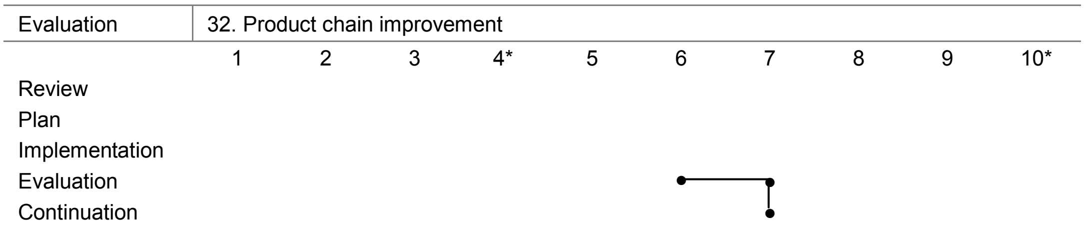

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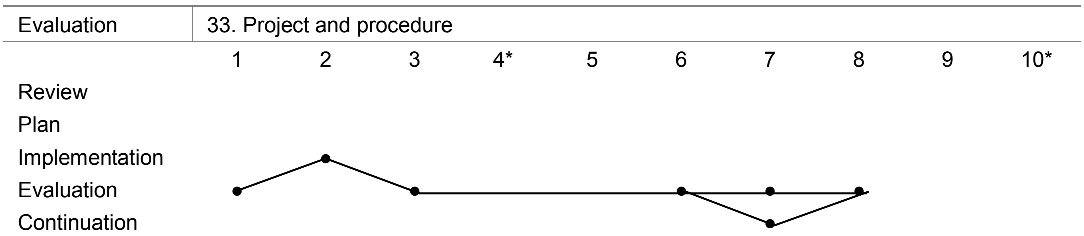

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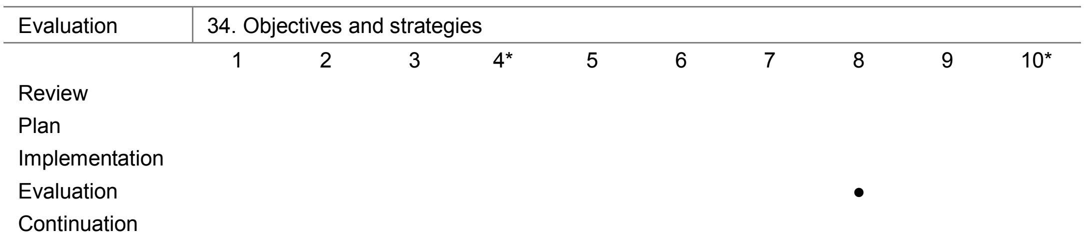

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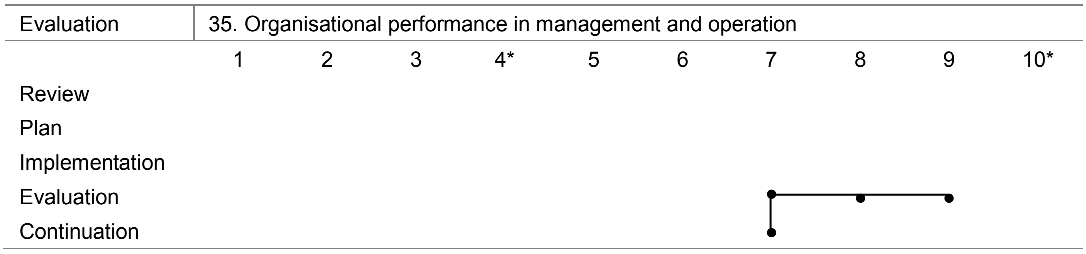
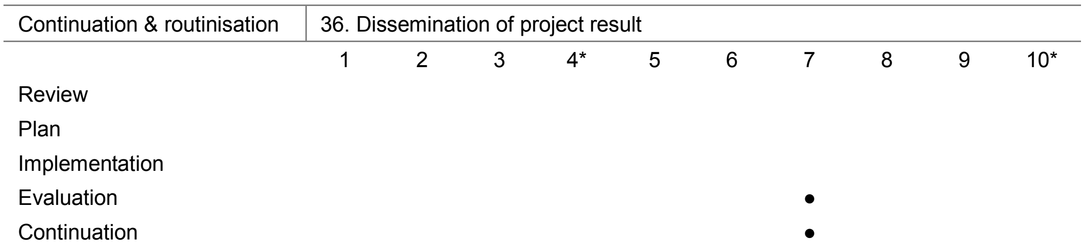


(5) Continuation and routinisation

Figure B.36



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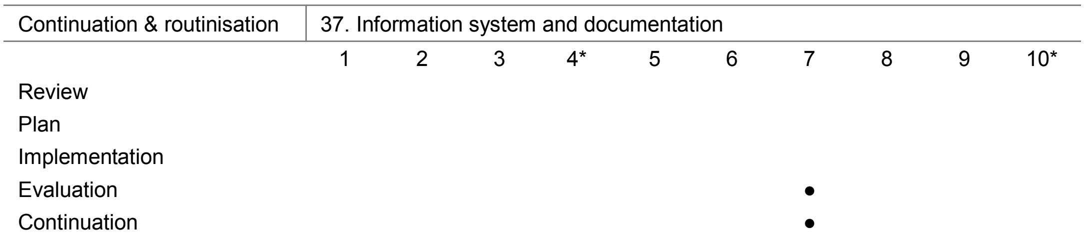

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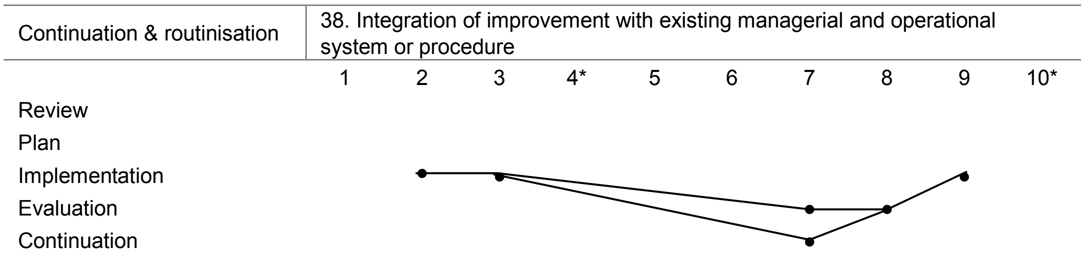

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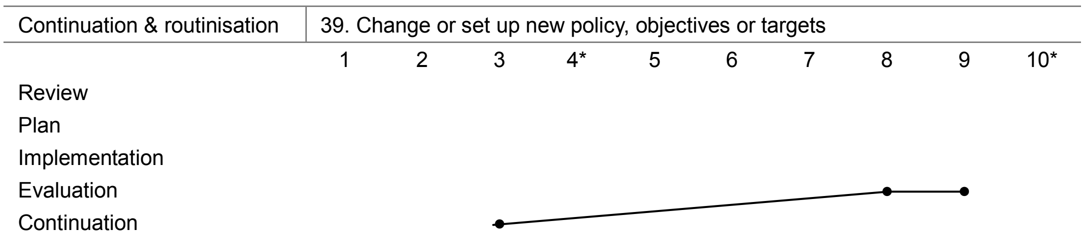

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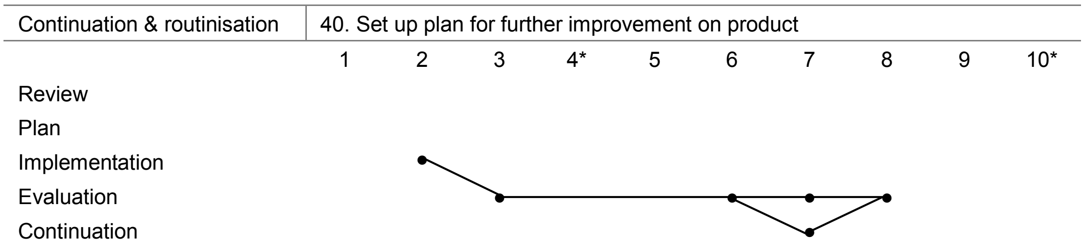

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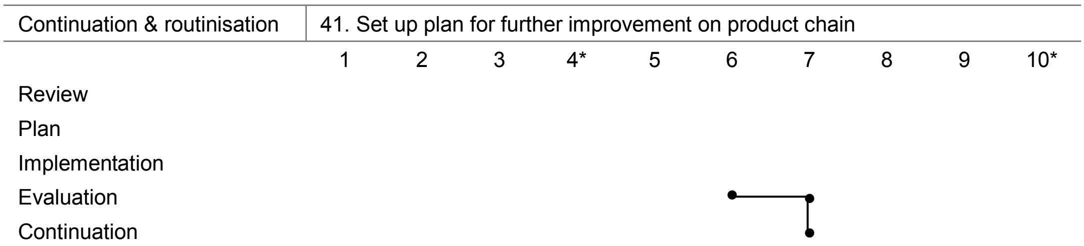

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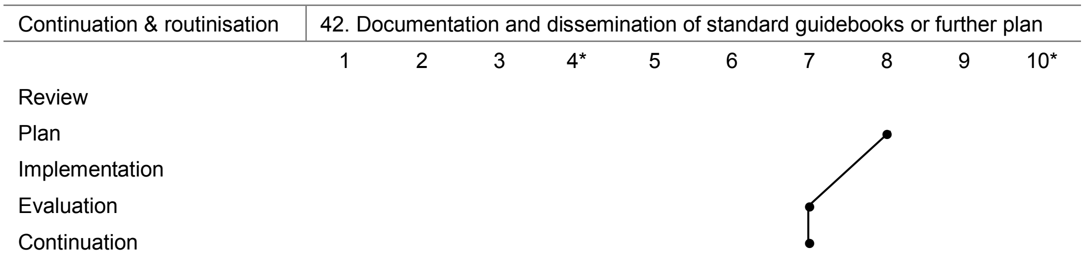

42 key elements are divided into four groups according to the following standards in each table. (The elements that less than 4 POEMS models indicate them in corresponding categories are not considered for analysis.)

1. Allocated in the same stages (more than 90% of the models agreed): 9 elements (21.43%)

Stages	Key elements allocated in stage
Plan (element 10-23):	**10, 11, 12, 13, 14**
Implementation (element 24-30):	**24, 25, 30**
Evaluation (element 31-35):	**31**

2. Allocated in fairly similar stages (less than 2 variations, more than 79% of the models agreed): 3 elements (7.14%)

Stages	Key elements allocated in stage
Review (element 1-9):	**1**

Evaluation (element 31-35):	**33**
Continuation and routinisation (element 36-42):	**40**

3. Allocated in various stages (Not in the first two groups): 16 elements (38.1%)

Stages	Key elements allocated in stage
Review (element 1-9):	**2, 4, 5, 6, 7, 8, 9**
Plan (element 10-23):	**15, 17, 19, 20, 21, 22, 23**
Implementation (element 24-30):	**29**
Continuation and routinisation (element 36-42):	**38**

4. Immeasurable: 14 elements (33.33%)

Stages	Key elements allocated in stage
Review (element 1-9):	**3**
Plan (element 10-23):	**16, 18**
Implementation (element 24-30):	**26, 27, 28**
Evaluation (element 31-35):	**32, 34, 35**
Continuation and routinisation (element 36-42):	**36, 37, 39, 41, 42**

Appendix C: Questionnaire and interview forms

Section 1 Introduction

(1) Guide for interviewees

Dear Participant,

Please read this introduction for the online participation of an interview and questionnaires.
This set of the online interview files consists of following documents;

<Section 1> Doc 1, Guide for interviewees Doc 2, Cover letter Doc 4, Element descriptions	**<Section 2>** Slide file of background research
<Section 3> Main questionnaire In-depth interview	**<Section 4>** Answer sheet A Answer sheet B

1. Please read 'Doc 1, Introduction' to get information of the interview framework.
2. 'Doc 2, Covering letter' helps you understand the background concept of this research project.
3. Please just read through 'Doc 3, Confidentiality agreement'. It does not require any signature but please observe the contents.
4. 'Doc 4, Requirements description' is to give information if there is any misunderstanding of some terms of requirements. Please contact the interviewer if you have any further questions on this subject.
5. From 'Questionnaire 1 to Questionnaire 3' is the main section of this interview and questionnaires. Please read through and answer the questions on the provided "excel sheets: Attachment A and B"

Thank you very much for taking part in this survey.
Yours sincerely,

Nakyung Kim
School of Engineering and Design
Brunel University, Uxbridge, UK, UB8 3PH
nkkim71@yahoo.com,
Office: +44 (0) 1895 266 352
Mobile: +44 (0) 7752 289 870

(2) Cover letter

Dear Sir/ Madam,

I am writing to ask you to participate in a survey, which is part of my PhD project. This project is being supervised by Dr. Ray Holland, Professor David Harrison and Dr. John Shackleton within the School of Engineering and Design at Brunel University.

This project investigates activities and factors relating to product-oriented environmental management system (POEMS) in industry- in general terms. Surveys consist of two parts including high-profile experts interviews from various areas in the subject and case studies with electronics manufacturers, and this survey is the first part.

I would be grateful if you could spare your time to complete this questionnaire and take an interview.
The information you have provided herein is confidential and used for academic purpose only.

If you would like, I could send you a copy of the results once they have undergone analysis. Please indicate on front of the questionnaire if you would like a copy of these results.

Thank you very much for taking part in this survey.

Yours sincerely,

Nakyung Kim
School of Engineering and Design
Brunel University, Uxbridge, UK, UB8 3PH

(3) Elements description

PS3: Company profiling

Corporate culture

- A company's general involvement in environmental issues and practices for action, such as a level of knowledge of relative legislations, technologies and management support required, and understanding of corporate vision for environmental improvement etc.

PS4: Managerial approach

Mutual agreement – internal

- Willingness to take account for environmental improvement within the organization

- Understanding and co-operation of group and individual tasks for successful implementation of any related activities within the organization

Mutual agreement – external

- Willingness to take part in the relative activities toward environmental improvement across the organisations and parties involved in the activities
- Understanding and co-operation of the activities for a successful implementation across the organisations and parties involved in the activities

PS7: Supply chain management (SCM)

Check communication

- Make sure that the communication between individuals, departments and organizations supporting the environmental activities is existing and efficient

Check co-operation

- Make sure that the co-operation between individuals, departments and organizations supporting the environmental activities is existing and efficient

PS8a: Managerial aspect 1: co-operation

Share norm/ value

- Staff of an organisation clearly understands the company's vision, direction and values of environmental innovation.

PS9: Operational aspect

Trace options for improvement

- Investigate and update potential options or alternatives to improve environmental impact

PS10: Product development

Social aspect

- Investigate any undesirable aspects of products related to social issues, such as child labouring, fair trade and etc.

