Supplier Involvement Strategies in Environmentally Friendly Product Development: Portfolio Approach

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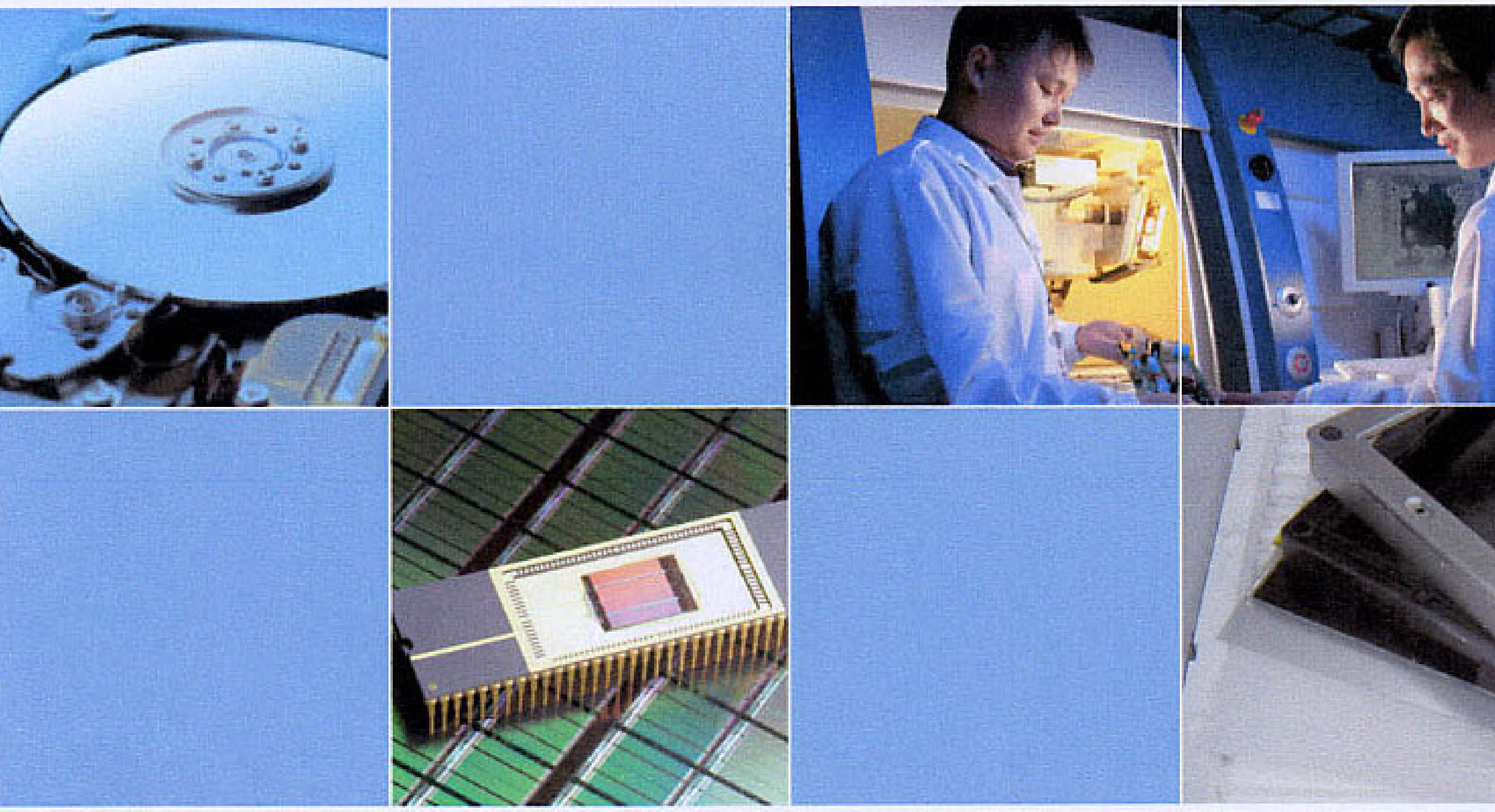

Supplier Involvement Strategies in Environmentally Friendly Product Development: Portfolio Approach

Strategieën om toeleveranciers te betrekken bij de ontwikkeling van milieuvriendelijke producten: Een portfolioaanpak

Thesis

to obtain the degree of doctor from the
Erasmus University Rotterdam
by command of the
rector magnificus

Prof.dr. S.W.J. Lamberts

and according to the decision of the Doctorate Board.

The public defence shall be held on
Thursday November 24, 2005 at 16.00 hours

by

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ISBN 89-91184-23-5

Acknowledgements

I would like to thank many people who have contributed to make this thesis possible. I am grateful to all of them.

First of all, I would like to thank Prof. Dr. Wim Hafkamp and Prof. Dr. Jan Jaap Bouma, who are my promoters. They have encouraged me to make most of my thesis, have challenged me to dig deeper into understanding my field by giving me the right support at the right time. My special thanks goes to Dean. Dr. Gun-Ho Cha of Hankook Aviation University, who introduced me this program in 1998; it was a privilege to work with you. I admire your enthusiastic and effective way of supervising.

I want to thank the members of the inner committee, Prof. Dr. F.H.A Janszen and Prof. Dr. A.L.N. Stevels for their valuable comments on the previous concept of this thesis. I also appreciate Prof. Dr. J.M. Cramer and Prof. Dr. G.I.J.M. Zwetsloot as members of the committee.

Heartfelt thanks are given to Prof. Dr. Leo Baas, for the arrangement of the Intensive Course Study, encouragement, and his prompt translation of the English Abstract into Dutch. I want to thank Prof. Dr. Ki-Hoon Lee, who works at Kwangwoon University, for his valuable support at the difficult moments to finalize the thesis. I also give my thanks to the faculty and staff of the Cleaner Product, Industrial Ecology and Sustainable Development Program.

Conducting doctoral research work is a very demanding process and I am very grateful for having completed successfully the Ph.D. with the full supports from my colleagues at the Samsung Global Environment Research Center (SGERC). The SGERC kindly provided me with financial support in part. Especially Dr. Jong Sik Park, the president of the SGERC gave me strong encouragement and emotional support during my whole Ph.D. process.

Lastly, but definitely not the least, I would like to thank my dear wife, Jung Hyun, who is probably the one who has suffered the most during the compilation of this thesis. I am indebted to you more than anyone. Also, my beloved children, Heeyeon, YoungJun, and my parents are my ultimate source of inspiration. I love you all.

Abstract

This study elaborates the portfolio matrix as a decision-making model for establishing supplier involvement strategies in environmentally friendly product development, based on the theoretical foundations of the supply chain management and ecodesign strategy.

This study: 1) identifies environmental requirements emerged in business management, understanding the present environmental challenges, 2) develops a model, providing a new insight into the strategy for involving suppliers in the development of environmentally friendly products, and 3) offers experimental evidence of the proposed portfolio matrix's feasibility, identifying the characteristics of the portfolio matrix. To test the feasibility of the portfolio matrix and answer the research question, empirical case studies of the development of 6 environmentally friendly products in K Electronics are applied.

In the results of the study, the portfolio matrix shows that the strategy for supplier involvement in environmentally friendly product development is not 'one-size-fit-all,' but dependent on the direction of environmentally friendly product development and the contribution of supplier input. These strategies would be used as a useful tool to support the decision-making process, which was defined as a core competence of a firm. This study also shows that the product characteristics and the supplier characteristics are differentiated by the supplier involvement strategies. By taking into account the power regime, moreover, this study could describe the diversity of the supplier involvement strategies according to the flow of values between the manufacturer and suppliers.

This study also demonstrates that more academic research is necessary to test and prove the applicability of the portfolio matrix model in other corporate cases in different industries and nations.

Korte weergave

Deze studie werkt de portfoliomatrix uit als een besluitvormingsmodel voor het instellen van strategieën om aanbieders bij de milieuvriendelijke productontwikkeling, gebaseerd op de theoretische fundering van aanbod-ketenbeheer en *ecodesign* strategie, te betrekken.

Deze studie: 1) identificeert milieueisen die aan het bedrijfsmanagement worden gesteld, en die als actuele milieu-uitdagingen worden begrepen, 2) ontwikkelt een model, dat voorziet in een nieuw inzicht in de strategie om aanbieders bij de ontwikkeling van milieuvriendelijke producten te betrekken, en 3) het experimentele bewijs dat zowel de geschiktheid van het voorgestelde portfoliomatrix biedt als de kenmerken van de portfoliomatrix identificeert. Om de geschiktheid van de portfoliomatrix te testen en de onderzoeksvraag te beantwoorden, zijn empirische casestudies van de ontwikkeling van 6 milieuvriendelijke producten in K Electronics uitgevoerd.

De portfolio matrix toont in de studieresultaten aan dat de strategie van aanbieders-betrokkenheid bij milieuvriendelijke productontwikkeling niet 'één maat past alles' is, maar afhankelijk is van de richting van milieuvriendelijke productontwikkeling en de aanbieders-bijdrage daarin. Deze strategieën zouden aangewend kunnen worden als een nuttig instrument om het besluitvormingsproces, dat gedefinieerd wordt als een kernbevoegdheid van een bedrijf, te ondersteunen. Deze studie toont ook aan dat de productkenmerken en de aanbiederskenmerken worden onderscheiden door de aanbieders-betrokkenheid- strategieën. Deze studie kon, door het machtsregime in beschouwing te nemen, des te beter de diversiteit van de aanbieders-betrokkenheid-strategieën als onderdeel van de waardestroom tussen de fabrikant en aanbieders beschrijven.

Deze studie laat ook zien dat meer academisch onderzoek noodzakelijk is om de toepassing van het portfolio-matrix-model te testen en te bewijzen met behulp van andere cases in verschillende industrieën en landen.

Table of Contents

List of Tables

List of Figures

Chapter 1:
Introduction

1. Introduction

1.1 Background and Problem Definition

The current economic growth in developed and developing countries entails high rates of consumption of natural resources that nature is unable to restore, and great amounts of residues that cannot be absorbed. A change in this situation is becoming more and more necessary for future generations. Industry plays an important role in the process of achieving a better balance with nature, but it is essential that manufacturing companies adopt new strategies and initiate new practices to reduce environmental impact (Hart, 1997; Shrivastava, 1995).

By reflecting the above business environment, firms are required to have ability rapidly to meet customers' needs and to be more competitive in the global world. In particular, increasing customer demands for higher products environmental performance, development of environmentally friendly products is one of the key factors for a firm to achieve green competitive advantage.

On the other hand, many corporations recognize that the optimization of internal value chains is not fully sufficient to satisfy the needs of customers, because:

1) The mass customization had to meet the needs of a variety of customers and consequently increased the complexity of logistics management. Such increased complexity lengthened the time taken to satisfy their customers' needs;
2) The unlimited competition in the global market has emphasized the necessity to concentrate on core competence of a corporation. With the increased need to eliminate inefficient processes involved in other sectors than the core competence, the outsourcing has attracted considerable attention.
3) The importance of efficient and effective management for outsourcing is increasing. Most of added values do not occur inside, but outside of manufacturing processes. In manufacturing industries, the time for product manufacturing is much less than

that for supply acquisition or product distribution. The increase in such time consumed for external processes lengthens the response time to customers and therefore lowers its competitive advantage. Contrary to price or quality, it is hard to copy the management of external processes, so that it is an important competitive strategy for a corporation;

These factors made corporations take an interest in their external value chain, and finally the environmental supply chain management emerged.

As such, many corporations have taken more interest in external value chains due to rapid change in management environment, and recognized that their competitiveness depends on not only their internal capability but also the whole supply chain. With this point of view, the environmental considerations in the supply chain are the environmental issues for a corporation, which require strategic decision-making. Therefore to achieve a competitive advantage and make more profit, a corporation should have environmental management strategies with not only internal processes but also supply chains that are comprehensively integrated with.

Recently, the core of environment management strategy is shifting from EOP (End of Pipe) management to environmentally friendly product development. Many experienced firms have already realized that the supplier involvement in product development is beneficial to the decrease in costs and time for product development and even to the improvements in quality of developed products. The supplier involvement in product development is to involve suppliers in the processes of product development from the decision of a product concept to the approval of developed products (Clark and Fujimoto, 1991; Weelwright and Clark, 1992; Ulrich, 1995; and Dussauge *et al*., 1996). Clark and Fujimoto (1991) reported that the supplier involvement in product development is a tool to reduce the lead time and to avoid high cost production processes, and that a firm can acquire most of their unique parts without increasing the engineering costs by having a strong relationship with suppliers with superior capabilities in part or product development. The supplier involvement in product planning, development, and design is in particular considered to be the source of potential business values (GEMI, 1999; Tischner *et al*., 2001).

As a result, better firms are involving their suppliers in the development of new products. This involvement naturally seems to have a range of forms, e.g. simple proposal of an idea in the design stage, share of full responsibility for part development, and design and engineering of a particular part or system, etc..

The fundamental idea of the supply involvement in product development is to environmentally differentiate the product and consequently achieve economic success in the long-term by involving suppliers in the early stages of product development such as planning and design, which covers over 80 percent of the total costs of the product life cycle and determines the environmental impact of the products (Tischner *et al*., 2001).

Steve *et al*. (1999) argue that companies must involve suppliers and purchasers to meet and even exceed the environmental expectations of their manufacturers. Green *et al*. (1996) also argue that companies are compelled to include suppliers if they want truly environmentally friendly practices for purchasing and materials management.

This involvement ranges from giving minor design suggestions to being responsible for the complete development, design and engineering of a specific part or sub-assembly (Wynstra and Pierick, 2000). Thus, the variety of supplier involvement caused a different level of collaborative relationship and contribution on the product development (Gullander *et al.,* 2001, Wynstra, 2001).

Wynstra and Pierick (1999) reported that the supplier involvement in product development does not always increase the effectiveness and efficiency of the development project, emphasizing the importance of differentiated supplier management. Dyer *et al*. (1996) said that it is important to take into account the supplier involvement in a strategic way; that is, the allocation of resources, e.g. the amounts of communication, administrative support, human resources assistance, and relationship specific investment, should be made depending on the relationship of a supplier. To involve suppliers in the product development effectively, therefore, it is necessary to develop product development strategies by taking into account differentiated supplier management.

However, most prior research has simply emphasized and focused on supplier involvement in environmentally friendly product development, regardless of the variety of supplier involvement. This dissertation argues that no one-size-fit-all strategy exists in supplier involvement in environmentally friendly product development

1.2 Research questions

The conventional theoretical approach in supplier management gives a limited insight on environmentally friendly product development without various type of supplier involvement. The core research question of this study is why and how differences occur in strategies for involving suppliers in the development of environmentally friendly products. This can be subdivided as follows:

What factors differentiate the strategies?;
How do the factors differentiate the strategies?;
What are the differences in the strategies?

1.3 Outline of the thesis

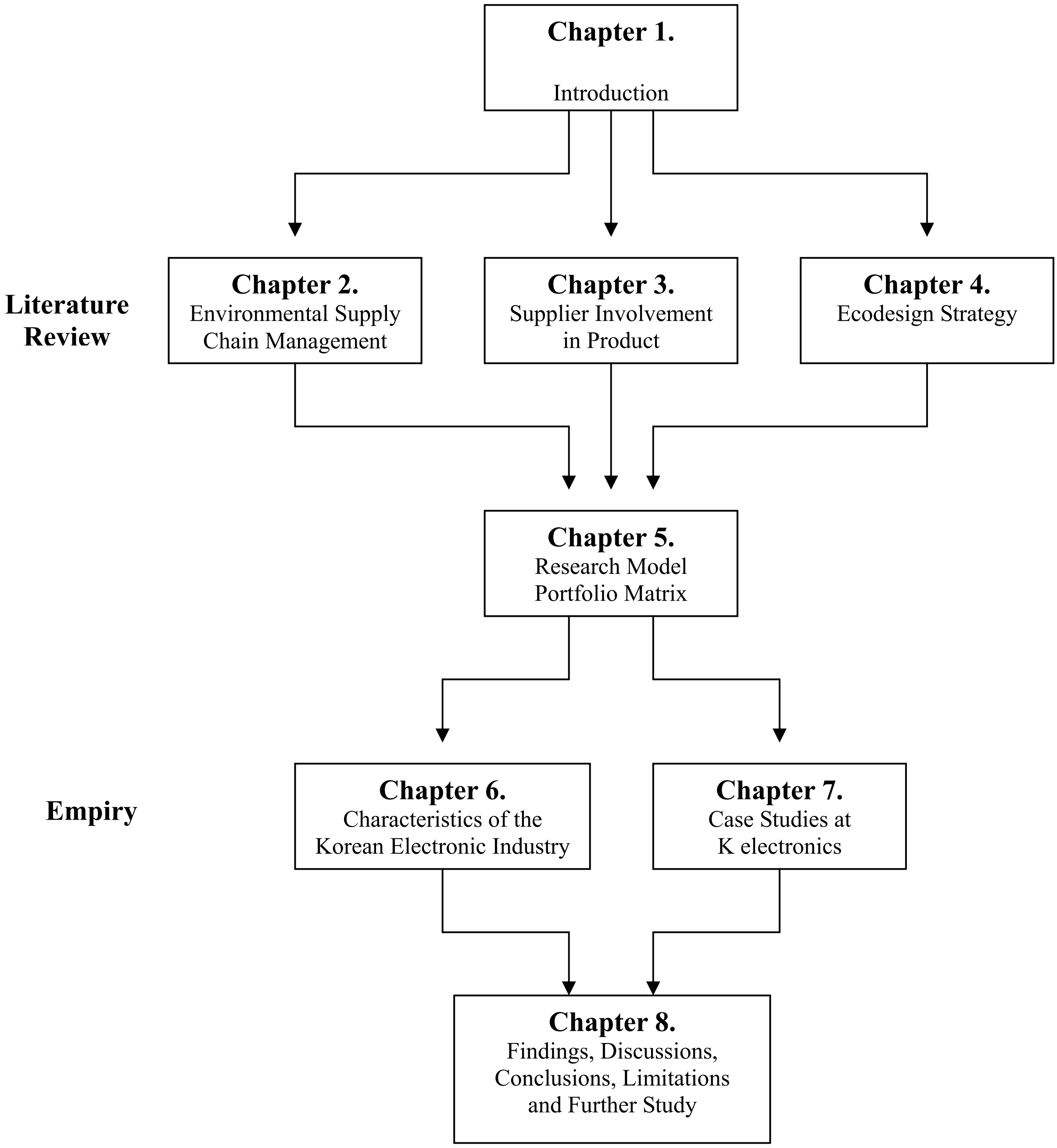
This thesis has two main folds. They are the literature review and the empirical part.

A literature review was started to find the factors that differentiate the strategies and derive a differentiated strategy. As there were a small number of studies on the development of environmentally friendly products in terms of the participation of suppliers, the literature review was only concentrated on the supply chain management and eco design strategy.

Having a deductive approach in this study, the literature review part is the critical starting point. The theoretical fields include supply chain management, transaction cost economics, strategic management, product development and design strategies. Based on the theoretical foundation through the literature review, a portfolio matrix of the strategies for developing environmentally friendly products was introduced. In order to examine the issue of study in product development as well as supplier involvement, the matrix model brings a usefulness to compare both environmentally friendly product development and supplier involvement. The model gives an analytical insight on how and why environmentally friendly products can be differently developed in a various way.

To test the feasibility of the matrix model, empirical case studies of the development of 6 environmentally friendly products in K Electronics were applied. Since the scope of empirical study is applied only to the Korean electronics industry, the case studies for in-depth research are chosen to answer the research questions. During the case studies, the cases were analyzed in terms of development management, supplier interface management, project management, and product management to identify the differences of the supplier management activities in the strategies.

Figure 1-1. The structure of the thesis



2. Methodology

2.1 Strategic management: Overview

Strategic management helps an organization decide its vision and operational goals, emphasizing the assessment of business environment changes and adaptation to risks and opportunities (Yin, 1994). Consequently, conventional research on the strategic management have focused on achieving the organizational goals under external limitations, developing technologies to sustain its value, or enhancing the accuracy of the information for strategic decision-making.

Business science is focused on helping a decision-maker make a systematic and objective examination (Zikmund, 1991). The most important managerial value of business science is thus to reduce uncertainty by providing necessary information for accurate decision-making in the development and performance of a strategy. In general, business science is defined as the systematic and objective collection, record, and analysis of the data for decision-making (Churchill, 1983; Zikmund, 1991).

In the business science, many researchers often know its questions. So, they are able to define them completely and answer them without additional preliminary investigations by designing the research so that a specific hypothesis is proved. Contrary to this, researchers or business managers may not recognize the characteristics of the research questions. In this case, an empirical research, based on empirical data, is used to obtain the insight into the questions.

From the viewpoint of the fundamental goal of research, business science seems to start with a series of grouping in a wide range, similar to other social science research (Selltiz *et al*., 1976; Zikmund, 1991). The objectives of this are to:

- obtain new insight or more precisely define the questions of the research and develop a hypothesis;
- describe the characteristics of specific individuals, situations, or groups with or without a specific hypothesis about them;
- determine the frequency of the occurrence of something, or of the relationship with another (typically, but not always, with a specific hypothesis);
- verify the hypothesis about the causal relationship between factors.

The research concerned with the first objective among the four above is called an exploratory study. As a preliminary step for other research, it is used to make a hypothesis by identifying the questions of, or finding relevant factors to, the study. It is ultimately intended to understand the characteristics and mechanism of the relationship between dependent and independent variables. Catching an idea or insight is very important in this study. Therefore, it should be designed so flexibly that other facets of the situations are fully taken into account.

Management in general has problems. In this type of study, however, it is necessary to understand more dimensions of the problems and to have helpful information for analyzing the environment and situations of the management. Finding decisive evidence to determine a specific course of action is not the objective of exploratory studies. Exploratory studies are typically concluded with an expectation that a follow-up study will be carried out (Selltiz *et al*., 1976; Zikmund, 1991).

The research under the second and third objectives among the four above is focused on accuracy. It is thus necessary to maximize the reliability of collected evidence and to minimize bias. This is called a descriptive study. The primary objective of descriptive study is to describe the characteristics of the population or the situations. In addition, they are used to identify the relationship among factors and to estimate their responses to the change in the situations. Identifying the situations and the relationships among factors are important in this type of study. Contrary to the exploratory studies, descriptive studies are based on the present understanding of the problems to be studied. As intended to obtain complete and precise information, the procedures of the study should be designed carefully, and economic characteristics should be considered (Selltiz *et al*., 1976; Zikmund, 1991).