PS15: Documentation preparation (general format)

Define precondition of documentation

- Check if there is a lack of related aspects to establish and support environmental information

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Section 2 Description of research and the C-POEMS model

SMEs & Environmental Improvement:

integrated management approach

Nakyung Kim
Brunel University, UK

A research summary of the background & literature research, edited from LCM data and background study draft, 2/11/2005

Outline and research summary

What I've done

•Background research: SMEs definition, barriers, advantages & disadvantages, and EE & SMEs sector's environmental issues (drivers, current situation, instruments, difficulties/barriers etc.)
•Literature research: context of integrated approach; product environmental aspect, review of existing tools, review of POEMS (product-oriented environmental management system); theoretical background & context, main factors, models & processes
•Development of a hypothetical model (C-POEMS): a process, principles and requirements, potential benefits, analysis of prioritisation and correlations of requirements

What I'm doing

•Survey for model verification and data collection of detailed requirements & sub-requirements
•Survey of C-POEMS verification & in-depth data collection
- High-profile expert interviews
- Case studies: data collection of EE manufacturers, application of the C-POEMS to EE industry

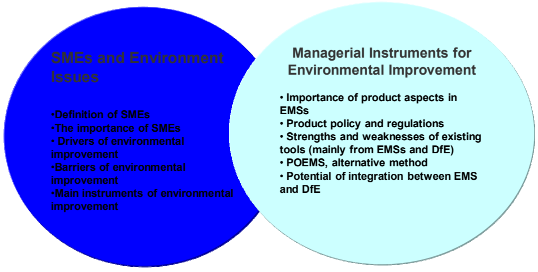
What I'm going to do

•Analysis of the survey results
•Refinement & amendment of the C-POEMS model (EE, SME sector supporting programme)
•Case study: application to German EE sector (potential)

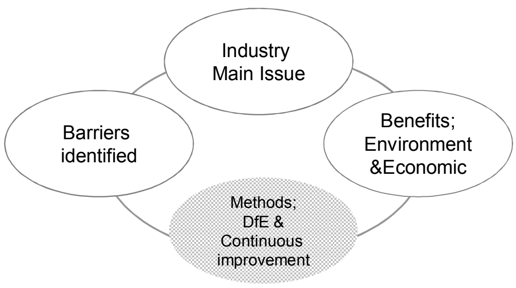
Primary Questions

•What is the problem for SMEs in environmental improvement?
•What is the crucial barriers to implement environmental performance for SMEs?
•How can SMEs overcome barriers?
•What are the key factors to make environmental activities successful?

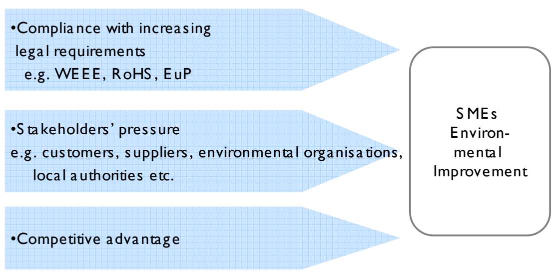
Research Areas and Scope



Key issues related to product and environmental improvement of SMEs



Main drivers

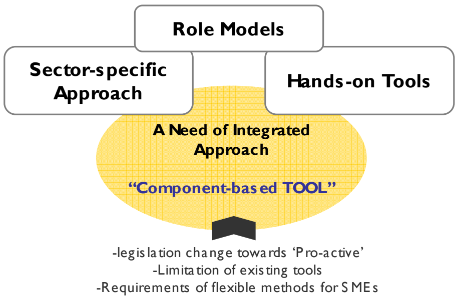


Barriers

- •Finance resources
- •Knowledge and information
- •Time
- •Perception
- •Human resources
- •System and culture
- •Support
- •Inappropriate tools (too complex or general)

Key support for SMEs

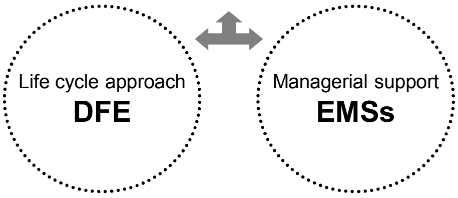
(main findings from the background research)



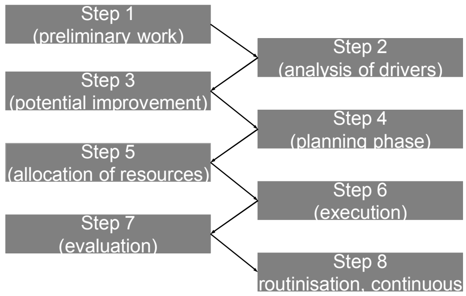
POEMS role: cooperate support

Product-oriented Environmental Management System

Organisational approach/support
Continuous improvement
Systematic innovation
Routinisation into usual business



Preliminary process of POEMS model



Principles in a preliminary procedure of POEMS

Categories	Principles
Preliminary work	Driver review Product profiling and potential opportunities Review of organisational capability
Plan	Project plan 1: Managerial Project plan 2: Operational Project plan 3: Market and sales Project plan 4: Supply chain management

Categories	Principles
Execution: POEMS & DfE implementation	Managerial aspects: Strategic management Operational aspects: Operational management Product development Production Chain improvement Marketing Knowledge building Documentation preparation
Evaluation	Monitoring/ review Audit/ evaluation
Informational work	Documentation support
Routinisation/ continuous improvement	Set up further actions Potential integration/ coordination of new requirements

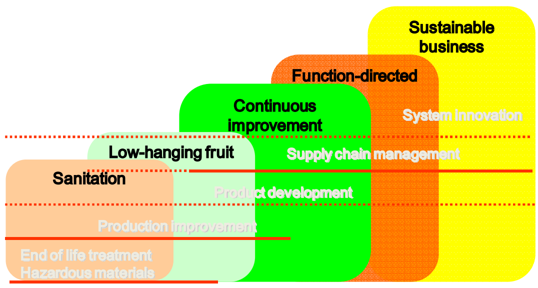
Principles in a preliminary procedure of POEMS

Categories	Principles
Preliminary work	Driver review Product profiling and potential opportunities Review of organisational capability
Plan	Project plan 1: Managerial Project plan 2: Operational Project plan 3: Market and sales Project plan 4: Supply chain management

Categorised elements in a preliminary procedure of POEMS

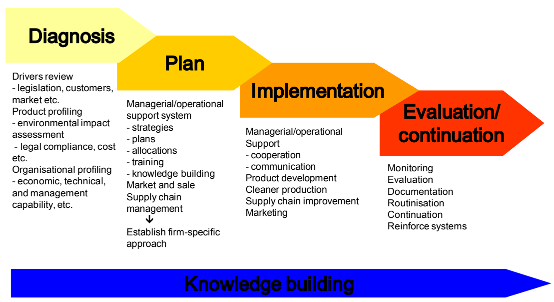
Categories	Principles	Requirements
Preliminary work	Drivers review	Legislations
		Stakeholders requirements: customers, suppliers, environmental organisations
		Competitors and market opportunities
	Product profiling and potential opportunities	Legal compliance
		Environmental impact/ cost assessment
		Environmental benchmarking and position
	Organisational profiling	Economical, technical, management capabilities
		Awareness, expertise support, staff qualification
		Communication and co-operation internal and external

Modified procedure towards sustainable business



Developed from "Evolutionary framework for product-oriented environmental policy " (Klinkers *et al* 1999)

Conceptual procedure of component-based POEMS programme



Potential POEMS Benefits

•Adjustable approach for firm's own needs
•Potential integration into product development process
•Less constraint by finance
•Continuous improvement/ Routinisation

Section 3 Main form of research questionnaire and interview

(1) General questions

This section of questionnaire is intended to gather the information of participant's general information. The analysis results of this survey will be used to indicate areas and scopes of respondents' professions and interests for which participants respond to one of the section 2 questionnaires based on the results.

Name ....

Organisation ....

Address ....

....

.... Postcode ....

Telephone .... Fax ....

Email ....

Please tick this if you wish to receive a copy of the results

1. What type of organisation do you belong to?

   National/ local government

   Public (accredited) organisation

   Private organisation

   Business association

   Consultancy

   Certification company

   R&D

   NGO

   Education

   Other, please identify ....

2. How many employees within your organisation?

<10	501 to 1000 employees
11 to 50 employees	1001 to 5000 employees
51 to 250 employees	> 5000 employees
251 to 500 employees	

3. Main areas of your occupation

(Please specify your professional area, e.g. supply chain management, EMS audit, environmental business consulting, education etc.)

   Legislation & environmental policy (WEEE, RoHS, EuP, REACH, IPP etc)

   Sustainable/business management

   (CSR, industry/product certification, information support, marketing etc)

   Please specify your area ....

   Technique development/ support

   Technical guide (supply chain, electronics manufacturing service, LCA,

   logistics, cleaner production, end-of-life treatment etc)

Please specify your area ....
Product development

4. How long have you worked your current position?

....

(2) Interviewee association with the elements and categories of the C-POEMS

Please read attachment A “C-POEMS categories and elements” and answer the questions 5 on the answer sheet A.

5. What are the most related areas to your work?

(This is the question of which areas are related to your main profession. Please mark (√) as many elements as appropriate on the “answer sheet A: C-POEMS categories and elements”)

Please specify if it is not on the list

....

....

(3) Questions for factorisation, categorisation, correlation and prioritisation

This section of questionnaire is intended to gather the information of allocation, importance and correlation of elements based on participant’s opinions and experiences.
These results will be a material for verification of elements and categories of C-POEMS.

Please read answer sheet A “C-POEMS categories and elements” and answer the questions 6 to 8 on the answer sheet A.

6. What would you think inappropriately categorised or unrelated elements to the categories? Please tick (√) as many as you think in the answer sheet A.

7. Please add if you think that there are elements omitted in each category.

8. In terms of successful implementation of environmental strategies to companies, please indicate how important the elements are according to your information and experiences. (1 unimportant, 3 neither unimportant or important, 5 very important)

Please read the answer sheet B “Correlation of categories” and answer the questions 9 on the answer sheet B.

9. Please indicate correlations between categories in the answer sheet B. (3 highly correlated, 2 medium, 1 poorly correlated, X no correlation)

(4) In-depth discussion of selected categories for prioritisation

This section aims to discuss in-depth information of elements that respondents have chosen in the Section 1 and Section 2.These results will be used to establish database of elements of C-POEMS.

Please read the answer sheet A "C-POEMS categories and elements" and answer the questions 10 to 11 on the answer sheet A.

10. What are the most important areas, do you think, when companies adopt environmental strategies and implement environmental improvement? Please select 5 priorities among the categories from the answer sheet A.

11. Free discussion based on the results of question 10.

(Online respondents, please explain the reason on the answer sheet A: Question 11)

Section 4 Answer sheet A (Please refer to the file 'Doc 4, Requirements description' if necessary)

Steps	Category	Elements		Q 5	Q 6	Q 7	Q 8	Q10	Q 11: Discussion
PS1	**drivers review**	ps1n1	legislation				1----2----3----4----5		
		ps1n2	customers				1----2----3----4----5		
		ps1n3	stakeholders				1----2----3----4----5		
		ps1n4	competitors				1----2----3----4----5		
		ps1n5	market opportunities				1----2----3----4----5		
PS2	**product profiling**	ps2n6	legal compliance				1----2----3----4----5		
		ps2n7	environmental impact				1----2----3----4----5		
		ps2n8	environmental cost				1----2----3----4----5		
		ps2n9	environmental benchmarking/position				1----2----3----4----5		
PS3	**company profiling**	ps3n10	economical capability				1----2----3----4----5		
		ps3n11	technical capability				1----2----3----4----5		
		ps3n12	management capability				1----2----3----4----5		
		ps3n13	staff capability				1----2----3----4----5		
		ps3n14	share norm/ value				1----2----3----4----5		
		ps3n15	environmental awareness				1----2----3----4----5		
		ps3n16	expertise support				1----2----3----4----5		
		ps3n17	communication-internal				1----2----3----4----5		
		ps3n18	communication-external				1----2----3----4----5		
		ps3n19	cooperation-internal				1----2----3----4----5		
		ps3n20	cooperation-external				1----2----3----4----5		
		ps3n21	corporate culture				1----2----3----4----5		
PS4	**managerial approach**	ps4n22	established business policy				1----2----3----4----5		
		ps4n23	established business strategies				1----2----3----4----5		
		ps4n24	established project objectives				1----2----3----4----5		
		ps4n25	established innovation targets				1----2----3----4----5		
		ps4n26	identification of related areas				1----2----3----4----5		
		ps4n27	established procedures				1----2----3----4----5		
		ps4n28	established network				1----2----3----4----5		
		ps4n29	established systems				1----2----3----4----5		
		ps4n30	prioritisation (strategies, activities)				1----2----3----4----5		
		ps4n31	communication/co-operation				1----2----3----4----5		
		ps4n32	mutual agreement-internal				1----2----3----4----5		
		ps4n33	mutual agreement-external				1----2----3----4----5		
PS5	**operational approach**	ps5n34	resource allocation-human				1----2----3----4----5		
		ps5n35	resource allocation-finance				1----2----3----4----5		
		ps5n36	resource allocation-technique				1----2----3----4----5		
		ps5n37	allocation-responsibilities, authorities				1----2----3----4----5		
		ps5n38	supporting system				1----2----3----4----5		
		ps5n39	knowledge building-management				1----2----3----4----5		
		ps5n40	knowledge building-environment				1----2----3----4----5		
		ps5n41	knowledge building-supply chain				1----2----3----4----5		
		ps5n42	knowledge building-market				1----2----3----4----5		
		ps5n43	knowledge building-BAT				1----2----3----4----5		
		ps5n44	integration with existing asset & system				1----2----3----4----5		
PS6	**market & sale**	ps6n45	established strategy-marketing				1----2----3----4----5		
		ps6n46	established strategy-sale				1----2----3----4----5		
		ps6n47	user/purchaser guidelines				1----2----3----4----5		
		ps6n48	environmental certificate				1----2----3----4----5		