The objective of the studies verifying a causal hypothesis is to understand the casual relationship with a factor or factors and to identify the cause and effect of a social situation. To reduce bias and enhance reliability, these studies require the following procedures that allow researchers to conclude the casual relationship. Experiments are in particular focused on the satisfaction of the latter. However, many studies verifying a hypothesis about the casual relationship are not carried out by experiments (Selltiz *et al*., 1976). Although it is difficult to find the casual relationship or an alternative in the complicated environment, most of scientific studies in business management have been intended to identify the ultimate relationship between cause and effect.

In fact, the three types of studies are not clearly divided. Any type of study has an element or element associated with two or more functions of other types of studies. However, their fundamental emphasis is typically placed on one of the functions. Although clearly defining the differences between other types of studies is not practically possible, it is at least helpful for designing a study (Lee, 1995).

Like other scientific requirements, business science is a series of activities that are highly interlinked. In other words, these activities do not follow a regulated routine, but are continuously overlapped. Moreover, business science often follows a generalized procedure (Zikmund, 1991): 1) problem definition; 2) study design; 3) sampling; 4) data collection; 5) analysis; 6) conclusion and report. These steps are chronologically overlapped and functionally interlinked. In this procedure, specific study strategies and data collection methods are determined after the type of study is designed. Each type of study has various study methods.

2.2 Study methods

This study has three objectives, which are compatible with the exploratory studies in Table 1-1. The first objective of this study is to identify environmental requirements emerged in business management, understanding the present (or contemporary) environmental challenges. The second is to develop a portfolio matrix, providing a new insight into the strategy for involving suppliers in the development of environmentally friendly products. The last is to offer experimental evidence of the proposed matrix's feasibility, identifying the characteristics of the portfolio matrix. Table 1-1 shows the objectives, strategies, and data collection/analysis methods of each type of study.

2.2.1 Conceptual Development

To identify environmental issues in business management, the first part of this study examined the background of today's environmental issues and approaches to environmental management by reviewing recent literature on management and environment, including environmental problems, strategic management, environmental supply chain management (ESCM), and eco design. Industrial and academic sectors have recently taken a lot of interest in the role of supplies in environmental management and the environmental values in supply chains. A lot of recent literature has also covered these topics. Moreover, these recent studies are characterized by increased sophistication, enhanced analysis technology, and improved procedures.

Table 1-1 Matching research type with strategy and technique

Type	Exploratory study	Descriptive study	Causal study
Objectives	-Understand hardly comprehensible situations -Have new insights into the situations -Identify or discover important factors-Make hypotheses for follow-up studies	-Describe causes of situations in question -Satisfy the network of causes -Document situations in question	-Set order of causal relationships or continuity of events -Measure effects of hypothesized causes -Identify causal factors
Strategies	-Literature review -Empirical survey -Study cases	-Vertical analysis -Horizontal analysis	-Experiment -Simulation
Data collection	-Participants observation -In-depth interview -Elite interview -Document analysis	-Participants observation -In-depth interview -Document analysis -Survey questionnaire	-Survey questionnaire (large scale sample)
Data analysis	-Interpretation -Insights classification -Charting	-Factor analysis -Difference in meaning -Multi-dimensional scaling	-Statistical test -Inter-factor correlation analysis -Multiple regression analysis -Simultaneous regression analysis
Target to understand	Insider's	Outsider's	Cause and effect

Source: adapted from Marshall and Rossman, 1989, p78, with additions from Selltiz *et al.,* 1976; Zikmund, 1991; Yin, 1994

The first step for increased recognition of environmental issues in the supply chain is usually to change the corporation's strategic actions and environmental performance. From this point of view, this study examined key environmental issues in business administration, which have contributed to environmental recognition. The environmental issues include environmental stakeholders, environmental problems, regulatory frameworks, and market condition changes. In relations to these issues, this study in particular discusses environmental supply chain management and environmentally friendly product development. The discussion was carried out through literature review.

The discussion was carried out through literature review. Most of the materials were those written in English and Korean mainly from various European countries and the United States. The main sources included books, academic or industrial journals, seminal materials, conference proceedings, articles, corporation publications, etc.

Internet and CDs were also searched to obtain the literature to be reviewed using computer catalogues (e.g. Samsung Economic Research Institute, National Association Purchasing Manager, etc.). Some materials obtained did not cover the latest study trends fully. So, the additional materials below were also used:

- Scientific journals and books on environmental management
- Papers from seminars and conferences including Environmental Management Network, forums, conferences (e.g. ERCP, GIN)

2.2.2. Model development

The primary objective of this study is to contribute to the theory development in environment management by developing a portfolio matrix for supplier involvement strategies in environmentally friendly products development. Ideas for this were obtained from the recent literature collected and reviewed, in particular about the development processes of environmentally friendly products, approaches to portfolios (see Chapter 5), and existing dimensional frameworks (see Chapter 2,3,4) for involving suppliers in product development. As a result, this study examined both key parts of the matrix: the direction of environmentally friendly product development and the contribution of supplier input. A comparison was also made between the existing dimensional frameworks. In addition, a conceptual model was elaborated to show the relationship between the two dimensions (see Chapter 5). Based on this conceptual framework, the portfolio matrix for involving suppliers in the development of environmentally friendly products was finally developed (see Chapter 5). The four different segments in the matrix were customized as the strategies for involving suppliers in environmentally friendly products development. And a case study was carried out to verify the feasibility of the proposed model by analyzing the cases of 6 kinds of products.

The portfolio matrix provides categorical frameworks for concept tests, which are typical means for different study procedures. It uses study procedures, that is, a series of stimuli is tested as a proxy for new/revised programs, products or services. Concept testing is a method to test an idea by providing an insight for the idea's merit based on the research and development, production, or reliance on other firms' resources. Therefore, the model proposed in this study can be a methodological tool for concept testing of business unit strategies.

2.2.3 Experimental analysis: a case study

The experimental analysis of this study was designed to prove the practical feasibility of the proposed portfolio and to identify strategic significance of its change. As a study strategy, this study used a methodology of case study. As shown in Table 1-1, social science research adopts a variety of strategies, and each of them has its own strengths and weaknesses. Decision making generally depends on the 3 conditions (Yin, 1994; Maanen, 1983): 1) study objective and type of questions; 2) size of the researcher's control of events; 3) level of concentration on the present against historical situations. According to Yin (1994), a case study is preferred when: the type of study is an exploratory study; the researcher is not able to control the events; and the focus is on the present situations. It is also preferred in case of qualitative data, which is simply understood with words or image analysis rather than figures.

This study used Korean electronic industries as the subject of the case study. As one of the leading industries in Korea, the entire Korean electronic industry has made a lot of effort to improve environmental performance and to develop a range of environmentally friendly products. There are two reasons in the backgrounds of casing the electronic industries in this study. First, the electronic industries are ideal to show the dynamics of environmental supply chains. The Korean electronic industries are so highly dependent of export that they are easily affected by international environmental regulations. In addition, competing in the global market, Korean major electronics have implemented proactive environmental management to reinforce their competitiveness. Consequently, most of the suppliers in the supply chain of the major electronics are pressured to improve their environmental performance.

Second, electronic industries are networked with many different types of suppliers. In the electronic industries, parts and components are supplied from many suppliers in a variety of industries and assembled into final electronic products. Electronic industries have a range and variety of products and processes, and have made a great effort in developing environmentally friendly products in order to respond to recent environmental challenges. This study examined representative products of four product groups: semiconductor; home appliances; information and communication; and media.

This study analyzed the products of K Electronics in Korea. K Electronics, with a variety of product groups, has responded to environmental challenges in a relatively positive direction. The reason that this study selected K Electronics was the possible access to experimental data. Most firms are reluctant to provide product-specific environmental information to researchers. However, I have worked for the corporation, and have a number of personal connections in the international network. That is why I could obtain a lot of support and assistance from many planning/environmental/business managers in the corporation.

To collect experimental data, literature review and in-depth interviews using a interview (see Appendix 7) were carried out. Although the interview is the most important data source in this study and is intended to collect objective data, it often results in incorrect outcomes due to inappropriate questions, respondents, recall or interpretation (Yin, 1994). To avoid these problems and bias in the interview, the materials sourced from outside K Electronics, and the questionnaire were revised to eliminate any possible inaccuracy. The corporation has published 'Green Management Best Practices' and 'Green Management Report' in 1995 and 1998, respectively. These publications were used to collect objective data. Analysis of the documents was carried out to: 1) understand the outline of the corporation; 2) identify strategic highlights, environmental practices, and product portfolio of the corporation.

In addition, multiple interviews were conducted with: 1) the planning manager in the headquarter and the product managers and the purchasing manager to identify the profiles of business groups and to select the products to be reviewed; 2) the environmental managers in the headquarter and business groups to investigate their environment management practices; 3) the product managers and the environment managers in the business groups to determine environment management performances of the products.

To achieve the objectives of this study, literature review was first carried out to review relevant literatures and conventional studies, and a case study was conducted to identify any methodological problems and to enhance the effectiveness of the study. Therefore, this study is an exploratory study composed of the literature research and the case study. The dimension of analysis and scope of this study is limited to the questions about the classification of type of strategy.

Part I. Literature Review Part

Chapter 2: Theoretical Basis of Environmental Supply Chain Management (ESCM)

1. Introduction

Klassen and McLaughlin (1996) defined the environmental management as "encompassing all efforts to minimize the negative environmental impact of the firm's products throughout their life cycle". Gupta (1995, p. 35) said that the environmental management system prevents adverse environmental effects and improves environmental performance by institutionalizing various environmental programs and practices such as initiating environment-related performance measures and developing green technologies, processes and products". Klassen and Angell (1998) reported that the environmental management policy is "the set of objectives, plans and management systems that determine manufacturing's position and responsiveness to environmental issues and regulation" (p. 185).

Facing an environmental issue, a corporation makes several strategic choices, and managers decide how to incorporate environmental considerations into their strategies (Banerjee, 2001). The introduction itself of environmental management is the subject of decision-making (Lee, 1997), and various practices for environmental management also need strategic decision-making. Based on the various studies (e.g. Banerjee, 2001; Klassen and Whyback, 1999; Sharma and Vrendenburg, 1998; De Ron, 1998; Zhang *et al*., 1997; Corbett and Wassenhove, 1997; Berry *et al*., 1993), Lee (2003) categorized the items to be decided to obtain environmental initiatives into 5 sectors (i.e. product; process; organization and system, supply chain and product take-back, and external relationship), and said that each sector requires different decision-making items (see Table 2-1). His categorization gave general overview on the current activities of environmental management; even current practical applications at industries are well matched with the category.

Table 2-1 The Issue of decision making in each sector

Sector	The Main Issue of Decision Making
Product	***Development and promotion of environmentally friendly products and technology*** - LCA or DfE is the most popular technology and practice to enhance environmental quality of products (Tischner *et al*., 2000; US EPA, 1999; Karna, 1998; Fiksel, 1996). - Environmental marketing is focused on customer public relations and environmentally friendly product development promotion.
Process	***Operation, manufacture, and production*** - Most of manufacturing processes include a range of steps from end-of-pipe clean up to recycled raw materials and closed loop operation. - Development of environmentally friendly processes and control technology is one of the important decision-making items (Klassen and Whybark, 1999; Zhang *et al*., 1997). - Cleaner production and pollution prevention has expanded to a range of industries. - Corporations focus their environmental activities on their employees (Banerjee, 2001).
Organization and System	***Organizational structure, performance/incentive system, and environmental education and training (Andersson and Basteman, 2000)*** - The focus of decision-making has recently been expanded from manufacturing to upstream/downstream of supply chains. - It is necessary to incorporate environmental issues into manufacturing processes by adopting an environmental management system like TQEM.
Supply chain / Product Take-Back	***Reduction of upstream/downstream environmental impacts*** - Environmental supply chain, product take-back and recycling, environmentally friendly distribution (Banerjee, 2001; Roome, 1998; Van Someren, 1995, Norwegian Ministry of Environment; 1995) - Regulations, e.g. EPR, WEEE, etc., created the necessity to strategic initiatives for product take-back (Berry *et al*., 1993; Berry and Rondimelli, 1998; De Ron, 1998).
External Relationship	***Cooperation with environmental organizations*** - Decision-making on creating and managing the partnership with external stakeholders become more important in environmental strategies (Hoffman, 1997; Van der Bosch and Van Riel, 1998; Denton, 1994; Azzone *et al.,* 1997 b; Ketola, 1993). - For example, environment prevention campaigns, partnership with NGOs, open information

To operate environmental management successfully, it is necessary to make an integrative approach, which is called ‘environmental management strategy,’ by incorporating environment-oriented perspectives into conventional management strategies. The integrative approach can be interpreted as the application of such perspectives to all the corporation strategies, business-unit strategies, and functional strategies. The reason for the necessity of environmental management by the integrative approach is that the change in environmental conditions significantly affects a corporation’s business activities and consequently, its decision-making.

Many firms recognize the necessity to incorporate their supply chains with the environmental management. For example, in order for a firm to respond to customers’ needs and to ensure its approach to the market in accordance with the regulations for hazardous materials, e.g. EU Directive of the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS), it has to understand environmental impacts of the parts and components supplied from its suppliers. In addition, the regulations for product take-back require it to expand its environmental responsibility to the entire life cycle of products. To respond to these requirements, firms have to incorporate the environmental supply chain management (ESCM) with their environmental management systems. This chapter describes the theoretical background of ESCM.

2. Studies on ESCM

Industrial and academic sectors have recently recognized the strategic importance of the cooperation or joint management between a manufacturer and its suppliers. Since the middle of 1980s, the importance of the relationship between a manufacturer and its suppliers and the enhancement of competitiveness in the market by efficient control of the relationship between them, not of their individual competitiveness, has been actively discussed. The discussion about the strategic network between firms was focused on the efforts to: eliminate overlapped indirect cost in transactions; improve flexibility in, or response to the market; and increase production efficiency (Ahn, 1999).

The most contributing early literature on the supply chain or strategic inter-firm network is 'Beyond Negotiation' by Carlisle and Parker (1989). It shifted the focus of transactions between firms from the dual theory (Nishiguchi, 1987), which is based on the difference in negotiation ability in conventional views, to the 'Win-Win' relationship. Such discussions have expanded, beyond the transaction between two firms, to a wide range of firms from manufacturers or suppliers of raw materials to those that deliver products to end users, and finally developed into the supply chain management (MacBeth *et al.*, 1989). Optimizing entire supply chain management activities has further emerged as a key issue (Hines, 1996).

Sako (1992) classified the inter-firm relationship strategies by comparing the relationship between manufacturers and suppliers in Japan and USA. Lamming (1993) has established the Lean Supply Model, in which he cased the automobile industries to show that the competitiveness of manufacturers and suppliers do not depend on their individual abilities or strategies, but on the establishment of reciprocal relationship between them.

Thackray (1986) found that there is a systematic vertical de-integration in the industries of automobiles, machinery, VCR, industrial robots, optical apparatus, and medical instruments. He reported that the management of a series of de-integrated chains has various forms, including the establishment of cooperative relationship based on official contracts, licenses, and trust. Special attention has been taken to the studies on the effect of the design and management of supply chains on the entire competitiveness of a firm or an inter-firm network (Campbell and Wilson, 1996).

Dyer (1994, 1996) has demonstrated that there is a positive relationship between asset specificity and manufacturing performance in automobile industries, in particular in Japan. He said the higher investment in the assets related to inter-firm relationships resulted in better production performance, in particular quality control and cooperative stock management. The asset specificity has been conventionally considered the most important factor to determine the transaction costs between firms. The concept of the transaction cost was later used, and regarded as the most important factor, to analyze the type of transaction between firms. The concept has also been used to reflect the characteristics of products and manufacturing processes in the studies on the design of optimal supply chains (see 4. Transaction cost economics).

In a study on strategic issues about the competitiveness of the network of firms, Harland (1995) showed that there is a certain relationship between the position of a firm in the supply chain and the information distortion, proposing the position in a supply chain as a new factor. As shown in Table 2-2, he modified the difference in products, processes, and other items by the positions in a supply chain, reported by Hayes and Wheelwright (1984), and applied them to the relationship between firms.

Table 2-2 Differences by the position of a firm in its supply chain

Category	Upstream	Downstream
Product	Relatively standardized	Relatively customized
Width of product line	Narrow	Wide
Time of continuous operation	Long	Short
Type of process	Automation, Continuous	Labor-intensive, non-continuous
Capital intensity in production	Relatively high	Relatively low
Break-even operation rate	Relatively high	Relatively low
Response to market depression	Lower price	Less production
Profit variability	High	Low

Source: Hayes R. H. and S. C. Wheelright (1984) Restoring our competitive edge: Competing through manufacturing, John Wiley & Sons, Inc

Compbell and Wilson (1995), showing important characteristics of the value-creating network, emphasized that it is necessary to expand the analysis unit from a single firm to a network of firms.

Stalk (1992) conducted a case study to present a series of evidences giving a logical background about the relationships between firms that allows using the knowledge of suppliers to enhance the competitiveness in the market. Many activities in the business processes of self-controlling firms are closely interlinked with the ability of each firm. From this point of view, Fine and Whitney (1996) showed that the processes of outsourcing decision-making itself could be a core competence of a firm, emphasizing the importance of determining which parts should be developed in the relationship between firms and which parts should be maintained in the firm.

Fine (1996) pointed out that it is necessary to apply the characteristics of industries in questions to the study on strategic aspects of the competitiveness of a firm, representing the concept of ‘industry clockspeed’. In a macroscopic view, a supply chain is composed of several firms in different industries, so that their characteristics are important factors that affect the structure and performance of the supply chain. The ‘industry clockspeed’ is divided into process technology, product technology, organization, and change speed.

With the recent emphasis on the importance of environment in managerial activities, ESCM has emerged as a key importance. Thus, studies on ESCM as an environmental management strategy have been recently carried out. Narasimhan and Carter (1998) reported that ESCM is the function related to purchase, including reduce, recycling, reuse, and raw material substitute. On the other hand, Zsidisin and Siferd (2001) defined ESCM as the initiative to set the supply chain policy, to take actions, and to make a relationship with relevant parties. The difference between these two studies is the viewpoint of environmental issues: Narasimhan and Carter limited environmental issues only to waste-related issues like reduction, recycling, and reuse, while Zsidisin and Siferd took into account environmental issues throughout the whole life cycle of products, emphasizing the relationship with relevant parties.

Zsidisin and Siferd (2000) represented 3R (reduce, reuse, recycle), link with quality, and control of supplier environmental activities as the themes of the functions affecting ESCM.

3R

General environmental approach to supply chain management is 3R (Carter and Carter, 1998; Carter and Ellram, 1998; Carter *et al*., 1998; Murphy *et al*., 1995). Resource reduction is "the minimization of waste which results in more efficient forward and reverse distribution proceses" (Carter and Ellram, 1998, p86). Reuse "is the use of a product or component part in its same form for the same use without re-manufacturing. Reuse may be considered as a form of source reduction" (Kopicki *et al*., 1993, p323). Recycling "is the process by which materials otherwise destined for disposal are collected, processed, and remanufactured into new products"(Kopicki *et al*., 1993, p323). Most of the studies on 3R were approached to strategic decision-making. Having a large responsibility for recycling strategies, ESCM should provide a guideline to the decision of the items to be recycled and allocate the responsibilities for collection, separation, and disposal of recycled items (Narashimhan *et al.,* 1998). Table 2-3 shows the activities for product design, process design, and technology acquisition (Sarkis, 1995).

Link with quality

Quality control is strongly linked with the environmental management in many aspects. It is because the improvement of product quality and durability results in the reduction of waste. The relationship between product quality and the environment can be expanded to the reduction of environmental impacts in all life cycles, aside from waste reduction. The design of products and processes is considered to have a key to reduce the environmental impacts of end products. In other words, it affects: the effectiveness of production processes; packaging processes; transportation; durability and reliability of products; disassembly; and other functions and performances. For the environmentally friendly design of products and processes, therefore, a corporation should integrate the ideas below:

design for ease of disassembly;
design for disposability that will not have a negative effect on the environment;
design to eliminate harmful processes in manufacturing;
design for ease of distribution and return;
elimination of many or all hazardous materials used;
design for durability and reliability;
design for customer success.

Table 2-3 ESCM Focal Areas for Design, Environmental and Cost Benefits

ESCM Focal Area	Design Activities	Environmental Benefits	Cost Benefits
Energy	- Use of more energy efficient parts and equipments - Miniaturization	- Less Energy used	- Lower bill of materials
Chemical Content	- Mono material - Elimination of flame retardants, heavy metals and hazardous materials (requirements under EU RoHS and WEEE)	- Better recyclability	- Volume discount - Lower bill of materials
Material	- Less material - Material substitution - Use of recycled material	- Less resources - Less environmental load - Closing the loop	- Lower bill of materials
End-of-life/ Recyclability	- Design for Disassembly	- Higher recycling yield	- Lower assembly cost

Source: Adapted from Stevels, 2001.

To make a quality initiative a success, it is important to have good communication about quality issues in the supply chain. Similarly, the communication for environmental purposes in the supply chain management is also necessary for the promotion of products, services, and equipment application, unless it makes a negative effect on the environment.

The supply chain strategy is also closely linked to the development of new products and processes and the joint activities of buyers and suppliers. The strategy for new product development decides a basic physical distribution in the supply chain, affecting the type of transaction inside and outside a firm. In particular, the strategy for product customization to satisfy customers' needs, including quality, price, time, environment, etc., significantly affects the supply chain management. Therefore, the product strategies play an important role in the design and management of structural and operational aspects of the supply chain, making a foundation of purchase strategies (Jahnukainen *et al.,* 1997). This indicates that the supply chain strategy should be developed according to long-term goals and strategies of a firm (Jahnukainen *et al.,* 1997, Carr *et al.,* 1999), and that it is necessary to develop the supply chain strategy based on the strategies described above before the key strategies for major suppliers are developed.

Control of supplier environmental activities

The relationship that can improve the environmental performance in a supply chain occurs from the exchanges between stakeholders including the government, suppliers, customers, competitors, etc (Carter and Ellam, 1998). The relationship between the stakeholders is a driving force for the supply chain to present environmental issues and problems in a proactive manner. There are many management technologies to improve environmental performance in the supply chain, e.g. ISO 14001, environment audits, environmental standards, and design specifications with environmental requirements (Noci, 1997; Lamming and Hampson, 1996; Zsidsin and Hendrick, 1998). What is important, however, is to view the environmental performance in a systematic viewpoint before adopting a specific management technology (Green *et al*., 1996).

The key to maintain a systematic viewpoint is open communication. The communication should be done with stakeholders inside a firm. Since products affect the environment in their entire life cycle, the supply chain management should take into account the whole life cycle of products and their actual effects on the environment (Carter and Carter, 1998; Klassen, 1993). The supply chain management should proactively respond to such issues as the selection and evaluation of suppliers, the development of suppliers, and the involvement of suppliers in environmental management practices (Walton *et al*., 1998).

Table 2-4 Integrated product and process development process

Stage	Tools and Methods	ESCM strategy
Concept development and product design	-Ecodesign -Life Cycle Assessment	-Simplified product structure purchasing -Substitutability of supplier provided material/ components
Process design	-Life Cycle Assessment -Environmental Risk Analysis	-Choice of process technology -Vertical integration through supply chain -Process waste from purchased materials
Fulfillment	-Statistic Process control -Environmental Performance Measurement	-Supplier process capability -Supplier process control -Supplier process performance and feedback
After/sales Service and Purchasing	-Environmental Information Management -Strategic Alliance with Key Supplier	-Post-sales customer feedback to suppliers -Recycling -Technical Assistance -Supplier Development

Source: Environmental Supply Chain Management, NAPM, 1998

If a transaction partner of a firm has an advantage in the supply chain but make less effort to improve the environmental performance, the cooperative efforts for the environment will be reduced (Walton *et al*., 1998). This is because the firm with an advantage in the supply chain is able to affect the environmental performance of its transaction partner. Therefore, it is required to take into account the power regime in the supply chain (see 5. Power balance in supply chain)

3. Core competence

Making more profit by achieving competitive advantage in the market should be the ultimate goal of a firm in a long-term view. Several researchers recently analyzed the success of firms in terms of the advantage of their resources (Pralahad and Hamel, 1990). Here, the resources should be considered as the sum of assets[1] and capability[2] of a firm (Day, 1994).

The capability necessary to achieve competitive advantage was conventionally thought to be inside a firm (Day, 1994). In other words, a firm had been thought to be a closed system in which the actions to control its resources and activities are taken inside. However, this recognition is changing. Recent various and strong competition in the market forced corporations to concentrate on their core competence and to outsource less important parts. Consequently, the concept of a firm has changed from a closed system, which controls its own activities and resources as a single unit, to an open system, which depends on external conditions.

Outsourcing includes the profit from increased economies of scale, the exploitation of product or service experts in the supply chain, the long- or short-term financial gains from resource sale, and the necessity of focusing on core competence (Behara *et al.,* 1995). Quinn (1992) reported that a buyer depends more on outsourcing when it needs larger flexibility or smaller product design or has the best supplier; in particular when it develops rapidly changing new technologies or highly complicated systems. He also said "Each supplier can (1) have a greater depth in knowledge about the design of its particular technologies and (2) support more specialized facilities to produce higher quality than the coordinating company could possibly achieve alone (Quinn, 1992, p48)".

With the increase in outsourcing, the relationship between firms is changing to a cooperative relationship. The increase in such a relationship is based on the cooperative and non-market transactions. Its emphasis is the capability to respond rapidly to the needs of customers, the consistency and quality in production, and the flexible time limit of delivery (Hall, 2000). This is based on the assumption that a firm cannot have the capability of making all of the resources necessary. In addition, it is difficult for a firm to independently

1) Superior assets and capability results in competitive advantage in the market and consequently increase in market share and profits. In this logic, a firm effectively accumulating the capability and resources, which are valued, not replaceable, and hardly copied, can achieve competitive advantage (Barney, 1991; Dierickx and Cool, 1989).
2) Even if many firms have similar human/physical resources, the methods and procedures of using them are significantly different, resulting in different performance. If the source of a firm's competitiveness is to be easily copied, it hardly achieves competitive advantage in the market. Therefore, the core competence of a firm should be based on the new development and improvement of products.

cover all of the value-creating activities that are necessary to produce a product due to today's rapid change and diversity in technology. Porter (1990) reported that most industry firms do not conduct all of the value-creating activities from product design to delivery to end-users. This is because firms specialize in particular areas, and each of them is a member of a large value system that develops and produces products. These indicate that firms depend on their external environment for their survival and resources (Hall, 2000). Therefore, a firm can be defined as a system that interchanges its resources with the external environment.

In relation to this, Hagg and Johansson said the modern firms thrive on their linkages with other firms, gaining sources of technology and other complementary assets. The competitiveness of a firm depends on not only its resources but also the capability of obtaining necessary resources from its supply chain. As a result, the success of a firm could be determined by the level of specialized knowledge and the capability of approaching external knowledge (Oslund, 1994).

The dependence of firms on each other and their conditions has been recognized since the late 1990s. Most of the dependence occurs from purchase decision-making (Hass, 1996). Wycherley (1999) reported that the supply chain management can play a more important role in the efforts to decrease environmental impacts of business activities. Linnanen and Halme (1996) supported this by pointing out that the range of interest is so open to cover a firm itself, i.e. not only production processes but also business system and strategies, as the point of view expands from products to the entire system.

However, every firm does not affect each other in their general environment like other organizations, but such mutual impact are intensively made between the members in the task environment. The task environment is composed of other firms that are related to a firm, i.e. competitors and firms in the supply chain (Boons, 1998). To understand how values are created in a firm, it is not sufficient to take into account only its internal position. Therefore, for the value creation and competitiveness, all processes should be analyzed and understood, in the supply chain (Porter, 1990).

Maintaining the competitiveness by outsourcing can be thought of as a dispersion of the risk of part department to suppliers (Quinn, 1992). Quinn said that a firm seems to maintain knowledge or advantage using its capability of changing suppliers if necessary. However, this advantage means a buyer-supplier relationship that is a bit different from a partnership or the lean supply model[3]. It is therefore necessary to separately take into account the

3) The Lean Supply Model was designed to appreciate and use the relationship network management, in particular supplier management, in the firms with competitive advantage in automobile industries (Lamming, 1993).

outsourcing for design activities. General discussion about this is made in 'make or buy' decision. However, it is very difficult to identify the pure knowledge and the relevant information. Elfring and Baven (1994) concluded that it is important to develop interfacing skills and reviewed the decision-making for knowledge intensive industries. They also reported that outsourcing knowledge intensive services were different from outsourcing components to manufacture products. Therefore, a firm that wants outsourcing needs not only strategic, interfacing skills but also the capability of controlling the transaction relationship.

4. Transaction cost economics

The transaction costs are those to overcome or avoid the problems related to the intention or behaviors of a transaction partner under incomplete information, which are necessary to search for an appropriate transaction partner, to make a negotiation and contract with the partner, and to watch the performance of the contract (Kim, 1998). The transaction costs, therefore, are high in cases of: bounded rationality of transaction parties; complexity and uncertainty of organizational environment; and opportunistic behaviors.

The focus of the transaction cost economics requires that the transaction relationship between firms should be made so that the transaction cost is minimized. The reason that the transaction cost economics is important in the supply chain studies (although it started from an economic background) is that what is most important in the supply chain competitiveness is the achievement of economies of networking through transactions between firms and the basic unit for the achievement is the optimization of the transactions. The costs related to the decision of an optimal type of transaction between firms include production costs, transaction costs, operating costs, and sunk costs. The type of transaction should be decided so that the sum of these costs is minimized. The production costs are used for the preparation and processes of production, while the sunk costs are in particular related to investment. Higher sunk costs also raise the cost to leave the existing transaction relationships, so that it affects the integration of the transaction relationships. The costs, except the two costs described before in the product production, are called operating costs, and are significantly affected by the characteristics of the business and the technologies related to products and processes.

Williamson (1975, 1985, 1981) and Grossman and Hart (1986), pioneers of the transaction cost economics, supposed that a contract between firms is always incomplete in this complicated reality. Due to such an incompleteness of a contract, firms that invest in relationship specific assets have a risk of being deprived of the profits from the relationship specific assets. In this case, one of the methods to obtain the profits is a vertical integration of transaction parties. That is, any hostile behaviors to obtain profits are eliminated by integrating the transaction parties. An alternative that is a less extreme method than the integration is a reciprocal buying agreement. In the agreement, each transaction party exchanges hostages and makes a partial ownership agreement to minimize its opportunistic behaviors and to specify the range of its profit. For the governance structure of a transaction relationship, the transaction costs economics provides a logical background to view the feasibility and characteristics of the governance structure at the viewpoint of transaction costs. The focus of the transaction costs economics is on the presentation of how to maximize the effect of the investment in relationship to specific assets.

The dimensions that cause the diversity of the types of transactions between firms are divided into 4 categories: 1) the necessity of relationship specific assets may change the type of transaction; 2) the transaction conditions in the future and the level of uncertainty of the partner's behaviors affect the type of transaction; 3) the complexity of contracts between firms also affects the type of transaction; 4) the frequency of transactions between firms influences the type of transaction. Although these four factors affect the governance structure of a transaction between firms, conventional studies point out that the relationship specific assets are the most important factor. Williamson (1985) defined asset specificity as "durable investments that are undertaken in support of particular transactions, the opportunity cost of which investments is much lower in best alternative users or by alternative users should the original transaction be prematurely terminated". The relationship specific assets include specialized physical assets, human assets, and knowledge about, or abilities for, specific firms.

According to the transaction costs economics, the type of transaction between firms is a series of continuum. One end of the continuum is a pure market structure, that is, a simple transaction of standardized commodity. In this pure market structure, price is the strongest tool in the aspect of a transaction motive, and a criterion for continuity or interruption of transactions. If the relationship specific assets are required or an alternative market to the products of a supplier is narrow, it is desirable to adjust mutual investment and effective to own jointly the transaction assets. Another end of the continuum is a vertical integration or a hierarchy structure. This kind of transaction with which ownership is integrated is suitable for preventing a transaction partner from doing opportunistic behaviors and adjusting decision-makings between organizations. In this hierarchy structure, the motive of profit maximization of a transaction partner is reduced, while bureaucratic costs are generally necessary (Milgrom and Roberts, 1990). Between the two ends of the continuum, there are several intermediate transaction relationships, including various forms of contracts, partial ownership contracts, etc.

This section describes the variation of transaction costs according to the types of transactions between firms. First, the operating costs decreases as the level of integration of transactions between firms increases. If a transaction partner is fixed, the knowledge and reliability of the partner are increase, so that the costs of negotiation or decision-making or those of audits significantly decrease. The costs of production also get lower with the integration of transactions. Closer cooperation between transaction firms results in a synergy effect, consequently improving the productivity of both. In addition, the extension and stabilization of the transaction relationship make a learning effect and positively affect the transaction conditions. The sunk costs in transactions increase with the integration. To achieve the higher level of integration and integrated management, corresponding investment is necessary. The sunk costs in production also increase with the integration.

This is because higher level of integration of the transactions increases the relation specific investment in the transaction partner, including costs of equipment or human resources. This indicates that there is a trade-off between operating costs and sunk costs. The operating costs are mainly linked with the easiness or efficiency of transaction relationship management. As the level of the integration increases, the operating costs in case of transactions between organizations in a firm is generally lower than those between two different firms. In case of the sunk costs related in transactions, however, those in a hierarchy structure are much higher than those in a pure market structure. In theory, the total cost curve is concave down when these relationships are made, and the minimization of the total costs is achieved by reaching the level of transaction integration corresponding to the point of intersection of the curves of the operating costs and the sunk costs. Except for the operating costs in production, however, it is hard to accurately measure the costs, and subjective opinions of the transaction parties are easily included. Therefore, it is necessary to view the optimal relationships between firms as a long-term and continuous adjustment process, not a static optimization.

The concept of the transaction costs economics is logically clear. As described before, however, it has many limitations in an empirical study. To apply the transaction costs economics to the determination of the types and management of transactions between firms, we should use an empirical study to develop practical criteria for important factors of the transaction costs economics (Klein and Shelanski, 1994). The most complicated part in the development of the criteria would be the method of dealing with the uncertainty of transaction conditions that affect the integration of transactions between firms. However most of the empirical models are unable to reflect the critical variables of the transaction cost economies such as asset specificity that deal with transaction uncertainties. Such results of practical studies consider uncertain factors in an insignificant manner, which lead to a rather negative perspective in actually applying the transaction cost economies (Dyer, 1994).

The transaction costs economics employed an economic background to analyze the types of transactions between firms using the principle of cost optimization. Since the main elements of competition in the recent market include quality, flexibility, time based competition, and the environment, it is thought that it is impossible to use the transaction costs economics to decide the type of transaction between firms although it provides a starting point for discussion.

5. Power balance in the supply chain

To improve environmental performance in the supply chain, it is more important to understand how to manage the connection between the upstream and downstream of the supply chain. The firms in the upstream of the product chain identify the demands of those in the downstream and their direction to reflect them in their operation. In this case an important factor is the position in the supply chain of the firms in the lowest downstream of the product chain; in particular the advantage in negotiation with other firms in the supply chain. The firms in the supply chain can be divided, according to their advantage in negotiation, into leading or key firms that design the whole strategies and other firms that concentrate on their own specialized parts.

In conventional supply chain management, a buyer, with the advantage of negotiation, supported their suppliers to lead them in its direction. However, this process is not applicable if suppliers have the advantage of negotiation. Therefore, copying the conventional supply chain management has a high risk of failure. To establish a successful supply chain management, it is necessary to understand that the relationship between firms in the supply chain depends on the conditions of the firms and the characteristics of products and industries and to exactly identify the current situations of the firms (Cox *et al.*, 2001).

Cox *et al.* (2001) introduced an approach to identify a key player by the negotiation abilities of the firms in a supply chain. They reported that the numbers of buyers and suppliers determine the relationship between them. According to their report, there are many suppliers when the number of buyers is small, and buyers have an absolute advantage over suppliers when the amount of purchases have a large percentage in the total sales of suppliers. This study result is identical with that of Ailawadi *et al*. (1995), that is, an exclusive business right gives a firm an advantage over its transaction partner. Other factors determining the price include the costs for a buyer to find a new supplier or those for a supplier to find a new buyer and the characteristics of supplies, e.g. standardization, innovation, product life cycle, and information asymmetry[4]. On the other hand, French and Raven (1959) represented the sources of power that a member in a society has over others, as shown in Table 2-5.

4) Information asymmetry means the possession of important information that is not identified by a transaction partner.

Table 2-5 Sources of power

Sources of power	Description
Reward	Where Entity B has the perception that Entity A has the ability to mediate rewards for him/her.
Coercive	Where Entity B has the perception that Entity A has the ability to mediate punishment for him/her.
Expert	Where Entity B has the perception that Entity A has some special knowledge or expertise.
Referent	Where Entity B identifies with Entity A.
Legitimate	Where Entity B has the perception that Entity A has legitimate right to prescribe behavior for him/her.

Source: Jeremy Hall, Environmental supply chain dynamics, Journal of cleaner production 8 (2000) 455-471

Depending on the situations of the firms in a supply chain, the relationship between them is divided into 4 categories, as shown in Figure 2-1 and below (Cox, 2001):

Buyer dominance: A buyer has an advantage in negotiation over a supplier, so that it takes dominance.

Interdependence: A buyer and a supplier depend on each other, so that they make a strong relationship to exchange their resources.

Independence: The market has many buyers and suppliers, so that transactions are determined by the prices and quality in the market. In general, buyers take a little higher dominance.

Supplier dominance: A supplier has an advantage in negotiation over a buyer, so that it takes dominance. There is an entry barrier in the supply market.

Figure 2-1 Decision factors for buyer-supplier relationship

Buyer dominance	Interdependence
-A few buyers /many suppliers -Supplier largely depends on buyers in sales. -The cost for a supplier to find a new buyer is high. -Supplies are commodity or standardized products. -Suppliers do not have information asymmetry.	-A few supplier/many suppliers -Supplier largely depends on buyers in sales. -The cost of a supplier or buyer to find a new transaction partner is high. -Supplies are not commodity or standardized products. -Suppliers have information asymmetry.
Independence	**Supplier dominance**
-Many buyers/many suppliers -Suppliers do not depend on buyers in sales. -The cost of a supplier or buyer to find a new transaction partner is low. -Supplies are commodity or standardized products. - Suppliers have information asymmetry.	-Many buyers/a few suppliers -Suppliers do not depend on buyers in sales at all, and have many alternatives. -The cost for a supplier to find a new buyer is low, which that for a buyer to find a new supplier is high. -Supplies are not commodity or standardized products. -Suppliers do not have very high information asymmetry.

Source : Andrew Cox, op.cit

Based on the division, Cox *et al*. (2001) determined the dominance between firms in a supply chain, and identified a key player that has the largest power in the supply chain. The key player, with the largest dominance over the firms in the supply chain, is able to lead other participants in their intended direction. Depending on the characteristics of the supply chain, they may be several key players. Cox *et al*. (2001) found that a buyer is a key player in the dependence or buyer dominance relationship; a supplier is a key player in the supplier dominance relationship; and both are key players in the interdependence relationship, and that there were many key players in the whole supply chain.

Cox *et al*. (2001) identified the flow of physical assets and that of values, in the supply chain. They defined the relationship network of power as power regime, and found that the relationships between network members are not identical and recognized values are not equally distributed. According to their results, values flow to the dominant side in the relationship, and it is impossible to create an effective, integrated supply chain in the power regime that includes a member that can interrupt the flow of values in the supply chain. They reported that such a case occurs when the relationship is thought independent or suppliers dominate the buyer-supplier relationship. They also said that the integrated supply chain could only be created when the buyer-supplier relationship is dependent or the dominant buyer is close to end customers and just assemble final products. Their study is contrary to the belief that the integration of supply chain activities is generally facilitated by the integration of the members in the supply chain.

The importance of suppliers in supply chains has been also emphasized in many other studies. Imrie and Morris[5] (1992) reported that suppliers had drawn the cooperative relationship in supply chains. Gules and Burgess (1996) said that the cooperative relationship in supply chain could not result in the balance of power. Lyons *et al*. (1990) also found that suppliers had more power in supply chains.

The dominance of suppliers has an important implication in ESCM. In the studies described before, it was found that many suppliers do not have the same type or level of pressure as buyers, so that they have less incentive to participate in environmental innovation. It was also found that large-sized buyers were forced to involve their suppliers in their environmental innovation initiatives. This indicates that it is necessary to shift from exploiting the firms in the supply chain to pursuing win-win scenarios (Hall, 2000).

5) Imrie and Morris also reported that there is an evangelical flavor to the literature on buyer-supplier relation and those on the relationship between businesses and the environment.

6. Types and characteristics of buyer-supplier relationships

In a conventional viewpoint, the decision-making of purchase was mostly affected by the price, and most of the buyer-supplier relationships were transaction-oriented relationships. These were interpreted as hostile relationships, i.e. zero-sum game, where a buyer or supplier should suffer a loss. In this type of relationship, firms concentrate their efforts on optimizing short-term values (Janda *et al*., 2002).

For the last 10 years, the relationship with suppliers has been converted from the transaction-based relationship to a long-term and collaborative relationship (Heide, 1994). In particular the change in management environment, including concentration on key competence, increased competition and uncertainty, and dispersion of just-in-time principle, converted the relationship with suppliers to collaborative relationship. Moreover, increased factors to decide, such as quality, delivery, environment, etc., have forced firms to recognize the importance of strategic aspects of purchasing and supplier management. This type of relationship is intended to maximize the value of buyers and suppliers (Carr *et al*., 1999; Janda *et al*., 2002). Janda *et al*. (2002) reported that this type of relationship was featured by strong cooperation and consistent joint projects between buyers and suppliers. Carr *et al*. (1999) pointed out that firms which incorporate purchasing into strategic planning processes seemed to pursue collaborative relationship with supplies. Mansio (2002) defined the strategic supplier partnership as a collaborative relationship to achieve the strategic plans of both buyers and suppliers.

Suppliers can be classified according to the relationship with a buyer. However, it seems to be impractical to define the buyer-supplier relationship or the type of supplier (Mansio, 2002). The buyer-supplier relationship can be divided as shown in Table 2-6 according to the length of cooperation, emphasized aspects, objectives and type of relationship, and characteristics of input (Carr *et al.,* 1999; Halley *et al.,* 2002; Janda *et al.,* 2002; Dyer, 1996). Combining the arm's length relationship and collaborative relationship at the extremes of the buyer-supplier relationship continuum with the elements for each approach creates different types of intermediate forms (Axelsson and Wynstra, 2002). This kind of relationship is necessary for firms, but created for non-strategic input. Contrary to the arm's length relationship, in this relationship two or three selected suppliers are selected as long-term contractors and specific investment is made between buyers and suppliers to reduce the cost and time of transaction (Dyer *et al*., 1999).

Dyer *et al*. (1999) suggested the background of the creation of this type of relationship as follows:

1) Managing many vendors typically increases administrative or transactional costs (Hannaford, 1983);
2) Purchasing from many suppliers lowers the capability of suppliers to achieve economy of scale (Dyer & Ouchi, 1993). Moreover, it is not clear for buyers to get an advantage of larger bargaining power;
3) Two or three suppliers can make strong competition as long as they equally compete with each other and are technically controlled.

Halley *et al*. (2002) divided suppliers into regular suppliers, specialized suppliers or tactical partners, and strategic or preferred suppliers. Regular suppliers are located at the side of transaction on the buyer-supplier relationship continuum. They usually make short-term contracts by which they provide items of lower priority and subcontract their capability. As long as ultimate requirements are met, competition is based on price (Halley *et al.,* 2002).

Table 2-6 Types of suppliers

	Regular	Tactical/Specialized	Strategic/Preferred
Length of cooperation	Short term	Medium term	Long term
Emphasized Aspects	Price and performance	Price reduction and quality development	Significant contribution to joint processes; JIT, TQM
Objectives of the Relationship	Maximize own value through competition between the suppliers	Increase cooperation based on Success, perhaps move towards Strategic relationship	Long term strategic benefits aligned with the corporate strategy
Characteristics of input	Commodity	Non-strategic but necessary input	Strategic input
Type of the relationship	Transactional/adversarial	⟷	Cooperative/relational

Source: Tomi Mansio, Strategic partnerships with supplier

Specialized suppliers are located at the center of the buyer-supplier relationship continuum, and depend on specific conditions of the relationship. Specialized suppliers or tactical partners make a specialty of design of specific products. It is easier to reduce the costs through cooperative quality development with them (Halley, 2002). Strategic or preferred suppliers, which are located at the side of cooperation on the buyer-supplier relationship continuum, develop their operation by cooperating, and make long-term contracts, with buyers (Halley, 2002). What is emphasized in the transaction with these suppliers is the importance of the contribution to joint projects. In literature, the term, key supplier, was widely used. Carr *et al*. (1999, p498) defined the key supplier as those that are very important for buyers in terms of the amount or rarity of their supplies.