Steps	Category	Elements		Q 5	Q 6	Q 7	Q 8	Q10	Q11: Discussion
PS7	**supply chain management (SCM)**	ps7n49	Sustainable purchasing plan/set up guide				1----2----3----4----5		
		ps7n50	decision-making suppliers/products				1----2----3----4----5		
		ps7n51	check communication				1----2----3----4----5		
		ps7n52	check cooperation				1----2----3----4----5		
PS8-a	**managerial aspect 1 cooperation with:**	ps8a53	project team				1----2----3----4----5		
		ps8a54	managerial & operational team				1----2----3----4----5		
		ps8a55	whole department				1----2----3----4----5		
		ps8a56	suppliers				1----2----3----4----5		
		ps8a57	customers				1----2----3----4----5		
		ps8a58	shareholders				1----2----3----4----5		
		ps8a59	NGOs				1----2----3----4----5		
		ps8a60	other stakeholders				1----2----3----4----5		
		ps8a61	question guide for customers cooperation				1----2----3----4----5		
PS8-b	**managerial aspect 2 communication**	ps8b62	established formal interface				1----2----3----4----5		
		ps8b63	established ecodesign support				1----2----3----4----5		
		ps8b64	project team				1----2----3----4----5		
		ps8b65	managerial & operational team				1----2----3----4----5		
		ps8b66	whole department				1----2----3----4----5		
		ps8b67	suppliers				1----2----3----4----5		
		ps8b68	customers				1----2----3----4----5		
		ps8b69	shareholders				1----2----3----4----5		
		ps8b70	NGOs				1----2----3----4----5		
		ps8b71	other stakeholders				1----2----3----4----5		
		ps8b72	record & answer enquiries related to products				1----2----3----4----5		
PS9	**operational aspect**	ps9n73	trace options for improvement				1----2----3----4----5		
		ps9n74	R&D of chosen alternatives				1----2----3----4----5		
		ps9n75	decision-making of best alternative				1----2----3----4----5		
PS10	**product development**	ps10n76	check DfE requirements				1----2----3----4----5		
		ps10n77	development DfE concept				1----2----3----4----5		
		ps10n78	DfE implementation				1----2----3----4----5		
		ps10n79	sustainable option validation				1----2----3----4----5		
		ps10n80	decision-making best alternative				1----2----3----4----5		
PS11	**cleaner production**	ps11n81	energy				1----2----3----4----5		
		ps11n82	material				1----2----3----4----5		
		ps11n83	toxicity				1----2----3----4----5		
		ps11n84	health & safety				1----2----3----4----5		
PS12	**chain improvement**	ps12n85	education of customers, suppliers				1----2----3----4----5		
		ps12n86	improvement information management				1----2----3----4----5		
		ps12n87	support suppliers' declaration				1----2----3----4----5		
		ps12n88	recheck efficient communication				1----2----3----4----5		
		ps12n89	recheck efficient co-operation				1----2----3----4----5		
PS13	**marketing**	ps13n90	market introduction				1----2----3----4----5		
		ps13n91	ecodesign after-sale plan				1----2----3----4----5		
		ps13n92	environmental information to customers				1----2----3----4----5		
		ps13n93	check additional market-related issues				1----2----3----4----5		

Steps	Category	Elements		Q 5	Q 6	Q 7	Q 8	Q10	Q11: Discussion
PR14	knowledge building	pr14n94	general investigation/information				1----2----3----4----5		
		pr14n95	environmental information (LCA data update)				1----2----3----4----5		
		pr14n96	market information				1----2----3----4----5		
		pr14n97	management information				1----2----3----4----5		
		pr14n98	technical information				1----2----3----4----5		
		pr14n99	chain information				1----2----3----4----5		
		pr14n100	social information				1----2----3----4----5		
		pr14n101	test/methods of measurements				1----2----3----4----5		
		pr14n102	information availability				1----2----3----4----5		
		pr14n103	collect supplementary data				1----2----3----4----5		
PS15	documentation preparation (general format)	ps15n104	define precondition of documentation				1----2----3----4----5		
		ps15n105	build-up base for documentation				1----2----3----4----5		
		ps15n106	supply documentation for product environmental impact				1----2----3----4----5		
		ps15n107	supply documentation for product opportunities				1----2----3----4----5		
PS16	monitoring	ps16n108	product, service monitoring				1----2----3----4----5		
		ps16n109	project/process monitoring				1----2----3----4----5		
		ps16n110	review strategies & targets				1----2----3----4----5		
		ps16n111	check DfE, process & performance				1----2----3----4----5		
		ps16n112	feedback from customers/stakeholders				1----2----3----4----5		
		ps16n113	check environmental work & initial ambition				1----2----3----4----5		
		ps16n114	check communication				1----2----3----4----5		
		ps16n115	check co-operation				1----2----3----4----5		
		ps16n116	check firm's other activities				1----2----3----4----5		
PS 17	evaluation	ps17n117	product requirements				1----2----3----4----5		
		ps17n118	product performance				1----2----3----4----5		
		ps17n119	product legal compliance				1----2----3----4----5		
		ps17n120	product other aspects				1----2----3----4----5		
		ps17n121	project & activities				1----2----3----4----5		
		ps17n122	internal & external communication & cooperation				1----2----3----4----5		
		ps17n123	use of tools & methods				1----2----3----4----5		
		ps17n124	data sources, data collection methods, data quality				1----2----3----4----5		
		ps17n125	market response				1----2----3----4----5		
		ps17n126	environmental benefits				1----2----3----4----5		
		ps17n127	cost effectiveness/benefits				1----2----3----4----5		
		ps17n128	social benefits				1----2----3----4----5		
PS18	documentation	ps18n129	product related information				1----2----3----4----5		
		ps18n130	co-operation with stakeholders				1----2----3----4----5		
		ps18n131	modification for various use				1----2----3----4----5		
PS19	routinisation	ps19n132	setup further action plan, timeframe				1----2----3----4----5		
		ps19n133	preparation new project				1----2----3----4----5		
		ps19n134	integration/coordination: new requirements & existing system				1----2----3----4----5		
PS20	continuation	ps20n135	prioritisation: resources, feedback for new target				1----2----3----4----5		
		ps20n136	possible change: policy, objectives & other elements in system				1----2----3----4----5		
		ps20n137	consistency of principles and procedures				1----2----3----4----5		

Section 4 Answer sheet B

	Categories	PS1 drivers review	PS2 product profiling	PS3 company profiling	PS4 managerial approach	PS5 operational approach	PS6 market & sale	PS7 supply chain management (SCM)	PS8-a managerial aspect 1 co-operation	PS8-b managerial aspect 2 communication	PS9 operational aspect	PS10 product development	PS11 cleaner production	PR12 chain improvement	PS13 marketing	PR14 knowledge building	PS15 documentation preparation	PS16 monitoring	PS 17 evaluation	PR18 documentation	PS19 routinisation	PS20 continuation
PS1	drivers review																					
PS2	product profiling																					
PS3	company profiling																					
PS4	managerial approach																					
PS5	operational approach																					
PS6	market & sale																					
PS7	supply chain management (SCM)																					
PS8-a	managerial aspect 1 cooperation																					
PS8-b	managerial aspect 2 communication																					
PS9	operational aspect																					
PS10	product development																					
PS11	cleaner production																					
PR12	chain improvement																					
PS13	marketing																					
PR14	knowledge building																					
PS15	documentation preparation																					
PS16	monitoring																					
PS 17	evaluation																					
PR18	documentation																					
PS19	routinisation																					
PS20	continuation																					

0- No correlation
1- Poorly correlated
2- Medium
3- Highly correlated

Do not use this section

Appendix D: Analysis data of question 1-4

Basic information of the participants

Table D1: Type of organisations (Question 1) (P: participant)

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
National/local government												
Public limited company (PLC)			√									
Private organisation	√			√	√			√				
Business association		√									√	√
Consultancy		√							√			
Certification company						√						
R&D		√				√						
NGO												
Education							√			√		
Others[1]					√	√						

Table D2: Main areas of occupation (Question 3)

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Legislation & environmental policy	√	√	√	√		√	√				√	
Sustainable & business management[2]		√	√		√		√	√				
Technique development & support			√									

[1] Other types of organisations include manufacture and limited company.

[2] Sustainable business and management include managing director, environmental regulation, eco-efficiency, SCM, E-KPIs, etc.

Technical guide[3]	√	√	√		√	√	√		√		√	
Product development										√		√
Others												

Participants' association with elements and categories of the C-POEMS

Table D3: Order of rank resulted from the mean value of total related areas of each category of the C-POEMS

Rank		Categories	Mean value
1	PS11	Cleaner production	7.5
2	PS2	Product profiling	7.2
3	PS7	Supply chain management (SCM)	7
4	PR14	Information system	6.4
5	PS20	Continuation	6.33
6	PS12	Chain improvement	6.2
7	PS17	Evaluation	6.17
8	PS1	Drivers review	6
9	PS15	Documentation preparation	5.75
10	PS3	Company profiling	5.33
10	PS9	Operational aspect	5.33
10	PS19	Documentation	5.33
10	PS20	Routinisation	5.33
14	PS8a	Managerial aspect 1: co-operation	5.11
15	PS5	Operational approach	4.91
16	PS4	Managerial approach	4.75
17	PS6	Market & sale	4.5
18	PS8b	Managerial aspect 2: communication	4.45
19	PS10	Product development	4.33
20	PS16	Monitoring	4.11
21	PS13	Marketing	3.75

Table D4: Selection of the high scored elements associated with respondents' work

[3] Technical guide includes hazardous materials, electronic manufacturing, development of technologies for treating PCB effluent, legislation support, BAT (best available technique) guide, recovering precious metal from PCBs, LCA, LCC, LCI, LCM, SCM, EoL eco-design, eco-labelling, etc.

Score	Elements		Categories
10	Environmental impact	PS2	Product profiling
9	Legal compliance	PS2	Product profiling
9	Legislation	PS1	Drivers review
9	Communication - external	PS3	Company profiling
9	Knowledge building - environment	PS5	Operational approach
9	Managerial and operational team	PS8a	Managerial aspect 1: co-operation
9	Material	PS11	Cleaner production
9	Product legal compliance	PS17	Evaluation
8	User/purchaser guidelines	PS6	Market & sale
8	Decision-making suppliers/products	PS7	Supply chain management (SCM)
8	Energy	PS11	Cleaner production
8	Environmental information (LCA data update)	PR14	Information system
8	Technical information	PR14	Information system
8	Test/methods of measurements	PR14	Information system
8	Information availability	PR14	Information system
8	Supply documentation for product environmental impact	PS15	Documentation preparation (general format)
8	Product requirements	PS17	Evaluation
8	Environmental benefits	PS17	Evaluation
8	Product related information	PS18	Documentation
8	Possible change: policy, objectives & other elements in system	PS20	Continuation

Appendix E: Descriptive statistics data of question

8

Descriptives

Descriptive Statistics									
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
ps1n1	12	4.00	5.00	4.7500	.45227	−1.327	.637	−.326	1.232
ps1n2	12	.00	5.00	3.9167	1.50504	−1.944	.637	3.820	1.232
ps1n3	12	2.00	5.00	3.8333	1.19342	−.392	.637	−1.446	1.232
ps1n4	12	2.00	5.00	3.9167	1.08362	−.837	.637	−.238	1.232
ps1n5	12	1.00	5.00	4.1667	1.19342	−1.918	.637	4.147	1.232
ps2n6	12	.00	5.00	3.8333	1.99241	−1.464	.637	.546	1.232
ps2n7	12	.00	5.00	3.4583	1.82730	−1.154	.637	.412	1.232
ps2n8	12	.00	5.00	3.5000	1.83402	−1.326	.637	.504	1.232
ps2n9	12	.00	5.00	3.3333	1.77525	−1.192	.637	.317	1.232
ps3n10	12	.00	5.00	3.4583	1.72493	−1.510	.637	1.369	1.232
ps3n11	12	.00	5.00	3.2083	1.61609	−1.439	.637	1.210	1.232
ps3n12	12	.00	5.00	3.3750	1.69391	−1.476	.637	1.246	1.232
ps3n13	12	.00	5.00	3.0000	1.59545	−1.128	.637	.441	1.232
ps3n14	12	.00	5.00	2.4167	1.92865	−.350	.637	−1.683	1.232
ps3n15	12	.00	5.00	2.8750	1.86017	−.806	.637	−.734	1.232
ps3n16	12	.00	5.00	2.7083	1.83969	−.543	.637	−.968	1.232
ps3n17	12	.00	5.00	3.0833	1.92865	−1.053	.637	−.590	1.232
ps3n18	12	.00	5.00	2.7500	1.76455	−.856	.637	−.669	1.232
ps3n19	12	.00	5.00	3.0833	1.92865	−1.053	.637	−.590	1.232
ps3n20	12	.00	5.00	2.9167	1.88092	−.840	.637	−.756	1.232
ps3n21	12	.00	5.00	3.0833	1.92865	−1.053	.637	−.590	1.232
ps4n22	12	.00	5.00	3.0000	1.95402	−.790	.637	−.856	1.232
ps4n23	12	.00	5.00	3.3333	1.82574	−1.024	.637	−.040	1.232
ps4n24	12	.00	5.00	3.2083	2.01650	−1.034	.637	−.668	1.232
ps4n25	12	.00	5.00	2.8750	1.81064	−.998	.637	−.610	1.232
ps4n26	12	.00	4.00	2.6667	1.66969	−1.052	.637	−.636	1.232
ps4n27	12	.00	4.00	2.9167	1.44338	−1.570	.637	1.471	1.232
ps4n28	12	.00	5.00	3.0000	1.53741	−1.261	.637	1.100	1.232
ps4n29	12	.00	5.00	2.7500	1.76455	−.856	.637	−.669	1.232
ps4n30	12	.00	5.00	3.0833	1.88092	−1.225	.637	−.379	1.232
ps4n31	12	.00	5.00	3.4167	1.67649	−1.633	.637	1.671	1.232

ps4n32	12	.00	5.00	3.1667	1.99241	-1.019	.637	-.654	1.232
ps4n33	12	.00	5.00	2.5833	1.72986	-.611	.637	-.865	1.232
ps5n34	12	.00	5.00	3.5833	1.83196	-1.384	.637	.866	1.232
ps5n35	12	.00	5.00	3.3333	1.72328	-1.260	.637	.807	1.232
ps5n36	12	.00	5.00	3.3333	1.72328	-1.260	.637	.807	1.232
ps5n37	12	.00	5.00	3.3333	2.10339	-1.021	.637	-.736	1.232
ps5n38	12	.00	5.00	2.7500	1.81534	-.759	.637	-.990	1.232
ps5n39	12	.00	5.00	2.9167	1.88092	-.840	.637	-.756	1.232
ps5n40	12	.00	5.00	3.1667	1.99241	-1.019	.637	-.654	1.232
ps5n41	12	.00	5.00	2.9167	1.83196	-1.025	.637	-.617	1.232
ps5n42	12	.00	5.00	2.6667	1.77525	-.680	.637	-.952	1.232
ps5n43	12	.00	5.00	2.8333	1.89896	-.671	.637	-1.061	1.232
ps5n44	12	.00	5.00	3.0417	1.63009	-1.090	.637	.318	1.232
ps6n45	12	.00	5.00	3.0000	2.00000	-.736	.637	-1.118	1.232
ps6n46	12	.00	5.00	2.9167	1.92865	-.772	.637	-1.045	1.232
ps6n47	12	.00	5.00	2.5000	1.93061	-.500	.637	-1.586	1.232
ps6n48	12	.00	5.00	2.5833	2.02073	-.423	.637	-1.590	1.232
ps7n49	12	.00	5.00	3.0417	1.91238	-1.012	.637	-.611	1.232
ps7n50	12	.00	5.00	3.2500	2.05050	-1.011	.637	-.704	1.232
ps7n51	12	.00	5.00	3.1667	1.94625	-1.167	.637	-.435	1.232
ps7n52	12	.00	5.00	3.0000	1.90693	-.944	.637	-.697	1.232
ps8aN53	12	.00	5.00	2.3750	1.92029	-.256	.637	-1.605	1.232
ps8aN54	12	.00	5.00	2.5417	2.01650	-.412	.637	-1.781	1.232
ps8aN55	12	.00	5.00	2.3333	1.87487	-.283	.637	-1.573	1.232
ps8aN56	12	.00	5.00	2.0833	2.02073	.182	.637	-1.628	1.232
ps8aN57	12	.00	5.00	2.0417	2.00520	.191	.637	-1.789	1.232
ps8aN58	12	.00	5.00	1.7083	1.88846	.717	.637	-.954	1.232
ps8aN59	12	.00	5.00	1.5833	1.72986	.780	.637	-.408	1.232
ps8aN60	12	.00	5.00	1.5833	1.72986	.780	.637	-.408	1.232
ps8aN61	12	.00	5.00	1.6250	1.77258	.723	.637	-.697	1.232
ps8bN62	12	.00	5.00	2.4167	1.92865	-.350	.637	-1.683	1.232
ps8bN63	12	.00	5.00	2.6667	2.10339	-.386	.637	-1.638	1.232
ps8bN64	12	.00	5.00	2.5833	2.02073	-.423	.637	-1.590	1.232
ps8bN65	12	.00	5.00	2.6667	2.05971	-.510	.637	-1.632	1.232
ps8bN66	12	.00	5.00	2.4583	1.94771	-.312	.637	-1.441	1.232
ps8bN67	12	.00	5.00	2.5833	2.15146	-.203	.637	-1.880	1.232
ps8bN68	12	.00	5.00	2.7500	2.17945	-.439	.637	-1.828	1.232
ps8bN69	12	.00	5.00	2.4167	2.10878	.035	.637	-1.781	1.232