Table 2-7 Spectrum of supplier integration

Supplier responsibility	Spectrum of supplier integration
None	The supplier is not involved in design. Materials and subassemblies are supplied according to customer specifications and design
White box	The level of integration is informal. The buyer "consults" with the supplier informally when designing products and specifications, although there is no formal collaboration
Gray box	It represents formal supplier integration. Collaborative teams are formed between the buyer and supplier's engineers, and joint development occurs.
Black box	The buyer gives the supplier a set of interface requirements and the supplier independently designs and develops the required component.

Source: David *et al*., Designing and managing the supply chain, 2000 (p 190)

Table 2-8 Levels of suppliers

Classification	Characteristics		
	General	Environment Management	Relation ship
Level 1: Spot Purchasing	There is little or no relationship with, or knowledge, of the supplier. Price is the key determinant of purchase. To the extent that quality is important, it is assessed, based on predictable product characteristics or supplier reputation alone. Each transaction is its own business contract. Commodity items and pencils are often purchased on the spot market.	To control EHS impacts, change products or product specs.	Arm's length
Level 2: Competitively Based Incumbent Relationships (CBIR)	Suppliers have a long-term business relationship, typically an annual contract against which purchase orders are issued. Contracts are renewed annually. Your business is theirs to lose. Relatively little technical cooperation is invested in these short-term relationships, because a better supplier may be located the next year.	To control EHS impacts, change specs for the annual bid, and let the world know you are always looking for suppliers who can better meet these specs.	
Level 3: Preferred Supplier	The intention is for a long-term relationship that requires and benefits from fairly frequent communication and collaboration to improve or adjust supplier inputs over time.	To control EHS impacts, include EHS issues in the periodic visits and meetings where progress and quality are discussed, and targets may be set.	Collab-orative
Level 4: Strategic Partnerships or Alliances	Relationships involve an even deeper level of commitment. Typically, there is an explicit or implicit understanding that supplier and buyer will share the business benefits of effective collaboration.	To influence EHS impacts, add EHS to the agenda of problems the partnership must address. Write contracts so that the business value of better EHS performance is shared among the partners.	

Source: GEMI, New paths to business value, 2001 (p35)

Monczka *et al*. (1997) suggested a concept of supplier integration spectrum. In particular they found a continuum of responsibility of suppliers from the smallest to the largest. Of course, approach to the black box does not mean the best approach. Therefore, firms have to develop a strategy that helps determine the appropriate level of supplier involvement.

GEMI (2001) recommended suppliers exposed to a certain risk due to the products or services they supplied or those of which environmental management performance is closely related to the productivity, quickness, and reputation of buyers. They should be carefully treated, and divide the level of suppliers according to dependence and relationship with buyers as shown in Table 2-8.

In particular, this classification implies the characteristics of each supplier's EHS management. As a firm takes into account the environment, the number of suppliers with which collaborative relationship should be maintained is larger. In this relationship, buyers typically depend on the level 3 and 4.

Since relationships with suppliers are treated in various ways, it is important for buyers to be able to control the various relationships (Bensaou, 1999; Spekman *et al*., 1999). Dyer *et al*. also reported that the classification of the buyer-supplier relationship is determined by the analysis of supplies and the dependence between buyers and suppliers. This diversity of the buyer-supplier relationships results from different collaborative relationships with suppliers (Gullander *et al*., 2001) and different contribution of suppliers to the product development (van Echtelt and Wynstra, 2001). Cousins (2002) reported that the buyer-supplier relationship be a progressive process and suppliers be assessed by their products or services. In other words, firms should approach different buyer-supplier relationships in different ways to allocate their resources effectively and efficiently.

In conclusion, firms should classify the relationship with suppliers in order to allocate their resources in an effective and efficient way. Since many firms have limited resources, they should be allocated to the suppliers in a collaborative relationship. However, buyers do not need to allocate important resources to other suppliers.

Suppliers that do not provide non-strategic input (i.e. do not contribute differential advantage to final products of buyers) do not need the same interest and resources as others in a collaborative relationship. Like a strategic partnership, however, a long-term relationship is developed to minimize purchasing costs and to achieve economy of scale. For this kind of supplier, buyers should make an effort to minimize the entire purchasing costs including unit costs and administrative costs.

7. Supply chain strategies and the environment

Many researchers have recognized the interconnection between environmental issues and supply chains (Lamming and Hampson, 1996; Hampson and Johnson, 1996; Florida, 1996; Hill, 1997). In particular, this recognition was expanded to the importance of life cycle considerations accordingly as the center of environmental management shifted from processes to products. The recent environmental issues even have a strategic connection with supply chain management (Hampson and Johnson, 1996).

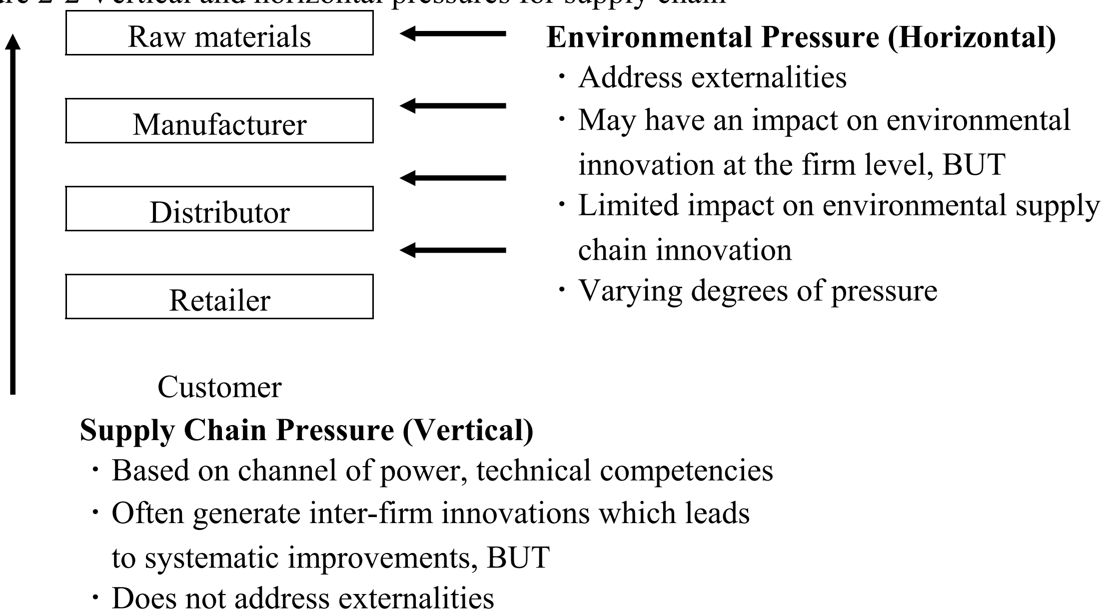
A close relationship between each member in a supply chain accelerates the creation of new opportunities for better economic and environmental performance (Florida, 1996). New *et al*. (1997) reported that not a partial but a complete approach in supply chain management would make a profit in the implementation of environmental management. This is, in particular, important in the industries, that the supply chain is a part of a competitive advantage, e.g. electronic and automobile industries. Steve *et al*.(1999) asserted that firms should involve suppliers in their efforts to meet environmental requirements. Their assertion agreed with the study results of Noci (1997) who pointed out that the supply chain management is the first step of green management and recommended specifying the environment management strategies, identifying environmental performance index of suppliers, and selecting official suppliers. Green *et al*. (1996) emphasized that the environmental supply chain management (ESCM) was an important and useful tool to convert the industry itself to raise environmental issues. They also asserted that the increase of the interest in environmental supply chain was resulted from the increased recognition of environmental issues, e.g. strategic importance of purchase, and stronger cooperation or partnership between buyers and suppliers, and that buyers should force suppliers to participate in their efforts for driving green purchasing and using environmentally friendly materials use. The UK Round Table on Sustainable Development (1997) advised "All organizations - but especially large companies and public sector organization – should use procurement as a way of encouraging those in the supply chain to improve environment performance".

Hall (2000) reported that even though not profitable to all members in a supply chain, closer relationships with them would provide common efficiency improving the whole system. He also asserted that the type of relationship would play a role of the signaling mechanism for supply chain change as in the dispersion of quality management. This agreed with the assertion of Green *et al*. (1996) who found that the firms with well-developed supplier assessment systems were able to integrate environmental factors well and preferred the suppliers with environmentally friendly products and processes.

Lamming and Hampson (1996) also asserted that the cooperative approach would help suppliers to understand environmental impacts of the supply chain, i.e. improve general performance of suppliers, and would result in potentially cost-effective solutions. They warned that the supply chain management would suggest potential environmental improvement, but too long of a supply chain would make it impossible because it would deteriorate the effectiveness of environmental pressure. They also questioned whether firms had enough power to apply pressure to the distant members of the supply chain. New *et al.* pointed out that there were many cases where proactive cooperative purchasing was impossible and that unselected suppliers used high costs and made risky efforts.

Figure 2-2 shows the summary of theoretical issues in these studies. One of them is the vertical pressure based on technical competition. This kind of pressure results in systematic improvement but does not treat externalities. The horizontal pressure does not have a systematic mechanism to provide larger efficiency.

Figure 2-2 Vertical and horizontal pressures for supply chain



Source : Hall, Environmental supply chain dynamics, 2000

Hall (2000) asserted that firms responded to the change in their selection environment and the supply chain pressure and the environmental pressure would make the environmental innovation of supply chains. They also reported that firms changed their environmental performance to respond to the pressures because they were not exposed to the same environmental pressure. For example, a firm under significant pressure to improve its environmental performance has a good performance but another without such pressure hesitates to invest in environmental innovation.

In addition, many suppliers on the side of the supply chain pressure may not be under environmental pressure, but are often significantly pressured by buyers due to other issues. These suppliers make an innovation through the exchange with trade partners and other external organizations.

The buyer-supplier relationship shows the increase in the exchange between buyers and suppliers because this change results in technical and organizational innovation as well as cost reduction. Most recent innovation was driven by buyers as an effort to respond to market pressure, and the suppliers that are not directly exposed to market pressure often resist it. The same kind of dynamics can occur in suppliers due to environmental innovation, but it is possible only under the environmental pressure of buyers.

This agrees with the assertion of Green *at al.* who pointed out that regulations make the largest influence on environmental innovation in both products and processes; is followed by cost reduction for process innovation, and the influence of the environmental pressure group is limited.

8. Conclusion

The introduction of environmental management is the subject of decision-making and various practices for environmental management, which also needs strategic decision-making. Many researchers have recognized the interconnection between environmental issues and supply chains. This recognition expanded to the importance of life cycle considerations accordingly as the center of environmental management shifted from processes to products. The recent environmental issues even have a strategic connection with supply chain management. A close relationship between each supplier in a supply chain accelerates the creation of new opportunities for a better economic and environmental performance.

This chapter dealt with the core research fields of ESCM including core competence, transaction cost economies, power balance in supply chain, buyer-supplier relationship, and supply chain strategies. It is worthwhile to note that recent transformation of supply chain management including the above issues. From a routine clerical perspective concerned with little more than purchase price and continuity of supply, the function's outlook has mutated first into a commercial orientation with an emphasis on cost savings and then into a proactive strategic outlook that is fully integrated into the competitive strategy of the company (Burt *et al*., 2003). This strategic orientation has been accompanied by a longer-term outlook on the relationship with key suppliers, which are often termed partnerships. In view of the argument that it is the short-termism of the competitive market economy that prevents attention to the degradation of the natural environment, such a new style of business relationship ought to be of great interest to those studying the interaction between private sector companies and the natural environment.

The supply chain function is also responsible for the management of all external resources and hence can make an important contribution to the competitive advantage of the organization. Seen from a life-cycle perspective, environmental initiatives are impossible without involvement of the supply chain management function.

The link between supply chain management and environmental protection needs to be stressed. Well functioning relations in the supply chain are a prerequisite not only for improvements in manufacturing practices, such as the development of novel products and alternative processes, but also for successfully tackling environmental problems. Techniques such as design for environment depend on the availability of materials and the technical capabilities of the supply chain and product take-back requires well-honed logistics operations. Hence supply chain management has been called 'the operationalisation of many of the topics within industrial ecosystems and industrial ecology' (Sarkis, 2001, p.21).

Chapter 3: Supplier involvement in product development

1. Introduction

With globalization and a rapid change of technology, the capability of developing superior products is an essential condition for a corporation to obtain and maintain competitive advantage in this highly competitive market environment. Among the elements in such a capability, the involvement of suppliers in the development of products has attracted a lot of interest and has been widely applied. Supplier involvement in product development is concerned with the strategy to focus on core competence (Snehota, 2000a). In the response to a new competition, firms have a tendency to reduce their organizations, focus on their key competence, and outsource other resources except for the key resources. As a result, effective supplier chain management becomes more important and the supplier and purchasing involvement in product development becomes more interesting.

Many researchers have emphasized the importance of product innovation through the supplier chain management. This is because the supplier chain management makes opportunities for the increase in product values and production efficiency. Lundvall (1998) and von Hippel (1998) found that there was learning by interaction between buyers and suppliers since products and services are made by the exchanges between them. For example, firms that drive interactive product innovation have a tendency to require innovative components of suppliers, so that they take a position of an innovator. Kamath and Liker (1994) found that effective purchasing policy was to give essential requirements to suppliers and to help suppliers achieve innovation.

This chapter describes the strategies which enable to develop the effective involvement of suppliers in the development of products by reviewing the literature on the supply involvement in product development, e.g. the history of the studies, supplier involvement models, supplier involvement management, etc. Furthermore this chapter describes the processes of supplier involvement in product development.

2. Conventional studies on supplier involvement in product development

Many researchers have taken interest in the supplier involvement in product development and the function of purchase in the management of such involvement (e.g. Mclean, 1964; Bergman and Johanson, 1978; Clark and Fujimoto, 1991; Womack *et al*., 1990; Lamming, 1986). Most of the early studies were focused on analyzing the achievements in Japanese automobile industries; in particular on defining and analyzing the factors and management technologies in the development of new cars. Imai, Nonaka and Takeuchi (1985) concentrated on the importance of supplier involvement in product development.

Clark and Fujimoto

Clark (1989) and Fujimoto (1991) introduced models to classify the types of supplier involvement in product development, based on information assets for specific components. These models used the buyer-supplier relationship in product development as a corporate strategy, which is highly related to a project strategy.

Table 3-1 Parts of the involvement of part suppliers

Parts	Specification
Supplier proprietary	- Catalogue item - Manufacturer has little control over quality
Black box	- High design quality, relatively low cost - Basic engineering (functional specification) is done by manufacturer, but detailed engineering (functional parts and subassembly system) is done by part suppliers - Manufacturer is able to utilize supplier knowledge, while maintaining control of basic design and total product integrity. - Risk of outsourced capability ・diminishing negotiating strength ・knowledge leak to competitor
Detail-controlled	- Parts which are developed entirely by assembler from functional specification to detailed engineering

Source: Clark and Fujimoto (1991) Product development Performance, Harvard Business Press: Boston, MA

To specify the type of buyer-supplier relationship, Clark and Fujimoto (1991) suggested an interesting typology for components by classifying them into 3 parts: supplier proprietary part, black box part, and detail-controlled part. In this classification, they specified the parts of buyer projects (how much they are carried out by buyers or suppliers), and linked it with performance parameters in product development processes (i.e. product quality, lead time, and productivity).

Appleby and Twigg

Appleby and Twigg (1988) classified suppliers by their responsibility. If a supplier has a full responsibility for product design, its customer gives design specifications. Here, the supplier takes responsibility for design input and quality standards, which is a typical example of black box and proprietary black box. Another case is a catalogue item supplier that does not provide design input at all. They allocated design responsibilities to suppliers and manufacturers. If these two extremes depend on each other, there are many situations, for example, where components are important for safety and performance or for entire design and appearance.

Table 3-2 Design Authorities and Component Type

Supplier input	Design Authority	Characteristics
Black box	80:20	Subassemblies, proprietary parts; major design authority with supplier; black box dimensioned by assembler
Performance/safety/ cosmetic critical components	60:40 to 40:60	Specification purchasing by assembler; design for performance or cosmetic aspects by iteration between supplier and assembler; specific supplier inputs being designed for manufacturing; specific assembler inputs being dimensioned for performance and so on.
Standard part	20:80	Assembler specifies and purchases from standard parts lists; in-house technical development by supplier for a wide range of customers

Source: Appleby and Twigg (1990), Diffusion in the west midlands automotive components industry, Report for West Midlands Enterprise Board Ltd., Birmingham

Kamath and Liker

Kamath and Liker (1994) emphasized the types of supplier-buyer relationships in product development, based on Japanese automobile companies. They suggested that buyers are able to get an advantage for their supply chains to improve product development processes by: 1) deciding the type of relationship with suppliers, the level of complexity of components, and the technical capability of suppliers; 2) controlling suppliers in the model to approach technical capability; 3) monitoring the capability and managing the movement from one model to another; 4) maintaining a definite guideline for stable development processes and key suppliers.

They also divided the supplier involvement into 4 types: contractual, child, mature, and partner, suggesting that each of them played a different role to different customers.

Partner: Typical suppliers in this type of supplier involvement provide a full service for design and manufacturing as primary suppliers of subsystems. They found, however, that there is a misconception by which all suppliers are not always treated as close partners in Japan. In a special situation, partners are put input the pre-concept stage where subsystem specifications are decided. Due to the complexity of products and the necessity of participation, both sides have intensive communication with each other.

Mature: Suppliers in this type of involvement design and manufacture a full system. Due to lower technical capability, however, they have a smaller responsibility for design than partner suppliers. In this case customers provide important specifications, e.g. performance, interface requirements, and spatial restriction, and have a responsibility for detailed design and prototyping. Similarly, intensive communication is made from the concept stage.

Child: In this type of involvement, suppliers interact more with buyers and are mostly involved in small modification of products. These suppliers take part in the concept stage as a consultant, but their main roles are played after detailed design and testing. However, customers seem to carry out important parts tests internally. Intensive communication is not made until the stage of component prototyping.

Contractual: Suppliers in this type of involvement are regarded as an outsourced manufacturing center. If the customer has a unique capability of manufacturing, it takes responsibility for all design. Therefore, communication is made only during the prototyping and manufacturing ramping-up.

Table 3-3 Supplier roles in product development (the Japanese model)

	Contractual	Child	Mature	Partner
Design Responsibility	Customer	Joint	Supplier	Supplier
Product Complexity	Simple parts	Simple assembly	Complex assembly	Entire subsystem
Specifications Provided	Complete design	Detailed specifications	Critical specifications	Concept
Supplier's Influence on Specifications	None	Present capabilities	Negotiate	Collaborate
Stage of Supplier's Involvement	Prototyping	Post-concept	Concept	Pre-concept
Component Testing Responsibility	Minor	Moderate	Major	Complete
Supplier's Technological Capabilities	Low	Medium	High	Autonomous

Source: Kamath and Liker (1994), Second look at Japanese Product Development, *Harvard Business Review*, Vol. 72, No. 6, November-December, pp. 154-170

These suppliers should acquire technical or administrative qualifications in the product development process in line with the responsibilities in the relationship models summarized in the table 3-4. Therefore, they should: 1) identify the complexity of products and their capability; 2) try to move from one relationship to another as the interaction with buyers is larger; 3) understand and initialize customers' product development processes; 4) appreciate the necessity of customers; 5) develop technical capability, which is important in the relationship with buyers.

Asanuma

Asanuma (1989) provided an insight to be used for new classification. Based on suppliers in Japan, they divided parts into those outsourced to manufacture according to the manufacturer's drawing (if the drawing is given) and those fully designed and manufactured by suppliers (if the drawing is approved). This model expanded the classification of input to the buyer-supplier relationship. His studies enable us to identify the sub-category of design capability continuum.

Table 3-4 Classifications of Parts and Suppliers

Supplier based on the degree of initiative in design of the product and process	Type	Criterion for classification
Drawing Supplied Parts	I	Vehicle manufacturer issues detailed drawing and instructions for the manufacturing process
	II	Supplier designs the manufacturing process based on drawings supplied by the vehicle manufacturer.
Quasi-drawing Approved Parts	III	Vehicle manufacturer provides partial drawings that are completed by the supplier.
Drawing Approved Parts	IV	Vehicle manufacturer provides specification and has substantial knowledge of the manufacturing process.
	V	Intermediate area between IV and VI.
	VI	Vehicle manufacturer specifies the parts, but has limited knowledge of the manufacturing process.
Parts Offered by Catalogue ("Marketed goods")	VII	Specification is created by the supplier, as a standard part, and offered to the vehicle manufacturer.

Source: Asanuma (1989), Manufacturer-Supplier Relationships in Japan and the Concept of Relation-specific Skill, *Journal of the Japanese and International Economies*, Vol.3, No.1, pp1-30.

This model assumes that the supplier involvement is classified, based on the level of design responsibility between suppliers and manufacturers and the main input to design processes by suppliers. Although suppliers make a high contribution to the manufacturing knowledge of design engineers, supplier involvement should be made at the stage of detailed design rather than at production.

Roy and Potter

Roy and Potter (1996) suggested a theoretical model to specify different types of development in the supply chain. This model divided the types into buyer-driven and supplier-driven. In one group, firms show their all-necessary design capability internally. In the other group, firms outsource their design jobs focusing on the balance of design processes. Between these two groups, there are many selections according to various levels of internal/external design capability. Roy and Potter (1996) specified the selections as buyer-driven and supplier-driven.

They identified several useful factors to determine the types; e.g. the type of industry, business or product, the position of suppliers in the supply chain, and the level of innovation of the development project.

Table 3-5 Buyer-supplier relationships in design and development

Type		Characteristics
Buyer-driven	In house	Buyers take full responsibility for development.
	Competitive Tendering	Buyers provide design specifications for open competition of suppliers.
	Partnership Sourcing	Buyers select suppliers in product development processes.
Supplier-driven	Supplier Interactive	Suppliers have consistent interaction with buyers to develop design.
	Fully Developed	Suppliers identify requirements for items, and fully develop, deliver, and install the items.

Source: Roy and Potter (1996), Managing engineering design in complex supply chains', *International Journal of Technology Management*, Vol. 12, No. 4, pp403-420.

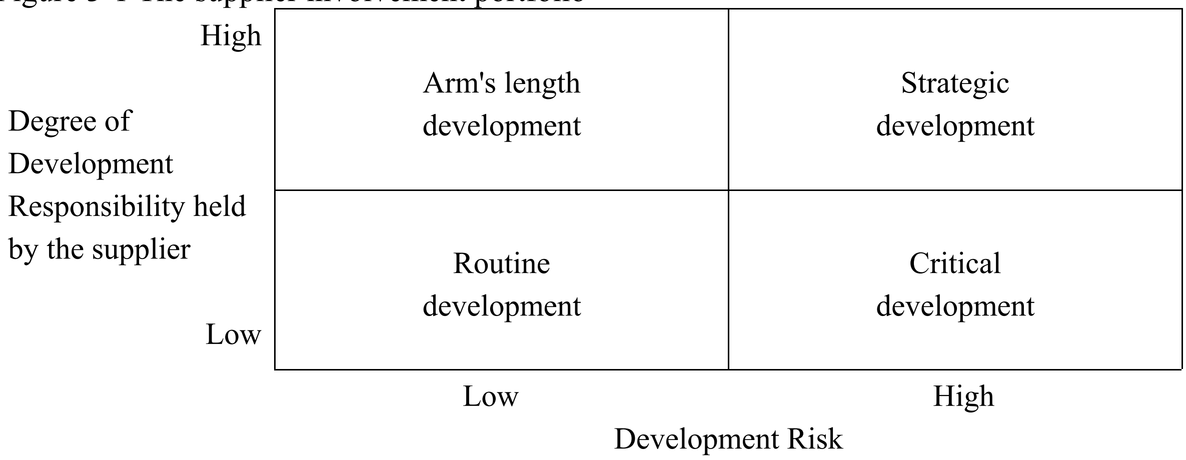
The most interesting fact in the model of supplier involvement is that the effect of supplier involvement in product development processes is more strongly emphasized. In other words, firms focus on assessing the actual profit from its performance. In relation to the effect of supplier involvement, what is interesting is the fact that the model deals with the positive role of supplier involvement in the enhancement of the level of product innovation. They also reported that supplier involvement in product development processes would convert suppliers to the source of technical solutions or development for buyers.

Wynstra and Pierick

Wynstra and Pierick (1999) discovered that supplier involvement in product development does not always increase the effectiveness and efficiency of a project and emphasized the importance of differential management of suppliers. This means that suppliers of different parts and components make a different contribution to the development of final products. They also said that many models or classifications of the types of supplier involvement, which are based on the characteristics of products, are: 1) static or inflexible; 2) not able to show how to manage supplier involvement. These disadvantages occur because: 1) the models focus more on the potential contribution of suppliers than the practical necessity of the contribution; 2) the models just show the guideline to, and the size of, the supplier involvement in product development projects without describing communication and coordination definitely.

To overcome these disadvantages, they employed a supplier involvement portfolio matrix with the variables of development risk and degree of development responsibility held by suppliers (see figure 3-1).

Figure 3-1 The supplier involvement portfolio



Source: Wynstra and Pierick, Managing supplier involvement in new product development: a portfolio approach, 1999

3. Driving factors and enabling factors

The supplier involvement in product development is ultimately caused by the complexity and uncertainty in product development. Therefore, close cooperation with suppliers will be a method of reducing the uncertainty in product development. This indicates that it is necessary to cooperate with, or control, each other by allocation and specialization of the responsibilities of buyers and suppliers (Pfeffer and Salancik, 1978).

Van Echtelt and Wynstra (2001) reviewed conventional literature to suggest the factors affecting the supplier involvement in product development: driving factor and enabling factor. The driving factor is defined as that affecting the necessity of the supplier involvement in product development. Many researchers have studied the business environment of firms and its effect on their organizational structure and strategies (Burns and Stalker 1961; Lawrence and Lorsch 1967; Eisenhardt & Tabrizi 1995). They have suggested driving factors at 3 different levels of business unit, project, and supplier relationship (see Table 3-7).

Driving factors in the level of business unit

The factors making potential influence on the necessity and type of supplier involvement in product development in the level of business unit included: market and technical uncertainty (Birou and Fawcett, 1994; Eisenhardt and Tabrizi, 1995; Fine, 1998, 2000), dependence on R&D (Wynstra *et al.,* 2000), dependence on suppliers (Wynstra *et al*., 2000), size of firms (Wynstra *et al*., 2000), and complexity of production (Wynstra *et al*., 2000).

Driving factors in the level of project

The factors in the level of project included the innovation and project objective. Researchers suggested that the factors depended on the characteristics (or strategies) of projects, so that it was necessary to make a differential approach (Handerson and Clark, 1990; Wheelright and Clark, 1992; Griffin and Page, 1996; Luthardt and Morchel, 2000). It was also pointed out that the objectives of projects and their relative importance vary depending on different levels of innovation (Griffin and Page, 1996; Tatikonda and Rosenthal, 2000).

Driving factors in the level of supplier relationship

Several researchers suggested the driving factors in the level of supplier relationship by studying the factors affecting the management of specific suppliers that developed parts or components (Wasti and Liker, 1997; Wynstra and Ten Pierick, 2000; Bensauo, 2000). They suggested development risk as the driving factor in the level of supplier relationship, which is categorized into: 1) the complexity of component development; 2) the technical uncertainty of components; 3) the contribution of components to general system functions; 4) the level of supplier competition in the market.

On the other hand, the enabling factor is defined as that affecting organizational capability in implementing projects (Wynstra *et al.*, 2002). Contrary to the driving factor, the enabling factor allows an organization to do specific activities if a certain situation needs a specific type (van Echtelt and Wynstra, 2001). These factors can be conditions, which help a firm to manage the suppliers required for product development. The enabling factor increases the capability of an organization to manage the supplier involvement in product development.

Many researchers suggested the factors that seemed to make a contribution to successful management of supplier involvement in product development (Wynstra, 2000; Burt & Soukup, 1985; Anklesaria & Burt, 1987; Guy and Dale, 1993; Atuahene-Gima, 1995; Dobler & Burt, 1996; Waisti & Liker, 1997; Hartlet & Zirger(1997), Birou and Fawcett, 1994; Handfield *et al.,* 1999; Lorange, 1988, Perlmutter and Heenan, 1986; Whipple and Frankel, 2000; Bruce *et al.,* 1995). They also categorized the factors into: those inside the customer organization (buyer's internal factors); those outside (characteristics of suppliers); and those occurring in the specific relationship between customers and suppliers.

Table 3-6 Driving factors for supplier involvement in product development

Researchers	Potential driving factors	Dependent variables	Level of analysis
Eisenhardt & Tabrizi (1995)	-Technological and Market Uncertainty. -Predictability of projects/ uncertainty surrounding a project	-The effectiveness of experiential vs. compression strategies	Business unit
Fine (1998)	-Industry clockspeed differences	-The effectiveness of outsourcing	Business unit
Birou & Fawcett (1994)	-Competitive conditions in customer markets	-The role of supplier participation	Business unit
Wynstra *et al*. (2000)	-R&D dependence	-Need for purchasing involvement activities	Business unit/firm
Wynstra *et al*. (2000)	-Supplier dependence	"	"
Wynstra *et al*. (2000)	-Company size	"	Business unit
Wynstra *et al*. (2000)	-Production complexity	"	
Griffin and Page (1996)	-Product newness to the market and to the firm	-Project performance measures	Project
Tatikonda & Rosenthal (2000)	-Technology novelty	-Project execution outcomes	"
Tatikonda & Rosenthal (2000)	-Project complexity	-Project execution outcomes	"
Wasti & Liker (1997)	-Technological uncertainty of the component	-Degree of supplier involvement	Supplier relationship
Wasti &Liker (1997)	-Supplier market competition	-Degree of supplier involvement	"
Wynstra and Ten Pierick (2000)	-Development Risk -Extent of involvement	-Differentiation of management of supplier roles in product development	"

Source: van Echtelt and Wynstra (2001), Managing supplier integration into product development: Literature review and conceptual model

Table 3-7 Enabling factors for supplier involvement in product development

Potential enabling factors		Researchers
Internal Enabling Factors	Internal organization of the purchasing department and development team	Wynstra (2000), Burt & Soukup (1985)
	Recording and exchange of information	Wynstra (2000)
	Quality of human resources	Anklesaria & Burt (1987), Guy and Dale (1993) Atuahene-Gima (1995), Dobler & Burt (1996), Wynstra (2000)
External Enabling Factors	Supplier technical capabilities	Wasti & Liker (1997), Hartley & Zirger (1997), Birou and Fawcett(1994), Handfield *et al*. (1999)
Relationship Enabling Factors	Past experience of collaborations	Wasti & Liker (1997), Farr & Fisher (1992)
	Compatibility of Culture/operating style	Lorange (1988), Perlmutter and Heenan (1986), Whipple and Frankel (2000), Bruce *et al*. (1995)
	Trust - Social Climate	Sako (1992), Gabarro (1987), Bensaou (2000)

Source: van Echtelt and Wynstra (2001), Managing supplier integration into product development: Literature review and conceptual model

Several researchers carried out experimental studies to find out the factors affecting the success of the supplier involvement in product development (Gullander *et al.,* 2001; McGinnis, 1998). Gullander *et al*. (2001) reported six factors: in relation to product characteristics, the degree of product innovation, the product architecture (modular or integral), and the product complexity; in relation to organizational characteristics, the cooperation pattern, the organization for integrated product development, and the risk of undertaking. McGinnis (1998) presented the factors from the viewpoint of the purchasing department. In particular, he suggested internal factors, including the willingness of consistent new product development, the processes of definite new product development, and the share of reliable information, and external factors, including the competitive market.

4. Effects of supplier involvement

The supplier involvement in product development ranges from just a suggestion of design idea to full responsibility for development or design and engineering of specific parts or subassemblies. Many researches reported that the supplier involvement in product development makes positive effects. A firm cooperates with suppliers to reduce the costs, ensure the provision of essential items, improve supply time, and enhance the quality of purchased items (Ellram, 1995). Therefore, a cooperative partnership with suppliers will contribute to better flexibility and support, increase the flow of information between the two sides, and make a consistent relationship (Janda *et al.,* 2002).

Several researchers such as Imai *et al*., 1985; Clark and Fujimoto, 1991 pointed out that supplier involvement in new product development processes would convert suppliers to the source of technical solutions or development for buyers. Imai *et al*. (1985) showed just positive effects, and emphasized the contribution of the supplier involvement to technical innovation. Clark (1989) reported that there was a trade-off between productivity performance and engineering lead-time. In particular, Clark and Fujimoto (1991) said "the challenge of managing the relationship with supplier is to explore the benefits of lead time and engineering hours while minimizing the deterioration of product quality".

Sanders *et al*. (2001) carried out experimental studies to find the firms that involved suppliers in product development in terms of buyer-supplier relationship showing higher market position. They reported that the supplier involvement strategy was featured by long-term contracts, partnership programs, early supplier involvement, supplier certification, information sharing, and higher performance and reliability, and that the firms with higher market position utilized the strategic partnership with key suppliers.

The supplier involvement in product development can be divided in terms of time horizon, giving potential advantage and a method of affecting the firm (van Echtelt and Wynstra, 2001). Van Echtelt and Wynstra(2001) divided the effects of supplier involvement into long-term and short-term effects in terms of the time horizon. Such a method can divide only definite effects, but does not have a clear background for the division of long-term and short-term effects (Wynstra *et al.,* 1999). Short-term effects, e.g. reduced cost or length of product development, higher product quality and reliability, and enhanced environmental performance, are identified when particular suppliers are linked with one or more projects.

Table 3-8 Objectives of strategic partnership with suppliers

Researcher	Objectives
Imai *et al*. (1985), Clark and Fujimoto (1991)	- The origin of technical solution - Reducing lead time and engineering time with minimizing deterioration
Ellram (1995), Halley (2002)	- Lower prices - Assurance of supply - Influence by the supplier over quality - Better delivery times - Influence by the supplier over technological choices
Krause *et al* (2002)	Strategic goals: - Increased financial strength of the supplier - Reduction of existing supply base - Product development capability improvements - Increased management capability - Improved supplier technical capability Performance goals: - Improved quality of the purchased item - Reduced cost of the purchased item - Improved delivery performance - Increased supplier service/responsiveness

On the other hand, long-term effects are not clearly characterized. However, they increase a firm's capability of ensuring the contribution of supplier involvement to future projects by providing potential advantages that are not directly quantified or traced. This agrees with the suggestion that most of the effects contributing to a buyer's performance, i.e. reduced cost and better quality, resulted from long-term development through a cooperative relationship (Wagner *et al* 2001; Janda *et al.,* 2002; Carr *et al.,* 1999). The long-term effects include: the consistent and long-term approach to key suppliers' technology to double the capability of product innovation; the improvement of design solutions; higher possibility of effective and efficient cooperation between buyers and suppliers (van Echtelt and Wynstra, 2001). This agrees with the experimental study results of Janda *et al*. (2002) that the cooperative relationship between buyers and suppliers improves the knowledge and experience of suppliers, resulting in increased quality of items and lower costs of acquiring the items and finding suppliers.

In the aspect of methodology, supplier involvement in product development makes strategic or operational effects on the buyer (van Echtelt and Wynstra, 2002). The strategic effects occur in the methods by which a buyer operates its business, and the size of approach to suppliers' technology decides the direction of future projects. The operational effects are made based on the factors affecting the success of specific projects, e.g. product quality, costs, development length, etc.

Van Echtelt and Wynstra (2001) divided the effects of supplier involvement in product development into strategic/long-term effects and operational/short-term effects. Based on this classification, they suggested that the supplier involvement would improve the effectiveness of product development results and the efficiency of product development processes in the operational aspect of product development.

Table 3-9 Potential effects of supplier involvement in product development

Nature of advantage		Potential advantages	Researchers
Long term	Strategic/ Effectiveness	Innovation and technology related advantages	
		Increased efficiency and effectiveness of future project - collaboration	Dyer and Ouchi (1993)
		Better access to technological resources and knowledge	Imai *et al*. (1985), Clark and Fujimoto (1991), Ragatz *et al*. (1997), Bruce *et al*. (1995), Bonaccorsi (1997).
		Long-term alignment of technological strategies	Bonaccorsi (1992)
		Possibilities to influence future technological 'investments'	Wynstra (1998)
Short term	Operational/ Efficiency	Time -to market related advantages	
		Lead-time reduction	Clark (1989), Clark and Fujimoto (1991), Kamath & Liker (1994), Hartley & Zirger (1997), Wasti & Liker (1997), Gupta & Souder (1998), Ragatz *et al*. (1997), Droge *et al*. (1999), Bonaccorsi & Lipparini (1994), Bruce *et al*. (1995)
		Development Cost related advantages	
		Reduced development costs (improved resource utilization)	Clark (1989), Bonaccorsi & Lipparini (1994), Dowlatshahi (1998), Birou & Fawcett (1994), Hartley *et al*. (1997a and 1997b) Wasti & Liker (1997)
		Reduced transaction costs	Dyer and Ouchi (1993)
	Operational/	Product Cost related advantages	

	Effectiveness	Provide suggestions on alternative materials increasing product quality/functionality and lowering costs	Dowlatshahi (1998)
		Reduced manufacturing costs	Dyer and Ouchi (1993), Kamath & Liker (1994), Mendez & Pearson (1994)
		Product quality related advantages	
		Development of better performing designs/improved product performance/Reduction quality problems	Clark (1989), Kamath & Liker (1994), Ragatz *et al.* (1997), Bonaccorsi & Lipparini (1994), Mendez & Pearson (1994), Wasti & Liker (1997)

Source: van Echtelt and Wynstra, 2001, Managing supplier integration into product development: A literature review and conceptual model

The reason for these contradictory study results is that the effects of supplier involvement depend on its type. In other words, the studies that suggested positive or negative effects did not take into account the questions in detail (e.g., Clark, 1989; Clark and Fujimoto, 1991; Handfield and Scannel and Hartley *et al*., 1997; Bidault, Despres and Butler, 1998). Moreover, recent studies have found that such practices could have positive or negative effects depending on the characteristics of the integration (Liker, Sobek, Ward, Cristiano, 1996; and Liker, Kamath, Wasti, Nagamachi, 1996). Therefore, it is necessary to understand that the decision of practices has positive or negative effects based on the results of supplier involvement. For example, Clark (1989, p1261) reported that "the critical managerial problem in product development is not securing effective collaboration within the firm, but managing the supplier to achieve integration in engineering efforts" and "There is a need for more research on the nature of integration, particularly in the development process and its interaction with the nature of financial and commercial relationships between firms". More recently, Bidault, Despress and Butler (1998, p731) said "we would also recommend further qualitative research in order to understand more closely the way organizations and managers make choices with regard to ESI".

5. Supplier involvement framework in product development

Ragatz *et al*. (1997) and Wynstra (1998) concluded that understanding how to manage supplier involvement in product development processes was very important for analyzing the success of the participation. In relation to this, Wynstra *et al*. (1999) divided the purchasing involvement in product development into three parts: project management, supplier interface management, and technology management. They reported that these three parts had different time horizons and included different types of activities, but are closely interlinked.

The studies on project management were intended to identify specific development activities for a certain period of time. Most of the studies on the role of purchasing functions in product development were based on individual projects. These types of studies were in particular focused on the role of the purchasing department rather than purchasing functions.

The studies on supplier interface management were intended to establish a permanent relationship with suppliers rather than for a specific development project. They showed methods of making an optimal contribution to technical position and product development capability, and included permanent and long-term tasks to maintain the relationship with suppliers. These tasks should be carried out not only during the development project but also and perhaps especially, in between projects (Bergman and Johanson, 1978; Axelsson, 1987; Bonaccorsi, 1992; Hakansson and Eriksson, 1993).

The studies on technology management were intended to combine the knowledge in specific technical rules and the physical objectives. They were focused on the allocation of work to manufacturers and suppliers to develop and maintain specific technical knowledge and capability. They are linked with what are regarded as make-or-buy issues or when they are connected to product innovation and develop-or-buy issues (Pralahad and Hamel, 1990; Wheelwright and Clark, 1992; Ford and Farmer, 1986; Quinn and Hilmer, 1994). This management is based on not only strategic management and product development but also strategic purchasing management and outsourcing (Wynstra *et al.,* 1999).

Wynstra *et al*. (1999) pointed out that existing studies included fragmentary characteristics of the purchasing involvement in product development, and also reported that while the focus of the studies was put on the supplier involvement management in individual projects and short-term effects, long-term effects, e.g. technical cooperation between manufacturers and suppliers, were not taken into account.

Table 3-10 Research stands and areas of purchasing involvement

Area	Emphasis	Researcher
Projects	• Tasks of purchasing departments in new product development projects	Burt and Soukup, 1985
	• Effects of supplier involvement on the scope and performance of new automobile projects	Clark, 1989
	• Purchasing tasks within development projects, differences between development and purchasing functions	Dowlatshahi, 1992
	• Influence of supplier involvement on project performance (cost, quality, product performance, development time)	Birou, 1994
	• Quantification of benefits of supplier involvement and the identification of effective management techniques at the level of individual projects	Hartly, 1994
	• Different roles suppliers may have in development projects in terms of moment and intensity of involvement	Kamath and Liker, 1994
	• Most and least successful cases of supplier involvement with regard to project outcomes, and managerial instruments used at project level	Ragatz *et al.*, 1997
Suppliers	• Manufacturer-supplier interaction in product development	Bergman and Johanson, 1978
	• Long-term access to supplier knowledge, joint development of new capabilities	Axelsson, 1987
	• Structuring and managing supplier involvement in the long run	Bonaccorsi, 1992
	• Underlying managerial processes involved in getting product innovations out of suppliers	Hakansson and Eriksson, 1993
Technologies	• Core competencies, resource allocation, and outsourcing	Pralahad and Hamel, 1990
	• Technology planning and strategy, external acquisition of technological capabilities (long term)	Wheelwright and Clark, 1992
	• Contribution of materials function to make-or-buy decisions	Ford and Farmer, 1986
	• Core competencies and range of outsourcing options	Quinn and Hilmer, 1994

Source: Wynstra *et al.*, Purchasing Involvement in Product: A Framework, 1999

Moreover, they described the types of purchasing involvement, and suggested a framework to identify the issues and processes of purchasing involvement in a comprehensive, not fragmentary, way. In the framework, purchasing involvement was divided into development management, supplier interface management, project management, and product management.

Table 3-11 Purchasing involvement framework in product development

Areas	Activity
Development Management	Determining which technologies to keep/develop in house Formulating policies for the involvement of suppliers Formulating policies for purchasing related activities for internal departments Communicating policies and procedures internally and externally
Supplier Interface Management	Monitoring supplier markets for technological developments Pre-selecting suppliers for product development collaboration Motivating suppliers to build up/maintain specific knowledge or develop products Exploiting technological capabilities of suppliers Evaluating suppliers' development performance
Project Management	***Planning:*** Determining specific development-or-buy solutions Selecting suppliers for involvement in the development project Determining the extent of supplier involvement Determining the moment of supplier involvement ***Execution:*** Coordinating development activities between suppliers and buyer Coordinating development activities between different first tier suppliers Coordinating development activities between first and second tier suppliers Ordering and chasing prototypes
Product Management	***Extending activities:*** Providing information on new products and technologies developed or in market Suggesting alternative suppliers, products, and technologies resulting in higher quality ***Restrictive activities:*** Evaluating product designs in terms of parts logistics, quality, and costs Promoting standardization and simplification of designs and parts

Source : Wynstra *et al.*, "Purchasing Involvement in Product Development", Eindhoven University of Technology, 1999

Development management

Deciding the technology to be developed inside or outsourced outside the firm means to identify suppliers' technology and to analyze its value. As the availability and stability of the technology is higher or the dependence on the technology is lower, suppliers in general have more responsibility for the development. The establishment of a supplier involvement policy shows if the firm has a guideline for supplier involvement. The foundation of a purchasing policy for internal departments shows if a department is able to check the responsibility for, or procedures of, the purchasing of other departments. Internal or external communication of the policy and procedures is intended to clarify the roles and responsibility of participating departments and to understand the policy and needs of the manufacturer.