ps8bN70	12	.00	5.00	2.1667	2.12489	.354	.637	−1.738	1.232
ps8bN71	12	.00	5.00	2.3333	2.14617	.142	.637	−1.888	1.232
ps8bN72	12	.00	5.00	2.5833	2.15146	−.203	.637	−1.880	1.232
ps9n73	12	.00	5.00	2.5417	2.01650	−.332	.637	−1.561	1.232
ps9n74	12	.00	5.00	2.6250	2.05741	−.421	.637	−1.631	1.232
ps9n75	12	.00	5.00	2.7500	2.13733	−.482	.637	−1.670	1.232
ps10n76	12	.00	5.00	3.5000	1.78377	−1.384	.637	.959	1.232
ps10n77	12	.00	5.00	3.4167	1.72986	−1.412	.637	1.106	1.232
ps10n78	12	.00	5.00	3.5000	1.73205	−1.575	.637	1.495	1.232
ps10n79	12	.00	5.00	3.1250	2.00142	−.914	.637	−.807	1.232
ps10n80	12	.00	5.00	3.2500	2.09436	−.895	.637	−.903	1.232
ps11n81	12	.00	5.00	2.5417	2.31063	−.210	.637	−2.143	1.232
ps11n82	12	.00	5.00	2.5000	2.27636	−.194	.637	−2.110	1.232
ps11n83	12	.00	5.00	2.3750	2.16506	−.175	.637	−2.049	1.232
ps11n84	12	.00	5.00	2.4167	2.23437	−.103	.637	−2.029	1.232
pr12n85	12	.00	5.00	2.5000	1.93061	−.500	.637	−1.586	1.232
pr12n86	12	.00	5.00	2.0833	1.92865	−.049	.637	−1.797	1.232
pr12n87	12	.00	5.00	2.2500	1.81534	−.226	.637	−1.425	1.232
pr12n88	12	.00	5.00	2.0833	1.92865	−.049	.637	−1.797	1.232
pr12n89	12	.00	5.00	2.0833	1.92865	−.049	.637	−1.797	1.232
ps13n90	12	.00	5.00	2.7083	2.13689	−.396	.637	−1.683	1.232
ps13n91	12	.00	5.00	2.6250	2.01274	−.560	.637	−1.648	1.232
ps13n92	12	.00	5.00	2.4583	2.06109	−.134	.637	−1.777	1.232
ps13n93	12	.00	5.00	2.2500	2.00567	.076	.637	−1.709	1.232
pr14n94	12	.00	5.00	2.0000	2.17423	.255	.637	−1.974	1.232
pr14n95	12	.00	5.00	2.1667	1.99241	−.109	.637	−1.934	1.232
pr14n96	12	.00	5.00	1.9167	2.06522	.207	.637	−2.036	1.232
pr14n97	12	.00	5.00	1.8333	2.03753	.347	.637	−1.873	1.232
pr14n98	12	.00	5.00	2.0000	2.17423	.255	.637	−1.974	1.232
pr14n99	12	.00	5.00	1.8333	1.99241	.274	.637	−1.854	1.232
pr14n100	12	.00	5.00	1.4167	1.88092	.844	.637	−.882	1.232
pr14n101	12	.00	5.00	1.9167	2.10878	.340	.637	−1.765	1.232
pr14n102	12	.00	5.00	2.0833	2.23437	.169	.637	−2.143	1.232
pr14n103	12	.00	5.00	1.6667	1.87487	.482	.637	−1.369	1.232
ps15n104	12	.00	5.00	1.6667	1.87487	.482	.637	−1.369	1.232
ps15n105	12	.00	5.00	1.6667	1.87487	.482	.637	−1.369	1.232
ps15n106	12	.00	5.00	2.0833	2.02073	.182	.637	−1.628	1.232
ps15n107	12	.00	5.00	1.7500	1.91288	.333	.637	−1.641	1.232

ps16n108	12	.00	5.00	2.3333	2.18812	−.012	.637	−1.915	1.232
ps16n109	12	.00	5.00	2.2500	2.09436	−.040	.637	−1.886	1.232
ps16n110	12	.00	5.00	2.4167	2.19331	−.207	.637	−2.094	1.232
ps16n111	12	.00	5.00	2.3333	2.14617	−.123	.637	−2.007	1.232
ps16n112	12	.00	5.00	2.3333	2.14617	−.123	.637	−2.007	1.232
ps16n113	12	.00	5.00	2.4167	2.19331	−.207	.637	−2.094	1.232
ps16n114	12	.00	5.00	2.3333	2.10339	−.247	.637	−2.121	1.232
ps16n115	12	.00	5.00	2.2500	2.05050	−.176	.637	−2.041	1.232
ps16n116	12	.00	5.00	2.0000	1.95402	.175	.637	−1.763	1.232
ps17n117	12	.00	5.00	2.8333	2.16725	−.580	.637	−1.667	1.232
ps17n118	12	.00	5.00	2.5000	2.23607	−.293	.637	−2.150	1.232
ps17n119	12	.00	5.00	2.9167	2.23437	−.580	.637	−1.701	1.232
ps17n120	12	.00	5.00	2.3333	2.14617	−.123	.637	−2.007	1.232
ps17n121	12	.00	5.00	2.2500	2.13733	.013	.637	−1.987	1.232
ps17n122	12	.00	5.00	2.6667	2.01509	−.652	.637	−1.636	1.232
ps17n123	12	.00	5.00	2.0833	1.97523	.032	.637	−1.875	1.232
ps17n124	12	.00	5.00	2.6667	2.05971	−.510	.637	−1.632	1.232
ps17n125	12	.00	5.00	2.5000	2.27636	−.194	.637	−2.110	1.232
ps17n126	12	.00	5.00	2.5833	2.06522	−.365	.637	−1.758	1.232
ps17n127	12	.00	5.00	2.6667	2.14617	−.341	.637	−1.799	1.232
ps17n128	12	.00	5.00	2.0833	1.97523	.032	.637	−1.875	1.232
pr18n129	12	.00	5.00	2.1667	2.03753	.040	.637	−1.727	1.232
pr18n130	12	.00	4.00	1.5000	1.62369	.229	.637	−1.999	1.232
pr18n131	12	.00	4.00	1.5000	1.62369	.229	.637	−1.999	1.232
ps19n132	12	.00	5.00	1.9167	2.06522	.207	.637	−2.036	1.232
ps19n133	12	.00	4.00	1.7500	1.86474	.132	.637	−2.203	1.232
ps19n134	12	.00	5.00	1.8333	1.99241	.274	.637	−1.854	1.232
ps20n135	12	.00	5.00	2.0833	1.97523	.032	.637	−1.875	1.232
ps20n136	12	.00	5.00	1.8333	2.08167	.482	.637	−1.561	1.232
ps20n137	12	.00	5.00	1.6667	1.87487	.482	.637	−1.369	1.232
Valid N (listwise)	12								

Appendix F: Final contents of C-POEMS

amended or added requirements | prioritised elements

Main Phase		Category	Element	
Diagnosis	PS1	drivers review	ps1n1	legislation
			ps1n2	customers
			ps1n3	market opportunities
			ps1n4	competitors
			ps1n5	internal drivers of organisation
			ps1n6	stakeholders
	PS2	product profiling	ps2n7	legal compliance
			ps2n8	environmental impact
			ps2n9	environmental cost
			ps2n10	environmental benchmarking/position
			ps2n11	social aspect
	PS3	company profiling	ps3n12	economical capability
			ps3n13	technical capability
			ps3n14	management capability
			ps3n15	staff capability
			ps3n16	share norm/ value
			ps3n17	environmental awareness
			ps3n18	expertise support
			ps3n19	communication-internal
			ps3n20	communication-external
			ps3n21	cooperation-internal
			ps3n22	cooperation-external
			ps3n23	corporate culture
			ps3n24	Information system (E-KPI)
Plan	PS4	managerial approach	ps4n25	established business policy
			ps4n26	established business strategies
			ps4n27	established project objectives
			ps4n28	established innovation targets
			ps4n29	identification of related areas
			ps4n30	established procedures
			ps4n31	established network
			ps4n32	established systems
			ps4n33	prioritisation (strategies, activities)
			ps4n34	communication/co-operation
			ps4n35	mutual agreement-internal
			ps4n36	mutual agreement-external
			ps4n37	organisational certificate (ISO 14001 etc.)
	PS5	operational approach	ps5n38	resource allocation-human
			ps5n39	resource allocation-financial
			ps5n40	resource allocation-technical
			ps5n41	allocation-responsibilities, authorities
			ps5n42	supporting system
			ps5n43	knowledge building-management
			ps5n44	knowledge building-environment
			ps5n45	knowledge building-technique (BAT etc.)
			ps5n46	knowledge building-supply chain
			ps5n47	knowledge building-market
			ps5n48	integration with existing asset & system
	PS6	market & sale	ps6n49	established strategy-marketing
			ps6n50	established strategy-sale
			ps6n51	user/purchaser guidelines
			ps6n52	environmental certificates - strategy & preparation

Main Phase		Category		Element
Plan	PS7	SCM (supply chain management	ps7n53	sustainable purchasing plan/set up guide
			ps7n54	decision-making suppliers/products
			ps7n55	check communication
			ps7n56	check co-operation
Implementation	PS8a	managerial aspect 1: cooperation with	ps8a57	project team (cross-functional team)
			ps8a58	managerial & operational team
			ps8a59	whole department
			ps8a60	suppliers
			ps8a61	customers
			ps8a62	shareholders
			ps8a63	NGOs
			ps8a64	other stakeholders (build-up relationship with residents)
			ps8a65	question guide for customers cooperation
	PS8b	managerial aspect 2: communication	ps8b66	established formal interface
			ps8b67	established eco-design support
			ps8b68	project team (cross-functional team)
			ps8b69	managerial & operational team
			ps8b70	whole department
			ps8b71	suppliers
			ps8b72	customers
			ps8b73	shareholders
			ps8b74	NGOs
			ps8b75	other stakeholders
			ps8b76	record & answer enquiries related to products
	PS9	operational aspect	ps9n77	trace options for improvement
			ps9n78	R&D of chosen alternatives
			ps9n79	decision-making of best alternative
	PS10	product development	ps10n80	check DfS requirements
			ps10n81	development DfS concept
			ps10n82	DfS implementation
			ps10n83	sustainable option validation
			ps10n84	decision-making best alternative
			ps10n85	product certificates (eco-labelling etc.)
			ps10n86	product declaration in chain system
			ps10n87	social aspect
	PS11	CP (cleaner production)	ps11n88	energy
			ps11n89	material
			ps11n90	toxicity
			ps11n91	water treatment (irrigation, industrial waste, waste water)
			ps11n92	waste management
			ps11n93	health & safety
	PR12	SCM (chain improvement)	ps12n94	education of customers, suppliers
			ps12n95	improvement information management
			ps12n96	support suppliers' declaration
			ps12n97	legal contract (formalise expectation, working relationship)
			ps12n98	recheck efficient communication
			ps12n99	recheck efficient co-operation
	PS13	marketing	ps13n100	market introduction
			ps13n101	eco-design after-sale plan
			ps13n102	environmental information to customers
			ps13n103	check additional market-related issues

Main Phase	Category		Element	
Knowledge building	PR14	information system	pr14n104	general investigation/information
			pr14n105	environmental information (LCA data update)
			pr14n106	management information
			pr14n107	technical information
			pr14n108	product chain information
			pr14n109	market information
			pr14n110	social aspect information
			pr14n111	test/methods of measurements
			pr14n112	information availability
			pr14n113	collecting supplementary data
	PS15	documentation (preparation of general format)	ps15n114	define precondition of documentation
			ps15n115	build-up base for documentation
			ps15n116	supply documentation for product environmental impact
			ps15n117	supply documentation for product opportunities
Evaluation & continuation	PS16	monitoring	ps16n118	product, service monitoring
			ps16n119	project/process monitoring
			ps16n120	review strategies & targets
			ps16n121	check DfS process & performance
			ps16n122	feedback from customers/stakeholders
			ps16n123	check environmental work & initial ambition
			ps16n124	check communication
			ps16n125	check co-operation
			ps16n126	check firm's other activities
	PS 17	evaluation	ps17n127	product requirements (improved products, using LCA)
			ps17n128	product performance & function
			ps17n129	product legal compliance
			ps17n130	product other aspects
			ps17n131	project & activities
			ps17n132	internal & external communication & co-operation
			ps17n133	use of tools & methods
			ps17n134	data sources, data collection methods, data quality
			ps17n135	market response
			ps17n136	environmental benefits
			ps17n137	cost effectiveness/benefits
			ps17n138	social benefits
	PS18	Documentation	ps18n139	product related information
			ps18n140	co-operation with stakeholders
			ps18n141	modification for various uses
			ps18n142	update
	PS19	routinisation	ps19n143	setup further action plan, timeframe
			ps19n144	preparation new project
			ps19n145	integration/coordination: new requirements & existing system
	PS20	continuation	ps20n146	possible change: policy, objectives & other elements in system
			ps20n147	prioritisation: resources, feedback for new target
			ps20n148	consistency of principles and procedures