Supplier interface management

Monitoring the supplier market related to technology development, that is, monitoring the technology development market including the capability of a specific supplier, is to carry out proactive and consistent studies to identify suppliers or technology for new product development. The subject of the monitoring is the supplier or technology for technical development, not cost reduction or competitiveness improvement for the same technology. In most cases, the monitoring seems to be conducted according to circumstances without definite planning. Pre-selecting suppliers for product development is to maintain a cooperative relationship with the supplier. Taking into account the supplier as a cooperative partner is different from supplier involvement in a specific development project. Primarily the type of supplier involvement is not related to a specific internal development project of a manufacturer, and secondarily the manufacturer does not want to involve the suppliers in product development projects, but to maintain a cooperative relationship with several cooperative suppliers for specific products. What should be considered when selecting a supplier for technical cooperation are its technical and organizational capability as well as its willingness and interest in the cooperation. Suppliers should have specific knowledge and incentive to develop a product utilizing their resources. Therefore, suppliers should use their resources to meet the needs of their buyers. In order for a manufacturer to use the resources of partner suppliers, it should provide suppliers with attractive incentives, e.g. business volume, images, new product ideas, new approaches to production technology, etc. Investigating the technical capability of suppliers include exploiting their capability, for example, observing and analyzing the capability of suppliers and accepting the parts and materials developed by suppliers. Exploitation is very effective for a powerful and innovative supplier. Evaluating the development performance of suppliers is selecting suppliers that will cooperate with a specific project, without the necessity of looking for or rating new suppliers to make a new supplier base. For this, regular evaluation of timely supply, reliable communication and documentation, quality, etc., should be carried out.

Project management

Planning in project management includes deciding a specific development or buy solution, selecting suppliers to be involved, and determining the size and time of supplier involvement. Different supplier involvement in time contributes to effective use of suppliers' resources and improvement of development processes. Project management includes balancing the development activities between suppliers and manufacturing departments, between primary suppliers, between different suppliers horizontally, and between primary and secondary suppliers, and ordering and examining prototypes. Balancing the development activities between primary suppliers seems to occur in the case of arm's length relationship. The development activities between primary and secondary suppliers are made vertically. In this case a manufacturer involves secondary suppliers in product development.

Product management

Product management is divided into extended activities and limited activities. The extended activities include providing the information about new products and technology that are developed or already available in the supplier market and suggesting alternative suppliers, products, and technology to further improve the quality of products. These activities are related to supplier interface management and project management, especially in availability, marketability, lead-time, quality, and cost. They also include suggesting new suppliers, products, and technology to enhance the quality of final products, that is, looking for and suggesting the parts with more general specifications for efficiency and purchasing functions.

The framework in particular provides a tool for implementing, enhancing, and appreciating the purchasing involvement in product development by defining and describing various activities of the purchasing involvement in product development.

6. Supplier involvement process in product development

Monczka *et al*. (2000), Wynstra *et al*. (2000), and Dobler *et al*. (1996) developed supplier involvement management processes. Dobler *et al*. (2000) suggested how purchasing functions should be involved in each stage of the design process. They reported that the desirable level of quality and reliability should be taken into account in the design stage, and suppliers should approach the product design as early as possible to ensure the use of their contributable technologies or processes. They regarded the design stage as the best point to reduce and control most of the costs of creating items. They also reported if the cost is not reduced at the design stage the excess would be permanently included in products, resulting in expensive and non-competitive products.

On the other hand, Monczka *et al*. (2000) and Wynstra *et al*. (2001) described a decisive process to manage the supplier involvement at the level of projects by integrating strategic and project aspects in relation to the purchasing involvement in product development. Monczka *et al*. (2000) divided the purchasing and supplier involvement in product development into strategic planning processes and supplier integration execution processes, suggesting an active model by which the processes were connected in consecutive order. Wynstra *et al*. (2001) divided the purchasing and supplier involvement in product development into long-term stratetic/tactical processes and short-term operational processes, and developed a contingency-based model to design and control relevant processes.

Table 3-12 Supplier involvement and management processes

Researcher	Processes
Monczka *et al*., (2000)	☐ Strategic Planning Process A. *Determining current and future needs* step 1. Establish internal core competencies and capabilities step 2. Establish current and future new product requirements step 3. Identify current and future needs for external technologies and capabilities B. *Establishing a strategically aligned world-class supply base* step 4a Select appropriate suppliers and build relationships step 5a Align objectives and technology roadmaps C. *Establishing a bookshelf of viable technologies and suppliers* step 4b Monitor supply markets for emerging technologies step 5b Continuously evaluate emerging technologies ☐ Supplier Integration Execution Process D. *Determining the Supplier's role and setting targets* step 1. Give suppliers an active role on the project team

	step 2. Jointly establish clear metrics and targets E. *Information sharing and learning from experience* step 3. Share information openly and extensively step 4. Involve suppliers in decision-making and problem solving during the design process. step 5. Monitor results and learn from experience
Van Echtelt and Wynstra (2001)	☐ Long Term Strategic and Tactical Processes 1. Formulating and communicating guidelines and process blueprints for integrated Product Development and Sourcing 2. Determining Internal vs External Provisioning of Technology 3. Surveying Supplier Markets and Individual Suppliers for Technical Developments 4. Pre -selecting Supplier Partners for Product Development Collaboration 5. Leveraging Suppliers' Existing Skills and Capabilities 6. Motivating Suppliers To Develop Specific Knowledge and/or Products 7. Evaluating Guidelines and Processes for Integrated Product Development and Sourcing ☐ Short Term Operational Processes 8. Determining Project-specific Develop-or-Buy Options for Development Work packages 9. Suggesting Alternative Suppliers/Products/Technologies 10. Selecting Suppliers For Involvement In Specific Development Projects 11. Determining the Extent and Moment of Project Involvement for Specific Suppliers 12. Coordinating Development/Design/Engineering activities Between Manufacturer and Supplier 13. Coordinating Development/Design/Engineering activities Between Various Suppliers 14. Evaluating Product Designs 15. Evaluating and Feeding-back Suppliers' Co-Development Performance

7. Conclusion

This chapter presents the strategies that enable the development of the effective involvement of suppliers in the development of products by reviewing the literature on supply involvement in product development.

As companies focus more tightly on their core competencies, they will rely more heavily on their suppliers for non-core activities such as new product development through early design and concurrent engineering (Prahalad and Hamel, 1990). With the added responsibilities being placed on the supply chain, businesses also find environmental risks can be passed on through suppliers. With companies increasingly relying on their supplier's environmental performance, managers are coming to understand that environmental compliance is not sufficient. The increasing interest in integrating environmental practices and supplier involvements finds 'ecological sustainability' as a framework for understanding management practices. These include product development and manufacturing practices (Clark and Fujimoto, 1991; Appleby and Twigg, 1988; Asuma, 1989; Kamath and Liker, 1994; Roy and Potter, 1996; Halley, 2002; Krause *et al*., 2002; Ragatz *et al*., 1997; Wynstra, 1998; Wynstra *et al*., 2001). As Janda *et al*. (2002) found that the cooperative relationship between buyers and suppliers improve the knowledge and experience of suppliers, resulting in increasing quality of items and lower costs of acquiring the items, the supplier involvement in product development can make strategic or operational outcomes on the buyer (van Echtelt and Wynstra, 2002).

The supplier involvement in product development ranges from giving minor design suggestions to being responsible for the complete development, design and engineering of a specific part or sub-assembly. Thus, the variety of supplier involvement is caused by the different levels of collaborative relationships and contributions on the product development (Janda *et al*., 2002; van Echtelt and Wynstra, 2002; Wynstra *et al*., 2001). However, most studies have simply emphasized and focused on supplier involvement in environmentally friendly product development, ***regardless of variety of the supplier involvement***. This chapter stresses and concludes that no 'one-size-fit-all' strategy exists in a supplier involvement during the process of environmentally friendly product development.

Chapter 4: Ecodesign strategies and process

1. Environmentally friendly product development and ecodesign

Environmentally friendly product development is one of the activities to balance customers' needs for quality, functions, prices and the environmental acceptability of the products to be developed (Tischner *et al.*, 2001). It can be a modification of existing products or a development of totally new products. The approach is determined by the unique process that the firm or organization has. Environmentally friendly product development is sometimes called Design for Environment (DfE), or ecodesign. This study defines environmentally friendly product development as an ecodesign.

Many researchers have already defined ecodesign. Fiksel (1996) defined ecodesign as the activities to incorporate environmental considerations into the design and engineering of products and processes by satisfying the requirements in price, performance and quality to develop environmentally acceptable products. Ecodesign was also defined as the activities to incorporate environmental aspects into the design of products and processes and to meet the requirements in price, performance, and quality in the early stage of product development by linking the development processes with environmental policy or strategies.

In Environmentally Oriented Product Design Guideline (1998) for electronic industries, the Finnish Ministry of the Environment defined ecodesign as a proactive approach to apply environmental acceptability to all the product development processes by reducing environmental impacts in the whole life cycle of the product to be developed. In Life Cycle Design Guideline Manual (1993) US EPA defined the life cycle design, i.e. ecodesign, as a systematic approach to design an environmentally or economically sustainable product system, aiming at reducing the environmental impacts to the whole product system from the early stage of product design. In addition to the environment, it was also emphasized that the performance, price, cultural or regulatory requirements should be balanced, and important elements include the total quality management, team organization, and multi-channel decision-making.

Tischner *et al*. (2000) explained, "Ecodesign means environmentally conscious product development and design. This term describes it in a systematic manner, which aims at including environmental aspects in the product planning, development and design process at the earliest possible opportunity. This implies that 'environment' be added as a criterion of product development alongside other classical criteria of functionality, profitability, safety, reliability, ergonomics, technical feasibility and, last but not least, aesthetics. One of principle ideas is rooted from Schumpeter's concept of ***innovation*** in his *'Small is Beautiful'*. Schumpeter identified the emerging trend of efficiency-focused smallness during the time of mass production and consumption. In his term, innovation means that the efficiency-based change requires a revolutionary reflection on products. In a similar way, we reflect his idea of innovation on ecodesign that has a characteristic of eco-innovation. The term ecodesign directly expresses the fact that ecology and economy must be joined inseparably by means of good design in ecodesign procedure."

According to Stevels (2001), ecodesign seeks to understand the life cycle of the product and its impact on the environment at each of its life stages and to make better decisions during product design so that environmental attributes of the product are kept at desired level. In order to obtain targeted performance level, ecodesign should occur early in the design phase to ensure that the environmental consequences of a product's life cycle are taken into account before any manufacturing designs are committed (van Weenen, 1997; Tischner *et al*., 2000; Stevels, 2001). Functionality of the product also contributes to the environmental consequences, which is also committed very early in product design. A majority of possible product end-of-life costs are committed during the conceptual design stage. The challenge is to provide as much relevant information as early as possible to proceed with design (Handfield *et al*., 2005; Perks *et al*., 2005).

As a summary of the definitions above, ecodesign in this study can be defined as a strategy to incorporate environmental considerations into the design and development of products. Ecodesign is generally intended to minimize the consumption of energy and natural resources and the environmental impacts of the products and to make products, systems, substructures, and services that minimize the emission of pollutants and waste in the life cycle. If the environmental impacts are taken into account in the early stage of product design, the product developed will have lower environmental impacts.

The reason for incorporating ecodesign depends on the strategy for each company. Some companies are defensive, proactive or cost driven in their reactions to external development related to environment (i.e., social pressures, additional legislation or taxes) (Rose, 2000). Ecodesign can lead to cost reduction, strengthen the market position of existing products, extend products to new markets, advert criticism by external stakeholders, and increase the possibility of company's surviving in the long-run (Cramer *et al*, 2000). Rose (2000) suggested that the ecodesign give companies such opportunities; satisfying customer, strengthening corporate competitiveness, and complying legislation. Ecodesign can improve the market position of companies' products by satisfying customer. And also, ecodesign can make companies' supply chain environmentally friendly by influencing their suppliers to contribute to their environmental success and image. In addition, ecodesign allows companies not to lose competitiveness in the market place, by reducing operating costs (i.e., costs of material, energy, and disposal waste) and proving products do not pose threat to consumer, and do not emit toxins after product disposal. Where competing companies' products are closely matched, the fact that a particular company has included environmental criteria into the product's design may sway to purchase that product

Heidenmark (2001) represented the difficulties in environmentally friendly product development: first, because environmental issues are diverse and complicated it is hardly practical for a manufacturer to develop an environmentally friendly product taking into account all the environmental issues. Second, customers' behavior or motive for buying environmentally friendly products is not certain. The uncertainty is related to the question of time: Is it timely to release the environmentally friendly product?; Are customers prepared to consume or pay for it?; Is its price acceptable? It is very important to offer a method of dealing with the uncertainty. By controlling the uncertainty, a firm can get loyalty from its customers and subsequently enjoy an advantage as a pioneer. Third, it is difficult to disperse the information about environmental features of the product. Not only customers but also purchasers have some difficulty in identifying the environmental impacts of the product because they hardly understand many indirect yet important parameters, e.g. transportation, production, packaging, etc. Forth, it is difficult to manage the supply chain to develop environmentally friendly products. Depending on the relationship of the participants in the supply chain, the use of environmentally friendly products may be accelerated or decelerated. This is because the power of the firm developing environmentally friendly products is determined by its position in the market; that is, all of the firms in the supply chain have the same interest in the development of environmentally friendly products.

Heidenmark (2001) also pointed out the requirements for the success of environmentally friendly product development. First, the environmentally friendly product should meet customers' needs. Here, it is necessary to compare the customers' needs with the product development process to identify problems. Beyond the customers' needs, it is especially important to expect a change in their tastes. Second, it is necessary to identify customers' minds to guide them to have a willingness to pay for environmentally friendly products. As the environment is generally regarded as a public good, it is necessary to make customers think of it as a private good, e.g. environmentally friendly products that are 'good for your health' (Reinhardt, 1999). In addition, it is important to provide the information that is trusted by customers. Third, it is necessary to make a consistent profit by preventing competitors from copying the environmentally friendly product developed.

Furthermore, Heidenmark (2001) showed that the factors affecting the decision-making in environmentally friendly product development are: organizational characteristics, environmental regulations, market pressure, and supply chain characteristics. This section focuses on describing the market pressure and supply chain characteristics. Market pressure is related to the relationship with buyers or competitors. The increase in customers' demands for cleaner production and hazardous material information in the B2B transaction forces manufacturers to incorporate environmental issues into their product development processes. This kind of change allows manufacturers to ensure the sale of the environmentally friendly products in the future, to reduce the costs, and to enhance the value of them and their brands. Activities of competitors also motivate manufacturers to develop environmentally friendly products. When planning a new product, what is most important is if it will make a long-term profit. If the market changes at the same time, more environmentally friendly products will be distributed. A firm could make a profit in the limited market by providing environmentally differentiated products and services. However, these effects are not shown in a short time, so that some proactive firms take a risk in developing environmentally friendly products to make a potential profit in the future and to have a competitive advantage in the market.

Besides the market pressure, stakeholders in the supply chain also pressure manufacturers to develop environmentally friendly products. As described in Section 5, Chapter 2, it is very important for initiatives to have the power to lead the supply chain in environmentally friendly product development. The pressure of the supply chain can be divided into 2 types: downstream steering, where customers change suppliers, and upstream steering, where manufacturers or suppliers change the supply chain. In downstream steering, many firms require their suppliers to join their environmental management. These requirements are limited to a narrow range, e.g. involving suppliers in environmental management systems or requiring environmentally friendly parts or components. This pressure on the supply chain often occurs vertically in the supply chain, affecting many suppliers. In upstream steering, suppliers take responsibility for the life cycle of products, as in the expanded producer responsibility. This means that the suppliers in the supply chain share the responsibility for environmental impacts of products.

Many researchers have also recommended the following: maintaining a systematic and consistent communication with suppliers in the supply chain and having chances to cooperate with, or to involve, various stakeholders in ecodesign. This is because ecodesign includes not only technical issues but also organizational ones, so that such cooperation is a key element to make ecodesign a success. Here the cooperation should cover both internal (with product managers, environmental experts, designers, marketing employees) and external (with suppliers, customers, recyclers, stockholders).

The most representative external cooperation is with suppliers. A firm should take into account the environmental impacts of its products from the stage of purchasing raw materials and pre-products. This means that suppliers should be involved in environmentally friendly product development. In ecodesign, all the aspects of environmental impacts are taken into consideration systematically from the stage of product design. Therefore, the ESCM, which is closely related to ecodesign, is the incorporation of environmental issues into purchase decision-making and supplier management processes. As described before, the objective of ecodesign is to avoid or minimize the environmental impacts through the life cycle of a product. Therefore, the supplier chain management is essential in the ecodesign.

Such actions, in particular, are varied according to the types of industries. A firm in the service industry, for example, does not typically have a function of product design. Its main activity is to purchase necessary products and materials. Therefore, most of the environmental impacts resulting from its activities is ultimately involved in the supply chain. In this kind of firm, all decision-making associated with ecodesign is managed through the supply chain management, and the principles and methodology of ecodesign seem to be applied by specifications control or purchase activities rather than direct product design.

Meanwhile, in the case of a firm in the manufacturing industry, the supply chain management is very important even if it has a function of product design. This is because lower environmental impacts of raw materials or components will be a part of ecodesign. This kind of firm has transactions with its existing partners or key suppliers, so that its design activities and environmental impacts of products will flow upstream in the supply chain. As a result, the supplier chain management is becoming more important. This means that it is necessary to integrate ecodesign and the supplier chain management into a single part of the approach to environmental management.

2. Types of Ecodesign

Many researchers have suggested various types of ecodesign. One of the most popular classifications is that reported by Stevels (1996) and Brezet *et al.* (1997): Product Improvement, Product Redesign, New product concept definition, and new production system definition. This classification was based on the level of eco-efficiency and the type of initiated change

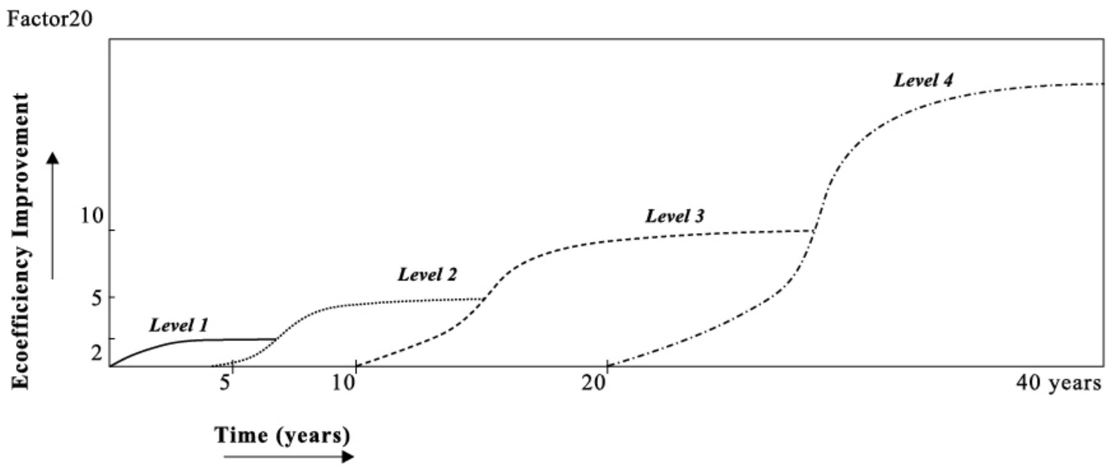
Level 1: Product improvement:
This is a progressive and incremental improvement of the product, a re-styling of the product; for example, it can consist of decreasing the use of materials or replacing one type of fastener by another;

Level 2: Product redesign:
A new product is redesigned on the basis of an existing product;

Level 3: New product concept definition
This is an innovation rupture as technical functions to fulfill product functionality are different.

Level 4: New production system definition
This occurs when innovation in the productive system is necessary.

Figure 4-1 Four levels of Ecodesign



Heidenmark (2001) classified ecodesign into 3 stages according to the unique processes of a firm or organization:

Stage 1: Cost optimization and short-term profit is ensured; products are consistently improved; new market needs are accepted.

Stage 2: Products are differentiated or changed so as to satisfy the needs of specific customers.

Stage 3: The concept of a product is changed, i.e. fundamental innovation is made to balance new products and the market (Manzini, 1991: Cramer, 1998).

In this classification, stages 1 and 2 are evolutional advances and stage 3 is a revolutionary advance. The evolutional advance is made in the stages of operation, aiming at cost-effective solutions to environmental issues in a short period of time. At step 1, firms are able to measure the costs and profits of the development, and minimize the risk of development. If short-term profits can be made at stage 1, most firms will make an active effort to improve environmental performance. From this point of view stage 1 has been the most popular method of product development. Stage 2 needs internal organizational change, so that it is more difficult to achieve than stage 1. However, it does not require external social change. Compared to stage 3, it is easier to carry out because firms at that stage must have experienced such an approach.

Stage 3 is related to the revolutionary advance, and starts at the early stages such as process or strategy development, know-how planning. This kind of change needs the strategic decision-making at the level of top management. At this stage, the division between the goals for environmentally friendly product development and traditional business becomes unclear, so that firms have initiatives for innovation. The approach at this stage needs revolutionary change not only in supply chains but also in the whole society. Balancing new products and the market means using a new method early to meet the social needs. In particular, at this stage, all the firms in supply chains have already made a large investment in technology and production systems, so that all social systems, including customers, need changing. In addition, substantial changes are expected in a series of supply chains, e.g. several suppliers may be excluded.

Martine Charter (2001), from the viewpoint of environmental protection, classified the type of ecodesign into 4 stages: repair, refine, redesign, and rethink. These stages seem not to be exclusive, but placed in parallel. Once a factor X is obtained, however, ultimate transfers are made. Until now, emphases have been placed on end-of pipe, repair modification of existing products, and refining of environmental efficiency. The next transfer is the redesigning of products through new technology and materials. The next ultimate transfer is to rethink, i.e. new innovation to new life styles and behaviors. This is the same as the introduction of new strategies (e.g. product replacement) or other consuming patterns. In particular, transfers to redesign or rethink require a high level of creativity and innovation in product development and design.

Although many researchers have divided the type of ecodesign into 3 or 4 subdivisions, it is ultimately classified into evolutionary ecodesign and revolutionary ecodesign. Evolutionary ecodesign is characterized by evolutionary, increment nature, and changing old behaviors, while revolutionary ecodesign is characterized by revolutionary, far reaching, and developing new behaviors. The following study adopted this classification.

Table 4-1 Classification of Ecodesign

Researcher	Classification			
	Evolutionary Ecodesign		Revolutionary Ecodesign	
Rathenau Institute (1996)	Product Improvement	Product Redesign	Function Innovation	System Innovation
Heidenmark (2001)	Stage 1	Stage 2	Stage 3	
Charter (2001)	Repair	Refine	Redesign	Rethink

Characteristics	Evolutionary	Revolutionary
	Incremental Nature	Far Reaching
	Changing Old Behaviors	Developing New Behaviors

3. Ecodesign strategies

As shown in Chapter 3, ecodesign strategies are drawn at step 2, environmental analysis/assessment. According to Ecodesign Guideline by Norwegisn University of Science and Technology (NTNU), ecodesign strategies are made through analysis, development of improvement methods, study of their feasibility, and final decision of ecodesign strategies.

The product development strategy is typically a part of a firm's whole strategy, which is a method of achieving the goals of the organization itself. Therefore, it is impossible to make the product development strategy a success without taking into account the organizational capability and conditions. In general the product development strategy becomes reactive or proactive depending on growth opportunities, protection for innovation, scale of market, competition, and position in the production/distribution system. Thus we should develop ecodesign strategy, taking into account the product development strategy.

Table 4-2 Reactive versus proactive strategies

	Reactive	Proactive
Growth opportunities	Require concentration on existing products or markets	Require rapid sales growth
Protection for innovation	Can achieve little protection for innovation	Means entering new markets
Scale of market	Are in markets too small to recover development costs	Provide high volumes or margins
Competition	Are in danger of being overwhelmed by competitive imitation	Offer a capability of achieving patent or market protection Supply resources and time necessary to develop new products Block competition from rapidly entering with a second but better product
Position in production/distribution system	Are in distribution chains dominated by other innovators	Provide reasonable power in the distribution channel

Source: Urban and Hauser, Design and marketing of new products, 1993

Ecodesign can result in the creation of new ideas. To make the largest profit from this innovation, it is important to think that ecodesign is the best solution in both the environmental and organizational views. Therefore, the focus should be placed on the development of the most promising strategy for the ecodesign project.

Before ecodesign should be analyzed in more detail at the stage of design, the questions defined are the environmental profile of products and the internal/external ecodesign drivers. Because the priority is determined based on the analysis of environmentally friendly product profiles and the drivers for ecodesign to select the most appropriate strategy. At this stage, the specifications about the environmental requirements for the planned products are determined. Different routes to be followed through ecodesign are called ecodesign strategies.

References on the ecodesign show various ecodesign strategy classifications. This study used the classification method developed by Van Hemel (1994) to identify the characteristics of ecodesign strategies. The classification represented the ecodesign strategies made by ecodesign principles and clustering them.

The objective of the ecodesign strategy classification is to provide product developers with general information about different elements. The strategies are general and applicable regardless of the type of products. They provide product developers with an insight into ecodesign thoroughly and help them not to select an ecodesign strategy that is not environmentally optimized or has a negative effect on the environment.

The ecodesign strategy classification has to meet at least two requirements (Van Hemel, 1998). First, the strategies should include essential elements of ecodesign. Second, the strategies should be feasible for the type of product development and be connected with specific product development processes, terms, and available environmental knowledge. Therefore, the classification plays the role of a supplementary means for ecodesign decision-making and application methodology, providing product developers with ideas of how to resolve environmental problems. Van Hemel (1998) defined the essential elements of ecodesign as the ecodesign principles, and clustered the ecodesign principles by the ecodesign strategies to apply them to design making.

According to existing literature, the ecodesign strategies have several characteristics. The basic classification is that of evolutionary or revolutionary strategy. Ryan (1993) and Manzini (1992) defined ecodesign 6, 7 and @ to be revolutionary and ecodesign 1, 2, 3 and 4 to be evolutionary. In addition, EPA (1992), OTA (1992), and Smals (1993) defined strategy @ as the revolutionary ecodesign strategy, while defining strategies 1 to 7 as the evolutionary ecodesign strategies.

The Table 4-3 shows the ecodesign strategies for product systems (strategies 6 and 7), those for product structure (strategies 3, 4 and 5), and those for components (strategies 1 and 2). In addition, the level of complexity ranges from very complicated to very simple. For example, it is far more difficult to reduce the use of raw materials than to change the product concept. This is because the ecodesign at the level of product components is less revolutionary, needs less decision-making, and has less uncertainty than that at the level of product systems or structures.

Table 4-3 Ecodesign strategies and principals

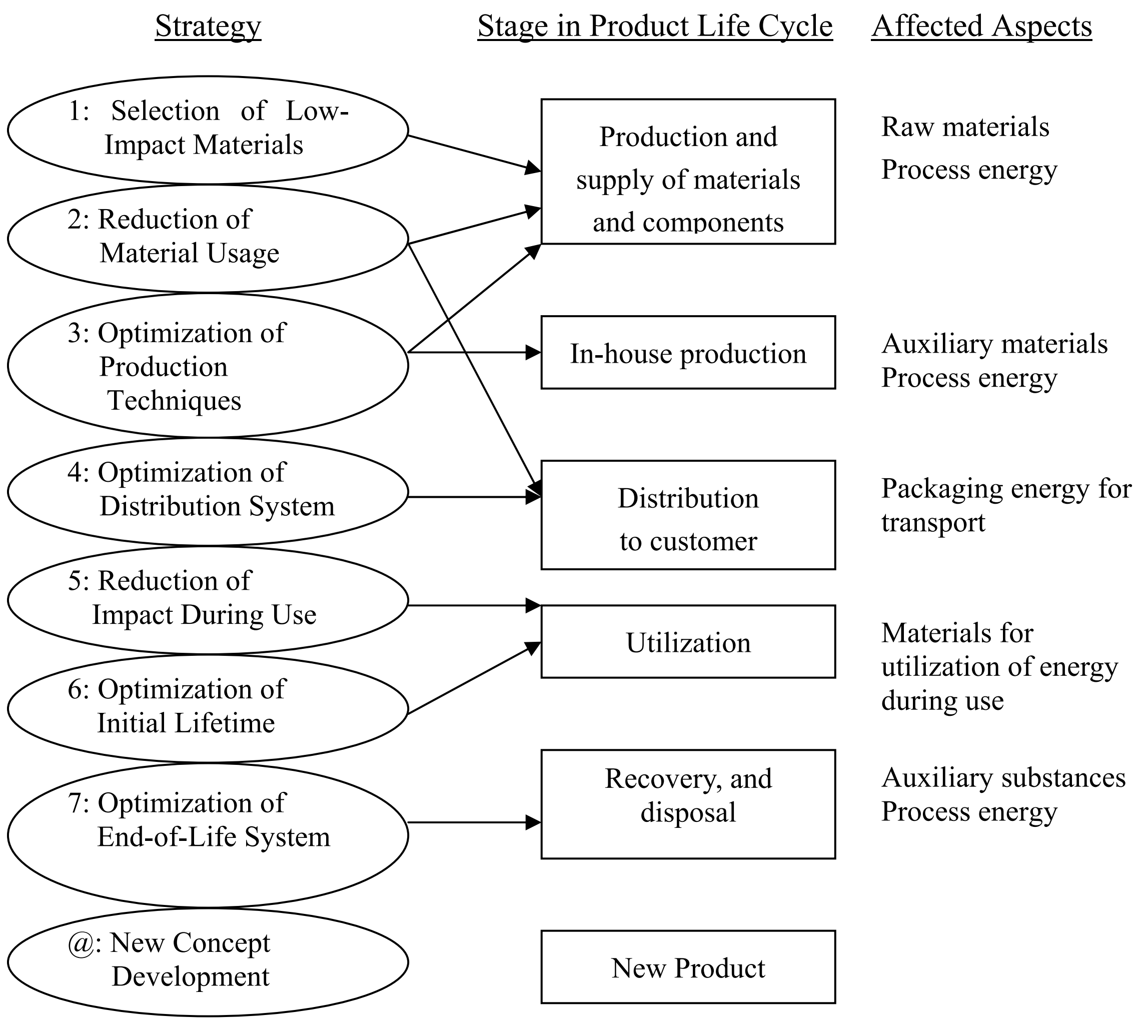
Strategies and Principles			Improvement points
Strategies	Ecodesign Strategies	Ecodesign Principles	
Evolutionary	1: Selection of low-impact materials	Clean materials Renewable materials Low energy content materials Recycled materials Recyclable materials	Components
	2: Reduction of material usage	Reduction in weight Reduction in (transport) volume	
	3: Optimization of production techniques	Alternative production techniques Fewer production steps Low/clean energy consumption Less production waste Few/clean production consumables	Product structure
	4: Optimization of the distribution system	Less/clean/reusable packaging Energy-efficient transport mode Energy-efficient logistics	
	5: Reduction of impact in the user stage	Low energy consumption Clean energy source Few consumables needed Clean consumables No wastage of energy or consumables	
Revolutionary	6: Optimization of initial lifetime	Reliability and durability Easy maintenance and repair Modular product structure Classic design Strong product-user relations	Product system
	7:Optimization of the end-of-life System	Reuse of product (components) Remanufacturing/refurbishing Recycling of materials Safe incineration	
	@: New Concept Development	Dematerialization Shared use of the product Integration of functions Functional optimization of product(components)	

Source : Van Hemel, Ecodesign empirically Explored, 1998

The decision for strategies 6, 7 and @ is typically made at the early stage of the process. They are related to the changes at the level of product systems and are able to change the entire product concept. On the other hand, the decision for strategies 3, 4 and 5 needs the changes at the level of product structures, and consequently it should be made before requirements are completely refined. Strategies 1 and 2 (starting points of the ecodesign), are especially important at the stage where the size and materials are decided, and making changes at the level of components. However, the priority of the strategies depends on the products and their implementation.

Figure 4-2 shows the connection between the strategies and the stages in product life cycle. It is possible to connect the problems at each level of the product life cycle to the strategies to resolve them.

Figure 4-2 Description of ecodesign strategies



Source : Guide tour in ecodesign, http://www.design.ntnu.no

4. Ecodesign Process

The process of ecodesign is not essentially different from conventional product planning process, however, its aim is to integrate environmental aspects into existing planning processes wherever this is meaningful and possible (Tischer *et. al.*, 2000). Ecodesign could be significantly restricted unless it is not integrated into a firm's dynamic management strategies and processes for sustainable increase in environmental performance. Cramer and Schot (1993) pointed out that it was necessary to have an innovative strategy to raise a firm's capability of developing environmentally friendly products by taking into account:

1) Integration of environmental considerations into business strategies;
2) Creation of organizational conditions to create synergy effects between environmental functions and other functions required for business strategy creation;
3) Increase in cooperation among firms.

This is in particular proved by the study results of Lenox and Ehrenfeld (1997) that reviewed how organizations obtain and raise the capability for ecodesign. In the study, they found three essential elements for ecodesign:

1) Appropriate environmental experts;
2) Good internal communication network;
3) Highly acceptable value in a design team

Organizational aspects rather than technical ones are emphasized (Simon *et al.*, 2000). Bragd (1997) reported that corporations were moving from technology to market-oriented strategies and it was necessary to change organizations to allow ecodesign and marketing practices to efficiently collect and distribute environmental knowledge. In order to raise the capability for ecodesign, therefore, a firm needs organizational communication and activities, e.g. efficient cooperation between cross-functional teams internally and involvement of suppliers and customers (McAloone and Evands, 1997).

Table 4-4 Internal and external requirements for ecodesign

External requirements	Internal Requirements
- Initial and sustained motivation - Communication and information flow - Whole-life thinking - Hands-on ecodesign - Position in a competitive market	- Innovative approach - Positive attitude to ecodesign - Commercial opportunity of an ecodesign project

Source: Simon *et al.*, Environmental priorities in strategic product development, 2000

For ecodesign to be effective, it should be not only integrated into product development processes but also taken into account at the early stage of a project like other technical or economic requirements. The integration depends on the type, size, and organization of the firm; that is, on the size of participants (e.g. engineers, suppliers, marketers). Ecodesign should be a process to consistently decrease environmental impacts of products. All the opportunities should be taken to expand the outcomes obtained from conventional products to new products. Contrary to this, innovation is based on experience.

Suppliers play an important role in ecodesign. In the electronic and automobile industries, about 70-80 percent of all parts are obtained from suppliers. For successful ecodesign, therefore, it is essential for a manufacturer to maintain a close cooperation and communication with suppliers. To accelerate the development and implementation of ecodesign initiatives, product-centered environmental management should (Rocha *et al.*, 2000):

1) Clarify the objective and scope of environmental aspects of products;
2) Ensure the capability for ecodesign, including the allocation of resources, knowledge, and responsibility;
3) Ensure the control and regulation of ecodesign.

This section reviews various approaches to the processes and tools for ecodesign to show what ecodesign activities are required at each stage. Bakker divided ecodesign processes into 6 steps: 1) product planning, 2) environmental analysis/assessement, 3) generation of environmentally oriented ideas, 4) evaluation and selection of ideas, 5) overall environmental evaluation/assessment, and 6) modification. The last step, modification, indicates that the design of environmentally friendly products is completed by the ideas for product improvement.

Figure 4-3 shows the analysis of conventional ecodesign processes compared with the 6 steps of Bakker. Since sales and marketing are also important elements for ecodesign, the production, sales and marketing are included in the 6th step, modification.

The various ecodesign processes included: ISO/TR 14062; Ecodesign promising approach (Brezet *et al.*); A Guide to EcoReDesign (Gertsakis *et al.*); Philips Ecodesign guideline (Meinders); Guidelines for product oriented environmental care (PWC); and Product Oriented Environment Management (Rocha *et al.*).

Figure 4-3 Ecodesign processes

<table>
<tr><th>Bakker[6] (1995)</th><th>ISO[7] (2001)</th><th>POEM (2000)</th><th>PWC (1999)</th><th>Promising Approach[8] (1997)</th><th>EcoRedesign[9] (1997)</th><th>Philips Ecodesign[10] (1997)</th></tr>
<tr><td rowspan="2">Product Planning</td><td rowspan="5">Planning</td><td rowspan="2">Orientation stage</td><td rowspan="2">Introduction of product police</td><td>Ecodesign project structuring</td><td>Product selection and general product analysis</td><td rowspan="2">General commitment</td></tr>
<tr><td>Product Selection</td><td rowspan="3">Analysis of the product's environmental impact and setting directions</td></tr>
<tr><td rowspan="2">Environmental analysis/ assessment</td><td rowspan="2">Definition stage</td><td>Selecting a product</td><td>Product specification</td><td>Environment Policy</td></tr>
<tr><td>Choice of a pilot project</td><td>Ecodesign strategy establish-ment</td><td>Green Ideas</td></tr>
<tr><td>Generation of environment-ally oriented ideas</td><td rowspan="3">Concept stage</td><td rowspan="3">Determining projects with partners</td><td rowspan="3">Idea gathering and selection</td><td rowspan="5">The realization of a new-environ-mentally improved product</td><td>Improvement items</td></tr>
<tr><td rowspan="2">Evaluation and selection of ideas</td><td>Conceptual Design</td><td rowspan="2">Implementa -tion</td></tr>
<tr><td>Detailed Design</td></tr>
<tr><td>Overall environ-mental evaluation/as sessment</td><td>Testing/Prot otype</td><td>Engineering stage</td><td>Project management</td><td>Embodiment of concept</td><td>Check</td></tr>
<tr><td rowspan="2">Modification</td><td>Production/ Market Launch</td><td>Volume validation</td><td>Evaluating the success of the project</td><td rowspan="2">Establish-ment for next action</td><td rowspan="2">Review</td></tr>
<tr><td>Product Review</td><td>Evaluation stage</td><td>Evaluation</td><td>Production</td></tr>
</table>

6) Conny Bakker, Environmental Information for Industrial Designers, Self-Published Ph D dissertation, Rotterdam, 1995, email: conny@knoware.nl

7) ISO/TR 14062, Environmental Management-Integrating environmental aspects into product design and development 2001

8) Brezet, Han; Van Hemel, Carolien: "Ecodesign – A promising Approach to sustainable production and consumption",United Nations Publication, Paris, 1997. http://www.unepi.org/home.html

9) John Gertsakis, Helen Lewis, Chris Ryan, A Guide to EcoRedesign, Center for Design at RMIT, 1997, http://www.cfd.rmit.edu.au/

10) Herman Meinder, Point of no return-Philips Ecodesign guidelines, Philips, 1997

Step 1: Product planning

Step 1 includes identification of product/market characteristics, selection of products, establishment of a project team, and decision of project goals and green marketing goals. When deciding the project goals, environmental policy and long-term/short-term goals of the firm’s environmental management system should be taken into account. The timetable, schedule, and budget of product development are also decided at this step.

To perform a project effectively, it is essential for management to declare the willingness for environmental improvement. According to ISO/TR 14062, the declaration should be made to ensure appropriate allocation of resources and time. The declaration was also thought to be necessary for effective integration of all existing management systems, i.e. the integration of an environmental management system and a quality management system. The Promising Approach and other methods also regarded the declaration as an essential requirement for determination of project goals and scope and effective performance of projects.

While the guidelines (PWC) suggested identifying if the firms have human resources to assist suppliers, the Promising Approach suggested an Eco-Portfolio Matrix based on the priority of ecodesign product selection (see Figure 4-4).

Figure 4-4 Eco-Portfolio Matrixes

Potential environmental advantage	Market potential: Low	Market potential: High
High	**2**	**1**
Low	**4**	**3**

Source: Brezet and Van Hemel, ecodesign – a promising approach to sustainable product and consumption, UNEP, 1997

The horizontal and vertical axes of the matrix were the market potential and the potential environmental merit, respectively. It is desirable to select products from which both the two factors are high. The matrix recommended selecting non-complicated products if possible at the beginning stage of ecodesign, because complications are not easily applied.

EcoReDesign regarded the marketability and environmental improvement as important factors in product selection, advising that too complicated or too simple products be excluded.

Philips Ecodesign compared environmental impacts between its products and competitors' products and labeled the products with relatively better environmental performance as Green Flagship. The products that were not included in such products but exhibited relatively good environmental performance were rated into: Eco-Gold, Eco-Silver, and Eco Bronze. This kind of classification was used to carry out the ecodesign in a systematic and consistent way. Such classification plays an important role in the product selection for ecodesign. If a product is selected for ecodesign, its characteristics are analyzed. The analyzed characteristics are used to decide if the product selected is suitable for ecodesign, or to analyze the environmental performance of reference products at Step 2.

Step 2: Environmental analysis/assessment

This Step 2, environmental analysis/assessment, is intended to identify environmental impacts of the product and to provide environmental information for Step 3. In this step an ecodesign strategy is drawn. When developing the ecodesign strategy, it should also be decided if the direction of ecodesign is evolutionary or revolutionary. For the environmental analysis of the product, its environmental information should be assessed. As a variety of requirements, including the market, are converted to a specific concept in this step, main ecodesign activities include participation of ecodesign staff resources, environmental benchmarking, identification of supplier and stakeholder (e.g. government, recycler, users, environmental organizations, etc.) information, analysis of environmental improvement options, development of ecodegisn development agendas, and realization of required environmental programs. In particular the guidelines of PWC recommended that the analysis of ecodesign be carried out with suppliers.

Each method varies depending on the type of environmental analysis and environmental information provision. The EcoReDesign pointed out several different types of environmental analysis tools, recommending selecting an appropriate tool depending on the project resources and time.

ISO/TR 14062, Promising Approach, and Philips Ecodesign recommended that in addition to environmental analysis of the product, internal/external requirements for the product, e.g. social flow, customer requirements, and regulatory trends, be analyzed.

There was a definite difference between the two groups: the former provided environmental information for environmental weakness improvement, while the latter provided general product improvement information with environmental impacts of, and internal/external requirements for, the ecodesign product.

The reason for the effort in environmental performance is that stakeholders, e.g. customers, government, society, etc., demand environmental improvement and taking it into account results in more profit. The ideas obtained during Step 3 are based on environmental improvement, but the profit that a firm can make by carrying it out is also an essential factor. The generation of environmentally oriented ideas should be drawn using not only the information obtained from the environmental analysis/assessment but also the analysis of internal/external requirements.

Step 3: Generation of environmentally oriented ideas

In Step 3, external consulting and supplier involvement is positively made, and the identified environmental weakness and the environmental improvement strategies are used to generate environmentally oriented ideas. The main activities here included assistance in environmental specifications and product concept, establishment of environmental inventory, understanding of the environmental quality of the product, and establishment of environmental programs. In the ISO/TR 14062, the identification of product specifications included product planning, environmental assessment, and generation of environmentally oriented ideas.

In the Philips Ecodesign, product requirement sets are determined by considering the strategies provided and environmental policy and long-term/short-term goals of the environmental management system, and consequently concept product design is decided. The guidelines of PWC in particular recommended developing improvement projects with suppliers in this Step 3. All the six methods required appropriate experts to participate in the process to generate the ideas for improvement. The improvement ideas can be those for parts and processes, the product structure, or the entire product system.

As a method in this step, the EPA manual analyzed the requirements and then used a multi-layer matrix, which include the steps to identify and satisfy the requirements for environmental aspects, performance and prices, and cultural and regulatory requirements.

Step 4: Evaluation and selection of ideas

In this Step 4, the ideas obtained from Step 3 are analyzed in terms of environmental improvement, satisfaction of customers' needs, cost reduction, and feasibility (technical, financial), and the most effective ideas are selected. A single idea or several ideas can be selected. Not only the environmental improvement but also the potential profit and feasibility should be taken into account. In general the ecodesign matrix is used. In the ecodesign matrix, the feasibility of the ideas and potential profits for the firm or customers are qualitatively assessed.

This step corresponds to the conceptual design and detailed design of the ISO/TR 14032. In the conceptual design, the feasibility of the ideas selected is tested. Another primary objective of the conceptual design is the repetitive assessment of conventional ideas and newly developed ideas. After the conceptual design, all requirements including environmental ones are satisfied and detailed ideas for improvement are decided.