Appendix G: Diagnosis template 1Da

Final form of the diagnosis template 1Da (for case studies)

COMPANY INFORMATION (for case study)		
1. Company profile	Size (Please fill in each question)	Employ number: Turnover: Location: Others (specify):
	Business area (Please choose as many as related to your company) (refer to Box1, if necessary)	□ 1 Large household appliance □ 2 Small household appliance □ 3 IT and telecommunication equipment □ 4 Consumer equipment □ 5 Lighting equipment: □ 6 Electrical and electronic tools (with the exception of large-scale stationary industrial tools) □ 7 Toys, leisure and sports equipment □ 8 medical devices (with the exception of all implanted and infected products) □ 9 Monitoring and control instruments □ 10 Others (specify):
	Market type (Please choose as many as related to your company)	□ Industrial market □ Consumer market □ Commodity market □ Capital market □ Others (specify):
	Main market (Please choose as many as related to your company)	□ Domestic (UK) □ EU (specify): □ International (specify): □ Others (specify):
	Main customers (Please specify)	

ENVIRONMENTAL DOCUMENTATION (E-KPIs)				
Document title (specify)	Subject (specify)	Existence	Format	Completion
1		□Yes □ No	□ Paper □ Electric □ Others	□ Completed □ Progressing □ Not at all
2		□Yes □ No	□ Paper □ Electric □ Others	□ Completed □ Progressing □ Not at all
3		□Yes □ No	□ Paper □ Electric □ Others	□ Completed □ Progressing □ Not at all
4		□Yes □ No	□ Paper □ Electric □ Others	□ Completed □ Progressing □ Not at all
5		□Yes □ No	□ Paper □ Electric □ Others	□ Completed □ Progressing □ Not at all

DIAGNOSIS TEMPLATE 1Da: COMPANY SPECIFIC INFORMATION		
Awareness		
Q1 What environmental drivers does your company face? Select as many as relevant and rank them if possible.	□ Legislation compliance □ Customers' requirements □ Market opportunities □ Relationship with local resident □ Local authorities' requirements □ Industry association claim □ Internal drivers	( ) ( ) ( ) ( ) ( ) ( ) ( )

	□ Others (specify): ( )
Q2 What environmental issues are you aware of in your business?	(specify)
Q3 Do you know of the following legislation? Check all relevant ones.	□ Waste Electrical and Electronic Equipment (WEEE) □ Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS) □ Eco-design of Energy-using Product (EuP) □ Registration, Evaluation and Authorisation of Chemicals (REACH) □ Others (specify)

Main drivers

Q4 What legislation are involved in your product or business? Check all relevant ones.	□ WEEE □ RoHS □ EuP □ REACH □ Others (specify)
Q5 How well do your products and products' performance comply with the requirements of the following environmental legislations? Score all the relevant legislations. (Options) 1. No compliance 2. Considered but main problem unsolved 3. Main problem solved but still more work 4. Almost complied 5. Completely complied 6. Pro-active and extended environmental activities 7. Information not available, unsure or relevant legislations still under development	□ WEEE 1___2___3___4___5___6 □ RoHS 1___2___3___4___5___6 □ EuP 1___2___3___4___5___6 □ REACH 1___2___3___4___5___6 Others (specify and rate): ____________ 1___2___3___4___5___6 ____________ 1___2___3___4___5___6 ____________ 1___2___3___4___5___6
Q6 What are the most difficult aspect of environmental legislation with which to comply for your company? (answer for all relevant legislations)	WEEE: RoHS: EuP: REACH: Others (specify):
Q7 How does compliance with environmental legislation impact on your business? (refer to Box2, if necessary)	□ Very positive □ Slightly positive □ Neither positive nor negative □ Slightly negative □ Very negative
Q8 What is the reason of the choice in Q7?	(describe)
Q9 What are the possible disadvantages of environmental legislation compliance to your company? (refer to Box2, if necessary)	(describe)
Q10 What are the potential benefits of environmental legislation compliance to your company? (refer to Box2, if necessary)	(describe)
Q11 What are the barriers to compliance with environmental performance for your company? (refer to Box3, if necessary)	(specify)
Q12 Is your job (work) associated with any environmental performance in your company?	□ Fully associated □ Little associated □ Not associated
Q13 Do you have concerns about environmental issues and activities for improvement in your company, regardless of the association with your job?	□ Yes □ No □ Don't know (information not available or unsure)
Q14 Would you lie to cooperate with other departments if they need your support for environment related work?	□ Very likely □ Quite likely □ Neither likely nor unlikely □ Quite unlikely □ Very unlikely
Q15 Who (or What department) are mostly involved (or contribute) to the environmental work in your company?	(specify the reason)
Q16 How do you think your company is tackling environmental issues in general?	□ Very good □ Quite good □ Neither good nor bad □ Quite poor □ Very poor
Q17 Do you think environmental improvement and activities in your organisation's business should be more active than they are now?	□ Strongly agree □ Agree □ Neither agree nor disagree □ Disagree □ Strongly disagree

Q18 What is the most important issue for environmental improvement in your company?	(specify)
Q19 Is your market main Business-to-Business or Business-to-Consumer?	□ Mainly Business-to-Business □ Mainly Business-to-Consumer □ Both
Q20 Are your customer interested in the environmental issues relating to your company?	□ Yes □ No □ Don't know (information not available or unsure)
Q21 Do your customers request your compliance with environmental issue?	□ Strongly pressure □ Weak pressure □ Not at all
Q22 What environmental issues are your customers interested in your business?	(specify)
Q23 What do your customers require of your products or services in environmental aspect? (choose as many as relevant ones)	□ Environmental legislation compliance □ Environmental information including positives and negatives of your products □ Health and safety information of your products □ General environmental information on products of the type □ Information on your company's environmental policies and performance □ Requirements for product's environmental improvement □ Request on improvement of general environmental activities □ Others (specify):
Q24 Does your company consider customer pressure of environmental issue?	□ Strongly consider and be proactive □ Consider and try to react □ Noticed but not bothered □ Ignore □ Don't know (information not available or unsure)
Q25 How do your customer express their concerns to your company of environmental issues? (e.g., particular methods to use for gathering customer feedback)	(specify)
Q26 Do environmental issues influence your company's market?	□ Highly influence □ Little influence □ Not at all □ Don't know (information not available or unsure)
Q27 To what extent is there market pressure of environmental issue on your business?	□ Strong pressure □ Litter pressure □ Not at all □ Don't know (information not available or unsure)
Q28 Does your company consider the environmental pressure from your market?	□ Strongly consider and be proactive □ Consider and react actively □ Consider and react passively □ Consider but not bothered □ Ignore □ Don't know (information not available or unsure)
Q29 Do you think that there is market advantage if your company achieves environmental improvement?	Improve corporate and brand reputation □Yes □No □ Don't know Market growth □Yes □No □ Don't know Product differentiation □Yes □No □ Don't know Service differentiation □Yes □No □ Don't know New business opportunities □Yes □No □ Don't know Market competition (competitiveness) □Yes □No □ Don't know Expand business change leading to market opportunities □Yes □No □ Don't know Others (specify):
Barriers	
Q30 What are the greatest difficulties in implementing environmental improvement in your company? Choose as many as relevant and rank them if possible	□ Finance resources □ Knowledge and information □ Time □ Perception □ Human resources □ System and culture □ Support □ Lack of tools □ Lack of management skills and support □ Others (specify):

Q31 Develop the detail and discussion on the chosen barriers in Q30.	
1	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
2	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
3	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
4	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
5	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
6	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
7	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
8	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
9	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:
10	(1) Detail of barriers: (2) Solution: (3) Responsibility: (4) Other comments:

Box 1-3 for Template 1D: Company specific information

Box 1: WEEE categories

Categories	Products
1. Large household appliance	• Large cooling appliances • Refrigerators • Freezers • Other large appliances used for refrigeration, conservation and storage of food • Washing machines • Clothes dryers • Dish washing machines • Cooking • Electric stoves • Electric hot plates • Microwaves • Other large appliances used for cooking and other processing food • Electric heating appliances • Electric radiators • Other large appliances for heating rooms, beds, seating furniture • Electric fans • Air conditioner appliances • Other fanning, exhaust ventilation and conditioning equipment
2. Small household appliances	• Vacuum cleaners • Carpet sweepers • Other appliances for cleaning • Appliances used for sewing, knitting, weaving and other processing for textiles • Irons and other appliances for ironing, mangling and other care of clothing • Toasters • Fryers • Grinders, coffee machines and equipment for opening or sealing containers or packages • Electric knives • Appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances • Clocks, watches and equipment for the purpose of measuring, indicating or registering time • Scales
3. IT and telecommunications equipment	• Centralised data processing • Mainframes • Minicomputers • Printer units • Personal computing • Personal computers (CPU, mouse, screen and keyboard included)

Box 1: WEEE categories (continued)

Categories	Products
3. IT and telecommunications equipment	• Laptop computers (CPU, mouse, screen and keyboard included) • Notebook computers • Notepad computers • Printers • Copying equipment • Electrical and electronic typewriters • Pocket and desk calculators • And other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means • User thermals and systems • Facsimile • Telex • Telephones • Pay telephones • Cordless telephones • Cellular telephones • Answering systems • And other products or equipment of transmitting sound, images or other information by telecommunications
4. Consumer equipment	• Radio sets • Television sets • Video cameras • Video recorders • Hi-fi recorders • Audio amplifiers • Musical instruments • And other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications
5. Lighting equipment	• Luminaries for fluorescent lamps with the exception of luminaries in households • Straight fluorescent lamps • Compact fluorescent lamps • High intensity discharge lamps, including pressure sodium lamps and metal halide lamps • Low pressure sodium lamps • Other lighting or equipment for the purpose of spreading or controlling light with the exception of filament bulbs
6. Electrical and electronic tools	• Drills • Saws • Sewing machines • Equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, bending or similar processing wood, metal and other materials • Tools for welding, soldering or similar use • Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means • Tools for mowing or other gardening activities

Box 1: WEEE categories (continued)

Categories	Products
7. Toys, leisure and sports equipment	• Electric trains or car racing sets • Hand-held video game consoles • Video games • Computers for biking, driving, running, rowing, etc. • Sports equipment with electric or electronic components • Coin slot machines
8. Medical devices	• Radiotherapy equipment • Cardiology • Dialysis • Pulmonary ventilators • Nuclear medicine • Laboratory equipment for in-vitro diagnosis • Analysers • Freezers • Fertilisation tests • Other appliances for detecting, preventing, monitoring, treating, alleviating illness, injury or disability
9. Monitoring and control instruments	• Smoke detector • Heating regulators • Thermostats • Measuring, weighing or adjusting appliances for household or as laboratory equipment • Other monitoring and control instruments used in industrial installations (e.g. in control panels)
10. Automatic dispensers	• Automatic dispensers for hot drinks • Automatic dispensers for hot or cold bottles or cans • Automatic dispensers for solid products • Automatic dispensers for money • All appliances which deliver automatically all kind of products

Box 2: Examples of potential impacts of environmental legislation compliance

- Environmental benefits
- Economic benefits (cost saving, market increase)
- Competitiveness increase
- Reducing risks (legislation relief etc)
- Improve management skill
- Management/operational innovation
- Technical innovation
- Chain system innovation
- Encourage pessimistic attitudes (searching easy way, such as taking fine rather than compliance, or move business to abroad)
- More cost for compliance
- Taking a risk as an early mover
- Reduce productivity growth

These are examples. Please consider your company's own situation first.

Box 3. Examples of main barriers and the features in environmental aspect

Barriers	Main features
Finance resources	• Lack of finance to invest, operate and maintain environmental performance (especially environmental management tools) • Economic short termism (i.e. quick payback on investments)
Knowledge and information	• Difficulties to access information (ill-informed) • Lack of understanding of environmental problem and the potential benefits of its improvements • Lack of relevant knowledge and information, for example, management information system and technology • Lack of understanding in both of general and specific environmental issue
Time	• Lack of time to carry out in-dept • Not sufficient time to staff to concentrate on the subject
Perception	• Unfamiliarity of some terminology and specific environmental concepts • Underestimation of benefits from environmental improvement and of importance of its activities • Misperception of environmental issues including costs, efforts, regulators and potential for environmental management to impact on the commercial aspects of the business • Over estimation of future burdens
Human resources	• Lack of staff having sufficient environmental knowledge and skills • Lack of cooperation and communication
System and culture	• Multi-task staff environment • SMEs are required to bridge a cultural gap
Support	• Not sufficient information service about environmental problem and potential benefit by implementing environmental improvement • Lack of sector-specific support and guidance • Institutional weaknesses
Lack of tools	• Unsuitable EMS tools for SMEs • Complication of using tools • Lack of support from existing tool for product development
Lack of management skills & support	• Lack of management information system • Lack of commitment from top management • Too complex and general management schemes for SMEs to handle
Others	• Initiative fatigue/overload (related to lack of staff resources)

These are examples. Please consider your company's own situation first.

Appendix H: Summary of companies' data of template 1Da

Company A:

COMPANY INFORMATION (for case study)		
1. Company profile	Size	Employ number: 500 (company unit) Turnover: NA Location: Domestic Others (specify): NA
	Business area	☒ 3 IT and telecommunication equipment ☒ 10 Others (specify): manufacturing test equipment
	Market type	☒ Industrial market
	Main market	☒ International (specify): South East Asia, US
	Main customers (specify)	Multinational IT brands

ENVIRONMENTAL DOCUMENTATION (E-KPIs)				
Document title (specify)	Subject (specify)	Existence	Format	Completion
1 Waste streams	Objectives and targets	☒ Yes	☒ Electric	☒ Progressing
2 Energy consumption	Objectives and targets	☒ Yes	☒ Electric	☒ Progressing
3 Comply with WEEE and RoHS	Objectives and targets	☒ Yes	☒ Electric	☒ Completed
4 Comply with China RoHS	Objectives and targets	☒ Yes	☒ Electric	☒ Progressing
5 Improve environmental awareness	Objectives and targets	☒ Yes	☒ Electric	☒ Progressing
6 Implement principles of LCA	Objectives and targets	☒ Yes	☒ Electric	☒ Progressing

DIAGNOSIS TEMPLATE 1Da: COMPANY SPECIFIC INFORMATION	
Awareness	
Q1 What environmental drivers does your company face? Select as many as relevant and rank them if possible.	☒ Legislation compliance (1) ☒ Customers' requirements (2) ☒ Market opportunities (4) ☒ Relationship with local resident (6) ☒ Local authorities' requirements (5) □ Industry association claim ( ) ☒ Internal drivers (3) □ Others (specify): ( )
Q2 What environmental issues are you aware of in your business?	Legislations and customer main concerns in techniques (e.g., thermal management of data storage equipment)
Q3 Do you know of the following legislation? Check all relevant ones.	☒ Waste Electrical and Electronic Equipment (WEEE) ☒ Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS) ☒ Eco-design of Energy-using Product (EuP) ☒ Registration, Evaluation and Authorisation of Chemicals (REACH) ☒ Others (specify): China RoHS
Main drivers	
Q4 What legislation are involved in your product or business? Check all relevant ones.	☒ WEEE ☒ RoHS ☒ EuP ☒ REACH ☒ Others (specify) : China RoHS
Q5 How well do your products and products' performance comply with the requirements of the following environmental legislations? Score all the relevant legislations. (Options) 1. No compliance	☒ WEEE 1_ _ _2_ _ _3_ _ _4_ _ _5_ _ _6 ☒ RoHS 1_ _ _2_ _ _3_ _ _4_ _ _5_ _ _6 ☒ EuP NA ☒ Others (specify and rate): China RoHS NA

2. Considered but main problem unsolved 3. Main problem solved but still more work 4. Almost complied 5. Completely complied 6. Pro-active and extended environmental activities 7. Information not available, unsure or relevant legislations still under development	
Q6 What are the most difficult aspect of environmental legislation with which to comply for your company? (answer for all relevant legislations)	WEEE: no problem RoHS: no problem EuP: no problem Others (specify): Requirements of China RoHS have not yet been fully defined but labelling and lab testing requirements will make. Compliance may difficult before the implementation date.
Q7 How does compliance with environmental legislation impact on your business?	☒ Very positive
Q8 What is the reason of the choice in Q7?	Being a European company aware and acting on EU law, we have a complete advantage over US competitors.
Q9 What are the possible disadvantages of environmental legislation compliance to your company?	Component availability for our products, e.g., RoHS components for PCBs.
Q10 What are the potential benefits of environmental legislation compliance to your company?	Competitiveness improvement.
Q11 What are the barriers to compliance with environmental performance for your company?	Supplier awareness and cooperation. Supply pipeline management (e.g., inventory of material to be used or scrapped).
Q12 Is your job (work) associated with any environmental performance in your company?	☒ Fully associated (with any environmental performance)
Q13 Do you have concerns about environmental issues and activities for improvement in your company, regardless of the association with your job?	☒ Yes
Q14 Would you like to cooperate with other departments if they need your support for environment related work?	☒ Very likely
Q15 Who (or What department) are mostly involved (or contribute) to the environmental work in your company?	CEO (chief executive officer) CTO (chief technology officer) Compliant department Development department Procurement department
Q16 How do you think your company is tackling environmental issues in general?	☒ Very good Monitoring and comply with legislation. Guiding customers and suppliers.
Q17 Do you think environmental improvement and activities in your organisation's business should be more active than they are now?	☒ Agree Started general environmental activities lately (e.g. ISO 14001).
Q18 What is the most important issue for environmental improvement in your company?	RoHS for engineers. Waste stream management for general employees. RoHS-WEEE net has been an important enabler to compliance together with management.
Q19 Is your market main Business-to-Business or Business-to-Consumer?	☒ Mainly Business-to-Business
Q20 Are your customer interested in the environmental issues relating to your company?	☒ Yes
Q21 Do your customers request your compliance with environmental issue?	☒ Strongly pressure
Q22 What environmental issues are your customers interested in your business?	Compliance with EU legislation. Our customers (some of them) supply product to the EU market and we must support their compliance.
Q23 What do your customers require of your products or services in environmental aspect? (choose as many as relevant ones)	☒ Environmental legislation compliance ☒ General environmental information on products of the type ☒ Information on your company's environmental policies and performance ☒ Requirements for product's environmental improvement ☒ Request on improvement of general environmental activities
Q24 Does your company consider customer pressure of environmental issue?	☒ Strongly consider and be proactive
Q25 How do your customer express their concerns to your company of environmental issues?	Executive level communication. Results of customer audits.

(e.g., particular methods to use for gathering customer feedback)	ISO 14001 view of registering body.
Q26 Do environmental issues influence your company's market?	☒ Not at all
Q27 To what extent is there market pressure of environmental issue on your business?	☒ Strong pressure (B2B customers) Customers are very involved in environmental issues but they do not influence our presence in the marketplace.
Q28 Does your company consider the environmental pressure from your market?	☒ Strongly consider and be proactive
Q29 Do you think that there is market advantage if your company achieves environmental improvement?	Improve corporate and brand reputation ☒Yes □No □Don't know Market growth (possibly) ☒Yes □No □Don't know Product differentiation ☒Yes □No □Don't know Service differentiation ☒Yes □No □Don't know New business opportunities (possibly) ☒Yes □No □Don't know Market competition (competitiveness) ☒Yes □No □Don't know Expand business change leading to market opportunities □Yes □No ☒Don't know

Barriers

Q30 What are the greatest difficulties in implementing environmental improvement in your company? Choose as many as relevant and rank them if possible	☒ Finance resources (4) ☒ Knowledge and information (3) ☒ System and culture (1) ☒ Lack of tools (2)

Q31 Develop the detail and discussion on the chosen barriers in Q30.

1 System and culture	(1) Detail of barriers: coordinated activities difficult in worldwide organisation with several decision (2) Solution: internal management issue (3) Responsibility: company top management
2 Lack of tools	(1) Detail of barriers: Lack of structure in use of tools similar to (2) (2) Solution: Better science in application of tools to environmental issues (3) Responsibility: Environmental management and the academic community
3 Knowledge and information	(1) Detail of barriers: Better linkage to environmental consequences to promote involvement (2) Solution: Understand practical responses to environmental issues (3) Responsibility: Environmental management / government bodies (4) Other comments: Specific institutions to business on response to environmental issues
4 Finance resources	(1) Detail of barriers: Improvement at location we largely through landlord who will apply a charge (2) Solution: More landlord environmental involvement / leadership (3) Responsibility: Landlord's management

Company B:

COMPANY INFORMATION (for case study)		
1. Company profile	Size	Employ number: 22 (company unit) Turnover: NA Location: EU Others (specify): NA
	Business area	☒ IT and telecommunication equipment
	Market type	☒ Consumer market
	Main market	☒ EU (specify) ☒ International (specify): NA
	Main customers (Please specify)	End user asking for phone numbers, addresses etc.

ENVIRONMENTAL DOCUMENTATION (E-KPIs)
No policy and no document

DIAGNOSIS TEMPLATE 1Da: COMPANY SPECIFIC INFORMATION

Awareness

Q1 What environmental drivers does your company face? Select as many as relevant and rank them if possible.	☒ Legislation compliance	(1)
	☒ Customers' requirements	(3)
	□ Market opportunities	( )
	□ Relationship with local resident	( )

	□ Local authorities' requirements ( ) □ Industry association claim ( ) ☒ Internal drivers (2) □ Others (specify): ( )
Q2 What environmental issues are you aware of in your business?	Important energy consumption for stand-by equipment (there are around 2 computers per person). Moderate natural lightning calls for use of artificial lightning. No controls on the call centre (outsourced).
Q3 Do you know of the following legislation? Check all relevant ones.	☒ Waste Electrical and Electronic Equipment (WEEE) ☒ Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS) ☒ Eco-design of Energy-using Product (EuP) ☒ Registration, Evaluation and Authorisation of Chemicals (REACH) □ Others (specify)

Main drivers

Q4 What legislation are involved in your product or business? Check all relevant ones.	No
Q5 How well do your products and products' performance comply with the requirements of the following environmental legislations? Score all the relevant legislations.	NA
Q6 What are the most difficult aspect of environmental legislation with which to comply for your company? (answer for all relevant legislations)	NA
Q7 How does compliance with environmental legislation impact on your business?	☒ Neither positive nor negative
Q8 What is the reason of the choice in Q7?	There is very little legislation regarding what we do, it just covers thermal isolation of the offices etc.
Q9 What are the possible disadvantages of environmental legislation compliance to your company?	None
Q10 What are the potential benefits of environmental legislation compliance to your company?	We could have cost savings if there was an incentive to pay attention to the PCs that are kept in operation.
Q11 What are the barriers to compliance with environmental performance for your company?	None
Q12 Is your job (work) associated with any environmental performance in your company?	☒ Little associated
Q13 Do you have concerns about environmental issues and activities for improvement in your company, regardless of the association with your job?	☒ Yes
Q14 Would you like to cooperate with other departments if they need your support for environment related work?	☒ Very likely
Q15 Who (or What department) are mostly involved (or contribute) to the environmental work in your company?	None for now. The HR or the parent company could motivate the Technical Director to form some policies together with the HR.
Q16 How do you think your company is tackling environmental issues in general?	☒ Neither good nor bad There is some understanding in personal level by the employees, but nothing in company level, and no obvious great damages to the environment.
Q17 Do you think environmental improvement and activities in your organisation's business should be more active than they are now?	☒ Agree With minor sacrifices we could have minor cost gains and some improvement for our image, which is important for our operations.
Q18 What is the most important issue for environmental improvement in your company?	Environmental benefits to society, and improvement of company image.
Q19 Is your market main Business-to-Business or Business-to-Consumer?	☒ Mainly Business-to-Consumer
Q20 Are your customer interested in the environmental issues relating to your company?	☒ Don't know (information not available or unsure)
Q21 Do your customers request your compliance with environmental issue?	☒ Not at all
Q22 What environmental issues are your customers interested in your business?	NA
Q23 What do your customers require of your products or services in environmental aspect? (choose as many as relevant ones)	NA (Don't know)
Q24 Does your company consider customer pressure of environmental issue?	We haven't noticed any pressure.

Q25 How do your customer express their concerns to your company of environmental issues? (e.g., particular methods to use for gathering customer feedback)	NA
Q26 Do environmental issues influence your company's market?	☒ Don't know (information not available or unsure)
Q27 To what extent is there market pressure of environmental issue on your business?	☒ Don't know (information not available or unsure)
Q28 Does your company consider the environmental pressure from your market?	☒ Don't know (information not available or unsure)
Q29 Do you think that there is market advantage if your company achieves environmental improvement?	Improve corporate and brand reputation ☒Yes □No □ Don't know Market growth □Yes ☒No □ Don't know Product differentiation □Yes □No ☒ Don't know Service differentiation ☒Yes □No □ Don't know New business opportunities (possibly) ☒Yes □No □ Don't know Market competition (competitiveness) ☒Yes □No □ Don't know Expand business change leading to market opportunities ☒Yes □No □ Don't know
Barriers	
Q30 What are the greatest difficulties in implementing environmental improvement in your company? Choose as many as relevant and rank them if possible	☒ Finance resources (2) ☒ Knowledge and information (1) ☒ System and culture (4) ☒ Lack of management skills and support (3)
Q31 Develop the detail and discussion on the chosen barriers in Q30.	
1 Knowledge and information	(1) Detail of barriers: We need money to do market research (2) Solution: Not easily. We need research to prove that research will pay off (3) Responsibility: Marketing department and finance department
2 Finance resources	(1) Detail of barriers: We need money to do market research (2) Solution: Not easily. We need research to prove that research will pay off (3) Responsibility: Marketing department and finance department
3 Lack of management skills and support	(1) Detail of barriers: I don't think there's anyone else here having a formal training on CSR and environment. (2) Solution: To appoint appropriate person for environmental work and give authority (e.g., technical director), train people or hire people
4 System and culture	(1) Detail of barriers: There is no real incentive to be environmentally conscious, and enforcing it might generate a backlash (2) Solution: Attention, information but very few hard rules. Most of the people here are responsible (3) Responsibility: HR and then all

Company C:

COMPANY INFORMATION (for case study)		
1. Company profile	Size (Please fill in each question)	Employ number: 45 (company unit) Turnover: NA Location: Asia Others (specify): NA
	Business area	☒ 1 Large household appliance: Refrigerator, microwave, air conditioner ☒ 2 Small household appliance: Coffee machine, clock ☒ 3 IT and telecommunication equipment: Centralised data processing, computer, printer, laptop, copier, fax, telephone ☒ 5 Lighting equipment: Straight/compact fluorescent lamps ☒ 9 Monitoring and control instruments: Smoke detector, thermostats ☒ 10 Others (specify): Automatic dispenser for hot drink
	Market type	☒ Industrial market: Oil and gas (users; e.g., refinery and oil production companies)
	Main market	☒ International (specify): NA ☒ Others (specify): NA
	Main customers (Please specify)	Multinational companies
ENVIRONMENTAL DOCUMENTATION (E-KPIs)		
None		

DIAGNOSIS TEMPLATE 1Da: COMPANY SPECIFIC INFORMATION	
Awareness	
Q1 What environmental drivers does your company face? Select as many as relevant and rank them if possible.	None
Q2 What environmental issues are your aware of in your business?	No answer
Q3 Do you know of the following legislation? Check all relevant ones.	None (but involved in ISO voluntary certification)
Main drivers	
Q4 What legislation are involved in your product or business? Check all relevant ones.	None
Q5 How well do your products and products' performance comply with the requirements of the following environmental legislations? Score all the relevant legislations.	Don't know about the legislations
Q6 What are the most difficult aspect of environmental legislation with which to comply for your company? (answer for all relevant legislations)	No answer
Q7 How does compliance with environmental legislation impact on your business?	☒ Slightly negative
Q8 What is the reason of the choice in Q7?	Oil & gas is the main cause of increasing CO2 in air. Main reason of increasing operation performance is for increasing customer's profit. But because of local environmental regulation, our product must minimise oil/gas content in over board produced water.
Q9 What are the possible disadvantages of environmental legislation compliance to your company?	More cost for compliance. Reduce productivity growth.
Q10 What are the potential benefits of environmental legislation compliance to your company?	Environmental benefits
Q11 What are the barriers to compliance with environmental performance for your company?	No answer
Q12 Is your job (work) associated with any environmental performance in your company?	☒ Not associated
Q13 Do you have concerns about environmental issues and activities for improvement in your company, regardless of the association with your job?	☒ Yes
Q14 Would you like to cooperate with other departments if they need your support for environment related work?	☒ Neither likely nor unlikely
Q15 Who (or What department) are mostly involved (or contribute) to the environmental work in your company?	I'm working on the development of new application for bio-diesel oil. Within company or project execution, no one has involved.
Q16 How do you think your company is tackling environmental issues in general?	☒ Neither good nor bad We don't have factory, thus it depends on person's life.
Q17 Do you think environmental improvement and activities in your organisation's business should be more active than they are now?	☒ Disagree We don't have factory, thus it depends on person's life.
Q18 What is the most important issue for environmental improvement in your company?	To minimise the use of paper.
Q19 Is your market main Business-to-Business or Business-to-Consumer?	☒ Mainly Business-to-Business
Q20 Are your customer interested in the environmental issues relating to your company?	☒ No (may be)
Q21 Do your customers request your compliance with environmental issue?	☒ Not at all
Q22 What environmental issues are your customers interested in your business?	Emission. Total operation/ maintenance cost of unit/system.
Q23 What do your customers require of your products or services in environmental aspect? (choose as many as relevant ones)	☒ Health and safety information of your products
Q24 Does your company consider customer pressure of environmental issue?	☒ Ignore
Q25 How do your customer express their concerns to your company of environmental issues? (e.g., particular methods to use for gathering customer feedback)	We normally work with customer for increasing customer's profit. Our concern is only local environmental regulation.
Q26 Do environmental issues influence your company's market?	☒ Highly influence
Q27 To what extent is there market pressure of environmental	☒ Not at all

issue on your business?		
Q28 Does your company consider the environmental pressure from your market?	☒ Don't know (information not available or unsure)	
Q29 Do you think that there is market advantage if your company achieves environmental improvement?	Improve corporate and brand reputation	□Yes □No ☒Don't know
	Market growth	□Yes □No ☒Don't know
	Product differentiation	□Yes □No ☒Don't know
	Service differentiation	□Yes □No ☒Don't know
	New business opportunities	□Yes □No ☒Don't know
	Market competition (competitiveness)	□Yes □No ☒Don't know
	Expand business change leading to market opportunities	□Yes □No ☒Don't know

Barriers

Q30 What are the greatest difficulties in implementing environmental improvement in your company? Choose as many as relevant and rank them if possible	No order of barriers: Finance resources, time, human resources, lack of tools ☒ Finance resources □ Knowledge and information (potentially) ☒ Time ☒ Human resources □ System and culture (potentially) □ Support (potentially) ☒ Lack of tools

Q31 Develop the detail and discussion on the chosen barriers in Q30.	
Finance resources	(1) Detail of barriers: Investor (client) requisition (2) Solution: New market should be opened/ found (3) Responsibility: Government
Time	(2) Solution: Invest new working style (3) Responsibility: Company managers and client
Human resources	(2) Solution: Financial resources (3) Responsibility: Client
Lack of tools	No answer
Potential barriers	
Knowledge and information	(2) Solution: Client (3) Responsibility: Advisor
System and culture	(1) Detail of barriers: Company rule (2) Solution: Change working style (3) Responsibility: Company managers
Support	(1) Detail of barriers: Our business will collapse if environmental issue is fully involved in our business; result in no power electricity, chemical, medicine in the world

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AN INTEGRATED APPROACH BASED ON PRODUCT-ORIENTED ENVIRONMENTAL MANAGEMENT SYSTEM (POEMS)

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1. Introduction

Industry has begun to pay attention to environmental improvement throughout product life cycles, rather than focussing on specific problems, largely due to recent environmental legislations*. However, small and medium-sized enterprises (SMEs) do not seem fully aware and active in relation to this issue, despite their substantial contribution to the economy and impact on the environment. In particular, the SMEs need specific sectoral support due to their diversity and size, using hands-on tools and various role-models as examples.

However, industry has focused on developing practices which are mainly oriented towards environmental management systems, (EMSs), such as ISO 14001 and EMAS. These existing tools have been developed for large-scale companies and do not suit SMEs' product development in a variety of aspects such as cost, time and lack of sector-specific information. They do not adequately support environmental product development. Design for Environment (DfE) tools have been developed to implement environmental improvement in product development. However, the shortcomings of DfE are also noted; characterised by pilot projects and discontinuation; lack of managerial function to support strategic and organisational change; lack of approach to find potential environmental improvement on product life cycle; lack of development of longer term capability and routine for environmental improvement. Furthermore concern for products and their life cycles perspective is important as most of the environmental impact is closely related to flows of materials, energy and products [1]. Thus it seems urgent for environmental management systems to encompass products and product development [2].

The aim of this research, therefore, is to investigate the main product development factors which affect a company's environmental improvement, and thus define the detailed environmental requirements for implementation of POEMS into the product development process. This also includes the benefits of adopting an integrated approach.

2. POEMS and the Process

POEMS is an EMS with a special focus on the continuous improvement of a product's eco-efficiency (ecological and economic) along its life-cycle, through the systematic integration of eco-design in the company's strategies and practices [3]. This paper emphasises the importance of the continual improvement of products and related work, as advocated by the extended approach of the Danish EPA manual [4]. Various research and practices of POEMS can be summarised into the following objective concepts; continuous (environmental) improvement; coordination with existing (environmental) management or operations; integration with DfE activities; extended and product-focused supply chain management and its cooperation.

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* WEEE and RoHS require improvement on material and product, and EuP recommends an environmental consideration in design stage providing ecodesign guideline.

2.1 POEMS models and process

POEMS has different flow-processes and focus areas depending on the application and approach backgrounds, and thus it requires tailor-made approaches which can be adopted for use by small companies. This study examined 13 POEMS models and related processes selected from 18 previous works ([1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18]). These are reviewed in terms of general procedure throughout the product life cycle, product development process or management procedure, the main principles extracted, and important requirements. The key factors are compared and categorised into main concepts, main features of (process) models, focus stages, principles and requirements, and benefits.

2.2 General procedures of POEMS

Even though each POEMS model features its own focus areas such as initial support, product management support, extension or integration of product aspects into EMS management, integration into general management or sector-specific approaches, most of them have common concepts and similar procedures. Those elements are processed here into principles and in-depth requirements on which this paper focuses. The following is a brief description of each phase in POEMS procedures:

- First step (preliminary stage): product profiling, review of organisational aspects; chain analysis; market review and position benchmarking
- Second step (analysis of drivers): legislation review; suppliers and customers' requirements: other stakeholders' demands; market needs.
- Third stage: clarification of potential improvement on product and related areas and the benefits for the firm and its customers and suppliers.
- Fourth step (planning phase): management/business strategies; POEMS and product policy/strategies; POEMS project objectives and targets; guidelines and requirements; formal procedures.
- Fifth step (allocation of resources): deployment of human, financial, technical, management; management level of commitment and support initial involvement of staff; teamwork support and training.
- Sixth step (execution of POEMS project): generating and verifying alternatives, control product chain with sustainable purchasing, cleaner production, building up knowledge with supplementary data, and preparation of documentation and marketing plan.
- Seventh step (evaluation): defined objectives and targets; project and product development process; a level of achievement of outcome compared to initial ambition of the firm; legal compliance, requirements and performance of product; services and management systems; sources, collection methods and quality of data; appropriateness of tools and methods used; collaboration and communication; benefits of environment and costs; response of market and stakeholders.
- Eighth step (routinisation and continuous improvement)

2.3. Prioritisation of main principles and requirements of POEMS

The above principles and requirements should be prioritised depending on an organisation's needs. Thus analysis clarifies the order of importance of POEMS activities. The most important of POEMS' principles and requirements is the product profiling, which includes a product's environmental impact and cost assessment, environmental benchmarking and position of the product in the market, production assessment, etc. This is aimed at identifying where environmental problems are created in the product life cycle in association with the location of potential improvements. It might at times require Life Cycle Assessment (LCA) screening to identify in-depth information, but many of POEMS projects get a brief profile without conducting a costly and time-consuming LCA screening.

The second challenge is to investigate potential improvement based on product profiling information, and external demands such as legal and customer requirements. To what extent activities can be integrated into existing system, which is one of key issues enabling continuous improvement afterwards, should be considered in the planning stage.

Allocation of resources and responsibilities is important, as well as empowerment of the staff. The seventh step comprises a review of preceding work. It is helpful if tools or methods of measurement are considered initially when planning. Co-operation and communication between companies and suppliers are crucial for environmental improvement in the whole chain system. Evaluation and feedback of various aspects is essential because it is not only an assessment of work done but also the start for further actions.

Finally, routinisation and continuous improvement are significant, though emphasised in few studies. This seems due to lack of interest and effort to establish a framework for the next step by companies. Therefore, key activities for routinisation and continuation of environmental improvement are as follows; integration of POEMS into existing management and systems, documentation; prioritisation of problems, opportunities and possible needs; setup of action plan for further work; consistency of principles and procedures.

Conclusion & Discussion

Successful POEMS application enables not only environmental benefits but also potential opportunities that companies usually pursue in their business and operations. Benefits of POEMS project has been verified in previous works in particular small companies (cf. [2] [3] [7] [16] [18]). Environmental tools need to be flexible and easy to apply especially for small size of enterprises. POEMS supports relatively flexible approaches to adjust for companies' own needs and level of ambition. In respect of the importance of product in environmental improvement, *collecting and processing product and related environmental information can be a key bottleneck for SMEs* [2]. This is the reason that POEMS principles particularly emphasise the product environmental profiling. In addition, POEMS systems can be easily incorporated into business operations; *its implementation is not hampered by major financial or organisational problems according to POEMS practices* [3].

However, despite of advantages of POEMS, various practices of POEMS need to be known by industry so that they may develop particular aspects of POEMS to adopt in an efficient way by integration into firms' existing system.

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Sector-Specific Product-Oriented Environmental Management System (POEMS) Model as an Integrated Approach to Environmental Product Development for Small and Medium-sized Enterprises (SMEs)

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Abstract

SMEs seem relatively untouched with regards to environmental issues. The focus of this paper is on this fundamental question and investigating core and technical aspects to improve this. The fist step is to understand the nature of SMEs and environmental related issues. In the second, environmental methods are reviewed including traditional and alternative tools. Based on the findings, there is a need for an integrated approach , of which the main factors of product aspects are mainly associated with the company's environmental improvement will be identified, and thus define detailed environmental requirements for implementation of POEMS into product development process will be investigated. It concludes with the benefits from adopting the integrated approach.

1. Introduction

Among the key issues of industrial change in the last few decades, the environment has been placed at the centre of debates and it effects on industry by legislation. In these circumstances, it is very important to give attention and support, to small and medium-sized enterprises (SMEs) who are not aware and active in relation to this issue despite their substantial contribution and impact on the economy. Furthermore, that attention needs to specify the sectoral support for SMEs industry due to their diversity and size. In respect of current issues on firms' environmental improvement, incorporating product's life cycle perspective into the product development process is a core requirement. However, most methods especially Environmental Management Systems (EMSs) that are broadly used in industry such as ISO 14001 or EMAS do not seem to account for the product aspects in their procedures. In addition, various approaches of Design for Environment (DfE) have been noted that they do not support certain aspects of environmental activities, for instance management viewpoint. Consequently, it is very important to develop simpler tools, hands-on support and diffusion of various role models in order to allow SMEs to more easily adopt environmental improvement activities.

Thus the aim of this research is to develop an integrated model and investigate requirements in relation to sector specification especially for SMEs. The research focuses on building practical and customised management tools for improving a product's environmental efficiency. For this reason, this paper is dedicated to preliminary research in terms of background knowledge of SMEs, environmental issues and analytical review of product focused environmental management tools as a basis for developing an integrated model. It consists of three main subjects; identifying main issues of SMEs and environmental improvement; a need for an integrated approach by clarifying shortcomings of existing tools and methods; introduction of product-oriented environmental management system (POEMS) as an integrated tool bridging the gap of shortcomings, and main principles and requirements of POEMS. Methodological approach is based on the critical review of current issues and existing tools proposed in different viewpoints.

2. SMEs and Environmental Improvement

2.1 Why SMEs and who they are

There are a few reasons, why we need to consider the SME sector. First of all, an economic perspective is examined in the light of their important role in economy. Secondly, environmental impact by SMEs may be more substantial than expected due to lack of statistical measurements. Lastly, in terms of response of SMEs on environmental issues, they do not seem actively involved due to many reasons including lack of SME support. A variety of perspectives that are likely to exist in the SME sector such as difficulties and trends of their activities, need to be investigated to understand and support the sector.

On the aspect of the important role of SMEs in economy, small firms are generally regarded as sizable sector in industry overall. For example, of the 3.7 million businesses in the UK, small business account for 99%; they account for 58% of all employment and for 38% of GDP (Fay 2000). Hillary's report also indicates that; "the SME sector is vast. In the UK alone, 99.8% of all enterprises fall into this sector. In Europe, around 90% of all enterprises are small or medium-sized. The percentages are similar in countries all over the world. And their numbers are set to increase. In the EU alone, the SME sector account for 70% of economy" (Hillary 2000). According to DTI report (DTI, cited by Hillary 2004) in 1998, 99% were small businesses employing less than 50 people and only 25000 were medium sized employing between 50 and 249 people. Number of employees is one of identifying characteristics of SMEs. There are different aspects to consider as in Table 1.

Table 1. A variety of definitions of SMEs

	No. of employees	Annual turnover (EUC)	Balance sheet total	Ownership	Financial independence	Market share
Bolton Report+ (1971)				Owner managed	Financially independent	Small market share
Business Link (2003, UK)+	Micro: 0-9 Small: 10-49 Medium: 50-249					
DTI (1995)+	Small:0-200 Medium:201-500					
IfM Bonn (2004)‡	Small: up to 9 Medium:10-499 Large: 500 and more	Small: up to 1m Medium: 1-50 m Large: 50 m and more				
European Commi-ssion (2005)**	Micro: under 10 Small: under 50 Medium: under 250	Micro: under 2m Small: under 10m Medium: under 50m	Micro: under 2m Small: under 10m Medium: under 43m	See ¶	See ¶	
Eurostat *	Micro: 1-19 Small: 10-99 Medium: 100-499					
US*	Micro: 1-19 Small: 20-99 Medium: 100-499					

+ Sourced from Bruce and Cooper (1999)

‡ Sourced from Günterberg and Kayser (2004)

** Sourced from European Commission (2005)

* Sourced from Recklies (2001)

¶ Definition by European Commission 2005

1) You are totally independent, ie. you have no participation in other enterprises and no enterprise has a participation in yours.

2) You have a holding of less than 25% of the capital or voting rights (whichever is the higher) in one or more other enterprises and/or outsiders do not have a stake of 25% or more of the capital or voting rights (whichever is the higher) in your enterprise.

It is generally accepted that SMEs largely contribute to the environmental problem although the total environmental contamination by SMEs is not really substantiated. In terms of the statistical issue of total environmental impact, national economic statistics on SMEs do not tally with data collected on emissions, waste generation and effluents from firms, so it is doubtful whether smaller firms' contribution to pollution can be calculated at all (Hillary 2000). Thus, in fact, there is little hard data to determine the sector's contribution to pollution load (Hillary 2000). However, this report (Hillary 2000) also states that 'collectively, their sheer numbers may mean their environmental impacts are substantial'. There are a few estimations of the environmental impact in the SME sector. According to the report of European Commission surveyed by ECOTEC (2000), it claims that small and medium enterprises make a very considerable and collective contribution providing an estimate of around 50% overall. The Environmental Agency (2004) notes that smaller businesses generate about 60% of commercial waste and are responsible for as much as 80% of pollution incidents.

SMEs support is also an essential issue on current environmental legislation because a great number of small companies are in the legislative categories and connected to their larger partner firms as suppliers. It is claimed that information about environmental problems and potential benefits by implementing environmental improvement are not sufficiently dealt with in SMEs perspective. The services seem to have a bent for being general, introductory and also oriented to larger companies. Thus, SMEs perceive particularly the environmental management process as generic and biased to larger companies (Gerstenfeld and Roberts 2000). Therefore, sector specific information should be offered, which includes legislation and industry specific assistance (cf. Gerstenfeld and Roberts 2000, Hillary 2004, Holt *et al*. 2000, Hobbs 2000)

2.2 SMEs' difficulties on environmental improvement

The lack of awareness and unwillingness to implement environmental performance by small firms needs to be addressed (c.f. Anglada 2000, Curtis and Walker 2001, Environmment Agency 2004, Holt *et al*. 2000, Gerrans and Hutchinson 2000 and MORI 1998). Many studies have been undertaken in terms of obstacles to diffuse environmental concern to the SME sector and to implement environmental management in small firms.

In this literature study, in reference to 'barriers of environmental performance', ten recent researches and opinions (Biondi *et al*. 2000, ECOTEC 2000, Hillary 2004, Holt *et al*. 2000, Kuhndt and Von Geibler 2002, Fresner 2004, Garrette 2000, Gerstenfeld 2000, Pimenova *et al.* 2003, Winsemius and Guntram 2002) were reviewed and categorised as shown in Table 2. Most of surveys on this subject cover the following issues – what inhibits small and medium firms' understanding of environmental issues, why they hesitate to adopt the environmental innovation, and which factors influence the implementation of a environmental management system. Some factors such as 'financial problems', 'human resources' and 'lack of information and knowledge' are mainly stated but more investigation is needed to tackle other problems in depth.

In consequence, there is a need to provide hands-on support, rather than self-help support (Environmental Business Network 2004), concerning the difficulties of the environmental instrument to be appreciated by SMEs. In particular, information and tools should be developed with regard to sectoral specification.

3. A need of integrated approach

Industry began to pay attention to environmental improvement incorporating product life cycle due to recent environmental legislations and changing focus. This paper summarises three possible aspects on this discussion. First of all, legislations and policies strongly indicate the importance of product aspects in sustainable agenda in their directions. For example, WEEE Directive (Directive on Waste Electrical and Electronic Equipment) and RoHS (the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment) require improvement on material and product, and EuP (Eco-design requirements for Energy-Using Products) recommend an environmental consideration in the design stage providing ecodesign guideline.

Table 2. Barriers of awareness and implementation of environmental performance

Barriers	**Main features**
Financial resource	• Lack of finance to invest, operate and maintain environmental performance (especially environmental management tools) • Economic shortermism (i.e. quick payback on investments)
Knowledge and information	• Difficulties to access information (ill-informed) • Lack of understanding of environmental problems and the potential benefits of its improvement • Lack of relevant knowledge and information, e.g. management information system and technology • Lack of understanding in both of general and specific environmental issues
Time	• Lack of time to carry out in-depth activities • Not sufficient time for staff to concentrate on the subject
Perception	• Unfamiliarity of some terminology and specific environmental concepts • Underestimation of benefits from environmental improvement and of importance of its activities • Misperception of environmental issues including costs, efforts, regulators and potential for environmental management to impact on the commercial aspects of the business • Over estimation of future burdens

Human resource	• Lack of staff having sufficient environmental knowledge and skills
System and culture	• Multi-task staff environment • Lack of management information system • Required to bridge a cultural gap in particular SMEs
Support	• Not sufficient information service about environmental problems and potential benefits by implementing environmental improvement • Lack of sector-specific support and guidance • Institutional weaknesses • Ineffective pathway of information to SMEs
Others	• Initiative fatigue/overload (related to lack of staff resources and unsuitable methods) • Unsuitable EMS tools for SMEs • Too complex or general management schemes for SMEs to handle • Lack of commitment from top management

In addition, IPP is a policy concept that takes a life cycle perspective and includes all relevant stakeholder viewpoints and considers the product development process from idea generation to product management and reverse logistics (Chater and Belmane 1999). Generally, existing approaches have focused on processes ('end of pipe' technologies and 'middle of pipe', e.g. Waste minimisation, cleaner production, and pollution prevention) (ibid). This approach limits environmental activities and scope of opportunities, thus it is hard to continue environmental improvement and adopt into usual business. In this respect, product and related issues are increasingly important in organisations' environmental activities. A wider scope of approach, as represented in IPP, is growing more from production and site focus environmental action broadening to market aspects and other perspectives by incorporating sustainable consumption and supply through ecoproduct and ecoproduct development.

In addition, shortcomings of existing tools such as EMEs and DfE can be evaluated. Industry has focused on developing practices, which are mainly oriented towards standardised EMSs such as ISO 14001 and EMAS. These existing tools that have been developed for large scale companies and are not suitable for SMEs and also product development in aspects such as cost, time and customisation character for sector-specification (cf. Gerstenfeld and Robert 2000, Holt *et al.* 2000, Kuhndt and von Geibler 2002, Pimenova and van der Vorst 2003). They do not adequately support environmental product development.

DfE has been developed to implement environmental improvement in the product development. However, drawbacks of DfE are addressed: pilot project characteristics and discontinuation of improvement; lack of managerial function to support strategic and organisational innovation; lack of approach to find potential environmental improvement on product life cycle; lack of affect to building up companies' capabilities and routine for environmental improvement.

Finally, in terms of difficulties and needs in SMEs' environmental improvement activities, it is significant to consider that flexible tools allows users to adjust them to different cases and functions to overcome the limitation of existing tools. Thus, this approach is the priority for efficient and continuous environmental innovation. In short, it seems urgent for management systems to encompass product and product development.

4. POEMS as an Integrated Solution

POEMS is an EMS with a special focus on the continuous improvement of a product's eco-efficiency (ecological and economic) along life cycle, through the systematic integration of ecodesign in the company's strategies and practices (Rocha and Brezet 1999). With this definition of POEMS, this research reviewed what elements are related to fulfil environmental development via POEMS work and what are the integrated factors and successful principles to implement POEMS.

In this section of research, eighteen representative studies (a-Ammenberg and Sundin 2004, b-Ammenberg and Sundin 2004, Baas 2002, Baumann et al. 2002, Brezet and Rocha 2001, Charter and Clark 2002, De Bakker 2002, De Bakker et al. 2002, De Graaf 2002, the Institute for Product Development (IPU) 2005, Klinkers et al. 1999, Pinkse and Graaf 2002, Rocha and Brezet 1999, Ries et al. 1999, Schmidt et al. 2001, Schmidt et al. 2002, UNEP 2004, Van Berkel et al. 1999) of POEMS based on theory and practices were examined and POEMS factors were analysed, categorised and prioritised.

One of the main findings is that continuation and routinisation are becoming important in an extended approach to the same extent as the following factors; coordination with existing (environmental) management or operation; integration with DfE activities; extended and product-focused supply chain management and cooperation internal and external. In the critical review of those studies, the following subjects are discussed: general procedure of POEMS work throughout life cycle process, product development process or management procedures; main principles; important requirements in-depth; merits and benefits of POEMS.

4.1 Review of POEMS models and main procedures

POEMS has different types of flow-processes or focus areas, in examined papers, depending on the application cases and approach backgrounds. Thus, collective processing was applied to take account of every potential and also it requires tailor-made approaches which can be adopted for use by small firms.

Each POEMS model features its own focus areas that are classified in this paper as follows: initial support; product management support; extended or integrated into EMS with product aspect; integrated into general management or sector-specific approach. However, they have similar profile of POEMS and many elements of POEMS are agreed as important ingredients. Following is brief description of each phase in POEMS procedures:

1. First step (preliminary stage): product profiling; review of organisational aspects; chain analysis; market review and position benchmarking
2. Second step (analysis of drivers): legislation review; suppliers and customers' requirements; other stakeholders' demands; market needs
3. Third stage: clarification of potential improvement on product and related areas, and the benefits for the firm and its customers and suppliers

4. Fourth step (planning phase): management/business strategies; POEMS and product policy/strategies; POEMS project objectives and targets; guidelines and requirements; formal procedures
5. Fifth step (allocation of resources): deployment of human, finance, technique and management; management level of commitment and support; initial involvement of staff; teamwork support and training
6. Sixth step (execution of POEMS project): generating and verifying alternatives, control product chain with sustainable purchasing, cleaner production, building up knowledge with supplementary data, and preparation of documentation and marketing plan
7. Seventh step (evaluation): defined objectives and targets; project and product development process; a level of achievement of outcome compared to initial ambition of the firm; legal compliance, requirements and performance of product; services and management systems; sources, collection methods and quality of data; appropriateness of tools and methods used; collaboration and communication; benefits of environment and costs; response of market and stakeholders.
8. Eighth step (routinisation and continuous improvement)

Table 3. Principles and requirements in a preliminary procedure of POEMS

Categories	Principles	Requirements
Preliminary work	Driver review	Legislations
		Stakeholders: customers, suppliers, environmental organisations
		Competitors and market opportunities
	Product profiling and potential opportunities	Legal compliance
		Environmental impact/ cost assessment
		Environmental benchmarking and position
	Review of organisational capability	Economical, technical, management capability
		Awareness, expertise support, staff qualification
		Communication and co-operation internal and external
Plan	Project plan 1: Managerial	Define and set up policy and strategies/ objectives and targets in business, project, product development
		Identify delineation of related criteria
		Establish procedures networked and systematic
		Prioritise strategies and activities
	Project plan 2: Operational	Allocation of resources (human, financial, technical), responsibilities and authorities
		Establish support for communication and co-operation internal and external
		Knowledge building (management, environment, supply, market)
		Check possibilities for integration of POEMS into existing system

	Project plan 3: Market and sales	Objectives & strategies of (green) marketing & sales	
		User & purchaser guidelines & directions	
		Environmental certificates	
	Project plan 4: Supply chain management	Sustainable purchasing plan/ guide	
		Define/ decide suppliers and their products	
		Plan for communication and co-operation	
Execution: POEMS & DfE implementation	Managerial aspects: Strategic management	Co-operation	Internal (project team, managerial & operational teams and whole department)
			External (suppliers, customers and other stakeholders etc.)
			Question guide for customer cooperation
		Communication	Share norms and values
			General: set up formal interface & tactical plan
			Internal (project team, managerial & operational teams and whole department)
			External (suppliers, customers and other stakeholders etc.)
			Internal dissemination of the pilot project results
			Record and answer external enquiries related product
		Ecodesign support and implementation	
	Operational aspects: Operational management	Trace options for improvement	
		Conducting a (small) feasibility study of the chosen alternatives	
		Making a selection of the best alternative for improvement	
	Product development	Develop and implement DfE concept	
		Search for alternatives (DfE requirements)	
		Green option validation	
	Production	Cleaner production (general)	
	Chain improvement	Education of customers and suppliers (if necessary)	
		Improvement of information management	
		Concern and support suppliers' declaration	
		Improvement of efficient communication and co-operation	
	Marketing	Market introduction	

		Ecodesign after sales plan (compose user or dealer instructions)
		Eco label
		Eco-marketing and sales plan
		Find additional market-related issues
	Knowledge building	Investigation and information in general
		Environmental information (LCA update etc)
		Market information
		Management aspect
		Technical aspects (capability: human, skill etc)
		Chain information
		Specific tests or methods of measurements
		Availability of information
		Collect supplementary data
	Documentation preparation	Define precondition of documentation
		Building up base for documentation flexible for various use, internal & external (e.g. designers or purchasers)
		Supply documentation for products' environmental impact and opportunities and use for product development
Evaluation	Monitoring/ review	Product, services and management system (product development process and results)
		Monitoring defined objectives and targets
		Check ecodesign (process)
		Monitoring criticism from stakeholders (customers, suppliers etc)
		Check between the environmental work and the level of ambition
		Check firms other activities (communication, collaboration etc)
	Audit/ evaluation	Evaluation of POEMS project (procedures, expertise, support etc)
		Evaluation of product (requirements, performance, legal compliance etc)
		Evaluation of internal & external communication
		Evaluation of environmental benefits (prevention/ reduction)
		Evaluation of cost effectiveness and benefits
		Evaluation of appropriateness of tools and method used
		Evaluation of data sources, data collection methods and data quality
		Evaluation of market response

Informational work	Documentation support	Basic product related information
		Co-operation with customers and suppliers
		Modification for various use of basic document
Routinisation/ continuous improvement	Routinisation (embedding, fixation)	Set up action plan and time frame for further actions
		Preparation for new POEMS project: integrate/coordinate new requirements with firm's management systems/ business strategy
		Control and routinisation of DfE
		Environmental improvement and market opportunities
	Continuation	Prioritisation of resources/ result feedback for new target
		Possible need for change to policy, objectives and other elements of the system
		Consistency of principles and procedures

4.3. Main principles and requirements in POEMS implementation

The above needs to be prioritised depending on an organisations' needs. This analysis clarifies the most important works of POEMS activities in order of their significance. The most important one from POEMS' principles and requirements is the product profiling which contains products' environmental impact/ cost assessment; environmental benchmarking and position of products and market; production assessment and others. This is aimed at identifying where environmental problems are created in product life cycle in association with the location of potential improvement. It might at times require Life Cycle Assessment (LCA) screening to identify in-depth information. Many of POEMS projects can get a brief profile without conducting a cost- and time-consuming LCA screening.

The second challenge is to investigate potential improvement based on product profiling information, and external demands such as legal or customer requirements. To what extent activities can be integrated into existing system, which is one of key issues enabling continuous improvement afterwards, should be considered in the planning stage. Allocation of resources and responsibilities is important as well as empowerment of the staff. The sixth step needs monitoring in each step of the process. It is helpful if there are tools or methods of measurement in the whole chain system. Evaluation and feedback must be measured in various aspects because it is not only an assessment of work done but also a start for further actions. Finally, routinisation and continuation of environmental improvement are as follows: integration of POEMS into existing management and systems, documentation; prioritisation of problems, opportunities and possible needs; setup of action plan for further work; consistency of principles and procedures.

5. Conclusion

Successful POEMS application enables not only environmental benefits but also potential opportunities that companies usually pursue in their business and operations. Benefits of POEMS project has been verified in previous works in particular small companies (c.f. a-Ammenberg and Sundin 2004, Brezet and Rocha 2001, the Institute for Product Development (IPU) 2005, Rocha and Brezet 1999, Schmidt *et al*. 2001). Environmental tools need to be flexible and easy to apply especially for small size of enterprises. POEMS supports relatively modifiable approaches to adjust for companies' own needs and level of ambition. In addition, POEMS system can be incorporated into business operations; its implementation is not hampered by major financial or organisational problems according to POEMS practices (Rocha and Brezet 1999). However, in the respect of the importance of product in environmental improvement, environmental information (collect and interpret related information) can be a key bottleneck for SMEs (a-Ammenberg and Sundin 2004). This may be the reason that POEMS principles particularly emphasise the product environmental profiling.

As this study is aimed at scrutinising the important action principles and detailed requirements, it may give SMEs a practical starting point to tackle the environmental action with product aspects. In particular, this approach can be tailor-made in accordance with organisation's own needs via prioritisation of principle areas and even requirements from different principles.

However, despite of the advantages of POEMS, various practices of POEMS need to be known by industry so that they may develop particular aspects of POEMS to adopt in an efficient way by integration into firms' existing system.

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