The detailed design is a process to decide the ideas selected in the conceptual design step in detail. This step can be defined as an expansion of the conceptual design. In the detailed design, analyzed are concrete and specified information and data, including risk and materials, production technology, recycling technology, market, relevant regulations, costs, and customers' needs. These two design steps are fed back to their prior step if a problem is found at feasibility or in other tests. The guidelines of PWC recommended selecting a project to improve with suppliers at this step.

Step 5: Overall environmental evaluation/assessment

After the evaluation and selection of ideas, the specifications of product structure and properties are drawn. This Step 5 is a process to evaluate or assess the environmental improvement of the finally designed product specifications. The main ecodesign activities at this step include consulting environmental properties databases and ecodesign experts. If the requirements for environmental improvement are not met, the design is fed back to the prior step. At this step, various environmental analysis tools are used.

In the EcoReDesign, the environmental improvement inventory (qualitative analysis) and the LCA analysis for prototypes are used. The analysis tools are selected depending on the goals and scope of the project. If the change from existing products is small, only the changed parts are estimated to assess the improvement. The environmental assessment of final products is also used to inform customers of environmental improvement of the products. Therefore, the evaluation of items should be decided by taking into account the recognition and response of customers.

Step 6: Modification

Step 6, modification, includes providing customers with environmental information of the product, establishing strategic green marketing and communication plans, researching the satisfaction of customers, and searching for information for future ecodesign. It is very important to review customers' or other stakeholders' responses to the environmental aspects of products because these are applied to the next product development.

How to market the developed green products is important as much as effective implementation of ecodesign from Step 1 to 5 because the green product developed will be excluded from the market unless it makes a profit. The ultimate objective of the green product development was to make a profit through such an effort, so that satisfaction of this requirement should be ensured to carry out ecodesign consistently. All the methods are carried out to utilize the environmental improvement information for product marketing and the outcome and response in the market for future ecodesign.

Summary of various ecodesign processes

As Bakker suggested, the 6 conventional ecodesign processes were analyzed and compared in terms of 6 different steps: 1) product planning, 2) environmental analysis/assessment, 3) generation of environmentally oriented ideas, 4) evaluation and selection of ideas, 5) overall environmental evaluation/assessment, and 6) modification. Step 1 includes identification of product/market characteristics, selection of products, establishment of a project team, and decision of project goals and green marketing goals. To perform a project effectively, it is essential for management to declare the willingness for environmental improvement. The goals and scope of the project should be defined based on the environmental declaration of the existing environmental management system and long-term/short-term goals and simultaneously the sales of the products should also be taken into account. The project team should include not only internal experts but also external experts related to the projects.

Step 2 is intended to identify the environmental impact of the product and to provide environmental information for generation of improvement ideas. Each of the methods had a different tool for environmental analysis.

In Step 3, the environmental weakness known and the environmental improvement strategies are used to generate environmentally oriented ideas. All the six methods required appropriate experts to participate in the process to generate the ideas for improvement. If the ideas are drawn based on upstream information, alternatives for improving detailed items are developed. If based on downstream information, ideas for improving a single or several main strategies are developed.

In Step 4, the ideas obtained from Step 3 are analyzed in terms of environmental improvement, satisfaction of customers' needs, cost reduction, and feasibility (technical, financial), and the most effective ideas are selected. Not only the environmental improvement but also the potential profit and feasibility should be taken into account. After the evaluation and selection of ideas, the specifications of product structure and properties are drawn. In Step 5, the environmental improvement of the finally designed product specifications are evaluated or assessed. If the requirements for environmental improvement are not met, the design is fed back to the prior step.

Step 6 includes providing customers with environmental information of the product, establishing strategic green marketing and communication plans, researching the satisfaction of customers, and searching for information for future ecodesign. How to market the developed green products is very important because the green product developed will be excluded from the market unless it makes a profit.

Critical value chain process

In addition to the creative process of product development, it is very important to examine value relationships that are particular to the company (internal value chain) and business in general (external value chain) influencing the product end-of-life. Linking business and end-of-life management is possible through examining the value systems inside and outside the company. After product characteristics, the complex interactions between stakeholders, such as government, producer, consumer, and recycler, determine what happens to a product at the end-of-life. The drivers are diverse and the incentives are relevant (Stevels, 1999; Rose *et al.*, 2000).

The definition of end-of-life is the point in time when the product no longer satisfies the functionality for the initial purchaser or first user (Stevels, 1999, 2001; Rose *et al.*, 2000). The end-of-life system includes the activities associated with strategic planning and implementation which include the collection of products, treatment of those products, and the associated impacts on society and environment. End-of-life treatment includes the activities associated with recovering value from the product manually and/or using automated machinery. On the other hand, the product end-of-life strategies include reuse, service, remanufacture, and recycle (Nagel, 2001; Rose *et al.*, 2002).

Rose *et al.* (2000) observed that lessening the environmental product impact at all stages of the product life cycles is an important topic for manufacturers of electronic and electrical products. The end-of-life is one of several stages of the life cycle gaining attention in the market. It is imperative that companies understand how to improve their products so that the environment impact is lowered at the end-of-life, while still maintaining the economical feasibility of the products. Knowledge of end-of-life strategies early in product design is necessary to develop new products with the highest possible eco-efficiency (Stevels, 1999; Nagel, 2001).

Rose (2000) suggested a new concept that is called Environmental Value Chain Analysis. This methodology links business and end-of-life management inside and outside companies. Besides the product company, parties in the system of methodology include government, producers, recycling company, and customers. The complex interactions between these four stakeholders can finally determine the environmental impact of the product at the end-of-life.

5. Conclusion

This chapter describes the way of developing definition of the environmentally friendly product, the types of ecodesign, and the ecodesign strategies and process. Since the terms of environmentally friendly product and ecodesign may have different meanings in different cases and industries, it is considered to define the exact meaning of the terms in this study.

The types of ecodesign are ultimately classified into evolutionary ecodesign and revolutionary ecodesign. The evolutionary ecodesign is characterized by evolutionary, increment nature, and changing old behaviors, while the revolutionary ecodesign is characterized by revolutionary, far reaching, and developing new behaviors.

According to existing literature, the ecodesign strategies have several characteristics. The basic classification is that of evolutionary or revolutionary strategy. The decision for the revolutionary strategies is typically made at the early stage of the process. They are related to the changes at the level of product systems and are able to change the entire product concept.

On the other hand, the decision for evolutionary strategies needs changes at the level of product structures, and consequently it should be made before requirements are completely refined. Also, the evolutionary strategies are especially important at the stage where the size and materials are decided, and changes are made at the level of components.

Chapter 5: The Research Model: Portfolio matrix for supplier involvement strategies

1. Conceptual framework

The previous chapters of two, three and four are reviewed to establish the research model in this study. Environmental supply chain management involves introducing and integrating environmental issues and concerns into supply chain management processes by involving suppliers on environmentally friendly products development. The supplier involvement in product development has been regarded as an effort to enhance its efficiency and effectiveness. In particular, many researchers have shown the importance of supplier involvement in environmentally friendly product development as a strategy to reduce environmental impacts throughout the life cycle of a product (Steve *et al*., 1999; Noci, 1997; Green *et al*., 1996).

Previous critical literature review chapters of two, three and four identified that most studies have just emphasized the importance of supplier involvement in environmentally friendly product development, while mostly failed to look at the necessity of different strategies by the type of the involvement. It may be, therefore, said that the different supplier management and the strategic approach for supplier involvement are critical considerations for environmentally friendly product development (Wynstra and Pierick , 1999; Dyer *et al*., 1996).

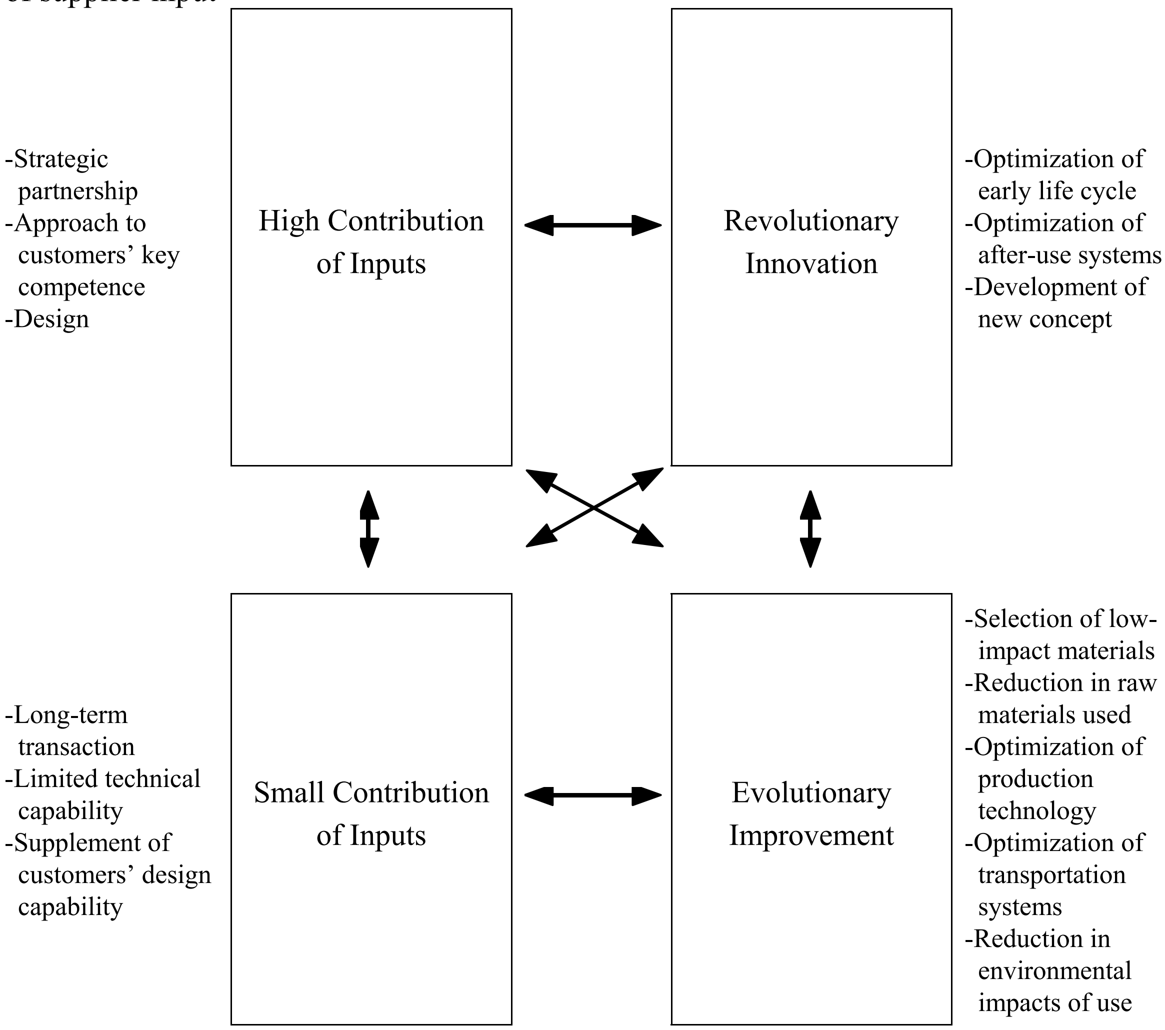
As mentioned earlier, this study suggested the direction of environmentally friendly product development and the contribution of supplier input as factors differentiating the strategy for supplier involvement. These factors were derived from reviewing the environmentally friendly product development processes literature. It was necessary to discuss the stages where suppliers were involved in the process of the environmentally friendly product development. In most of the current, environmentally friendly product development processes, developers first decided the direction of environmentally friendly product development, analyzed the given conditions of the firms to identify feasibility of the development, and then decided the supplier involvement. At this process, the factors for the supplier involvement in environmentally friendly product development was obtained from the questions; which direction of environmentally friendly product does developer have, and which suppliers does developer have to involve. Other studies before have focused on the design stage in environmentally friendly product development; for example, supplier early involvement of in product development (Sanders *et al.,* 2001) and the importance of supplier involvement in design (Dobler, 2000). It was noted that the design process was the best point for supplier involvement to solve and control the environmental problems of products (Dobler, 2000). Considering the various types of supplier involvement, the effectiveness and efficiency by supplier management, and the environmental friendliness regarding as an additional quality of product, however, it was required to establish the strategies of supplier involvement in a wide range from design to engineering stages.

The factor, the direction of environmentally friendly product development, was linked to the level of the innovation of the environmentally friendly product to be developed. In this study, the cluster of ecodesign strategy, proposed by Van Hemel (1998), was considered to analyze the direction of the environmentally friendly product development.

This study used the environmentally friendly product development processes (see Chapter 4) from the viewpoint of developers (manufacturers) to develop the portfolio matrix for supplier involvement strategies. To review the conceptual framework for supplier involvement in product development, it is necessary to describe the relationship between key factors of two different elements. As shown in Figure 5-1, the arrows in both directions between the four elements (two for ecodesign and two for differential supplier management) show all possible relationships. For example, the involvement of suppliers by which input is highly contributable in environmentally friendly product development would result in a single strategic choice. Based on the strategy, the firm is able to involve suppliers in its intended development of environmentally friendly products. However, any strategic selection cannot be made but provided between two elements at the same level. For example, the direction of environmentally friendly product development, i.e. the boundary of evolutionary improvement and revolutionary innovation, will be adjusted according to the ecodesign strategy.

Figure 5-1 shows the conceptual relationship between the direction of environmentally friendly product development and the differential supplier management. The direction of environmentally friendly product development can be classified into evolutionary improvement and evolutionary innovation. Van Hemel (1998) clustered ecodesign strategies according to the direction of environmentally friendly product development. He reported that ecodesign strategies in the direction of evolutionary improvement included the strategies for components and product structure, while those in the direction of revolutionary innovation focused on the strategies for product systems. This classification of ecodesign strategies reflects the difference in the level of complexity. For example, it is far more difficult to reduce the use of raw materials than to change the product concept. This is because the ecodesign at the level of product components is less revolutionary, needs less decision-making, and has less uncertainty than that at the level of product systems or structures. Ecodesign strategies and principles for each direction of environmentally friendly product development are shown in Table 4-2.

Figure 5-1 Framework for the relationship between ecodesign directions and contribution of supplier input



The differential supplier management can be divided into two different subcategories. One is the supplier management that depends on the collaborative relationship with suppliers (Gullander *et al.,* 2001). The collaborative relationship between suppliers and developers (manufacturers) can be divided into the arm's length relationship and the cooperative relationship according to their dependence. The focus of the arm's length relationship is put only on the input, while the attention of the cooperative relationship is taken to not only the input in a close and long-term relationship but also the assessment of suppliers' processes and organizations and other various issues.

The second subcategory is the supplier management that depends on the contribution of suppliers to the environmentally friendly product development. Suppliers can be classified into the strategic partners that provide strategic input (e.g. products, technology, services, etc.) and the partners that provide non-strategic but necessary input (Dyer *et al*., 1996).

This study was focused on the latter supplier management. For the management of supplier involvement in product development, it is more practical to place the focus on actual contributions than on potential ones (Gullander *et al*., 2001). The following characteristics of the relationship between suppliers and developers (manufacturers) show it is not sufficient to rely on the differential supplier management according to the collaborative relationship with suppliers:

1) The recent increase in outsourcing and product complexity has been moving the relationship with suppliers to collaborative, non-market transaction (Imrie and Morris, 1992);
2) Developers (manufacturers) have more depended on their collaborative partners and involved them in product development;
3) The environmental supplier management is typically concentrated on the suppliers in which environmental performance is closely related to the productivity and reputation of the developers or manufacturers (GEMI, 2001).

Table 5-1 shows the characteristics of firms, products, and suppliers according to the contribution of supplier input.

Before developing the strategy for supplier involvement in environmentally friendly product development, two considerations should be taken into account. The first one is which party has a channel of power between the manufacturer and supplier. El-Ansary and Stern (1972) defined the channel of power as "the ability of one channel member (i.e. a firm within a supply chain) to control the decisions of another". The collaborative relationship with suppliers is ultimately created by manufacturers, and the suppliers are controlled in a layered form by manufacturers that have a responsibility for the collaboration (Imrea and Morris, 1992; Gules and Burgess, 1996). This is because there is a difference between environmental pressure from suppliers and manufacturers. If a manufacturer has the channel of power, it will be able to control the collaboration and development. However, in an opposite case, the result will be very dynamic. Therefore, the channel of power is an important criterion for the direction of strategies for supplier involvement in environmentally friendly product development.

Table 5-1 Characteristics of firms, products, and suppliers according to the contribution of supplier input

<table>
<tr><th rowspan="2">Characteristics of</th><th colspan="2">Contribution of supplier input</th></tr>
<tr><th>Small</th><th>High</th></tr>
<tr><td>Firms</td><td>-Products are manufactured in accordance with developer (manufacturer) design
-Technical capability of suppliers is limited.
-Suppliers are involved after detailed design.
-Long-term contracts are made as long as unique production equipment of suppliers is necessary.</td><td>-Design and production services are provided in accordance with developer (manufacturer) specifications.
-Responsible for subsystems
-Mostly affiliates of the developer
-Suppliers are involved before concept decision.
-Full services are provided.</td></tr>
<tr><td>Products/inputs</td><td>-Non-strategic but necessary inputs
-Technical skills or engineering capability is not required.
-There is no interaction between other inputs.
-Gray box</td><td>-Strategic inputs
-Based on technically complicated new technology
-Multi-interaction with other inputs
-High value inputs
-Black box</td></tr>
<tr><td>Supplier management</td><td>-Durable arm's length relationship
-Single functional interface
-Competition between a few suppliers
-Price benchmarking
-Compensation for transaction-specific investment is ensured.</td><td>-Strategic partnership
-Multi functional interface
-Frequent communication
-Capability bench marking
-Non-contracting supplier performance (innovation, quality, response) is important.</td></tr>
</table>

The second thing to be taken into account is the conditions of firms. Literature on supplier involvement in product development has used the contingency theory to suggest a topic (e.g. Souder *et al*. 1998). The contingency theory is to understand and describe the situations and organizational issues. According to the theory, firms have different conditions and unique organizational characteristics. They need to adapt themselves to the most appropriate management. To involve suppliers in product development, it is necessary to analyze the method of the involvement and the key processes to be controlled. Therefore, it is necessary to understand that there is no single way to approach the product development and collaborative processes.

2. The establishment of a research model: Portfolio matrix for supplier involvement strategies

For the supplier involvement in environmentally friendly product development, we suggest a portfolio matrix for environmentally friendly product development. The matrix in Figure 5-2 can be used to develop strategies for supplier involvement in environmentally friendly product development. The portfolio matrix was based on the approach by conceptual classification, not the quantitative rating system. It was not intended to show the characteristics of a specific subject, but to provide a useful integrator for the analysis and determination at a preliminary stage of supplier involvement strategy development (Day, 1977).

Figure 5-2 Portfolio matrix for supplier involvement strategies

Directions of environmentally friendly product development		Contribution of supplier input: Small	Contribution of supplier input: High
	Revolutionary innovation	Leadership Development	Partnership Development
	Evolutionary improvement	Manufacturer-Driven Development	Exploitation

Manufacturer-Driven Development

In this strategy, manufacturers involve suppliers that provide input with smaller contribution in the evolutionary improvement of environmentally friendly products. Since the suppliers are not able to resolve the environmental issues of their input independently due to technical limits, the development processes are driven by manufacturers. The development of environmentally friendly products is carried out systematically based on the channel of power of manufacturers. The role of manufacturers is limited to supplementing the capability for environmentally friendly product development of suppliers, while suppliers have a chance to meet a higher level of technology for manufacturers, getting a supplier's goodwill from the manufacturers. If a supplier is not able to provide the input to meet the needs of customers, it will be deprived of the opportunities to make a transaction with the manufacturer by a small number of its competitors. In this strategy, the information from manufacturers is accurate and definite, and frequent communication is not required.

Exploitation

In this strategy, manufacturers involve suppliers that provide input with higher contribution in the evolutionary improvement of environmentally friendly products. Contrary to the manufacturer-driven development strategy, manufacturers exploit the input from suppliers that have technology they don't have. Since suppliers participate in environmentally friendly product development with their own environmental technology, their involvement is not decided by the channel of power of suppliers in the supply chain, but is the result of environmental pressure in the market. Therefore, manufacturers are not able to drive the environmentally friendly product development systematically, but suppliers should be involved in the development processes in an actual and effective way. Besides the relationship that satisfies specific standards for environmentally friendly product development, information for a competitive advantage is required. Suppliers do not obtain detailed information from manufacturers. Although the necessity of information communication is lower than in the partnership development strategy, manufacturers mainly drive it.

Leadership Development

In this strategy, manufacturers involve suppliers that provide input with smaller contribution in the revolutionary innovation of environmentally friendly products. This is similar to the manufacturer-driven development in the aspect of implementation. However, it is a strategic approach to improve environmental quality of non-key components and first requires manufactures to focus on environment-centered business ethics and values. Therefore, it plays the role of a horizontal strategy for product differentiation since it is not focused on satisfying the needs of all but particular customers. In addition, the main stream is not direct responses to environmental regulations, but those beyond regulatory compliance. There are many cases of this strategy, and most of them are concentrated on the design of packaging materials. For further innovation, manufacturers require concrete information from suppliers and make limited communication with supplier in order to reduce uncertainty.

Partnership Development

In this strategy, manufacturers involve suppliers that provide input with higher contribution in the revolutionary innovation of environmentally friendly products. Manufacturers share environmental vision, and drive close communication and collaboration, with suppliers to improve their environmental competitiveness. In addition, they count suppliers as strategic partners in product development, and response to business environment changes jointly with suppliers to enhance their status. Suppliers typically provide components that are highly customized or subsystems that need strong technical or engineering capability. In particular the subsystems of suppliers are close to the key competence of manufacturers, so that they make an effort to maintain their exclusive technology and make rapid innovation. For this, both sides exchange information on a regular basis. The relationship between manufacturers and suppliers is based on trust. Both of them commonly accept the risks, and simultaneously enjoy the benefits involved in the investment to enhance their environmental competitiveness. Consequently, technical innovation accompanying long-term investment is required. New and environmentally responsible products will be developed, resulting in a profit in the long run.

This study elaborated the portfolio matrix as a decision-making model for establishing supplier involvement strategies in environmentally friendly product development. The portfolio matrix showed that the strategy for supplier involvement in environmentally friendly product development was not 'one-size-fit-all,' but dependent on the direction of environmentally friendly product development and the contribution of supplier input. These strategies would be used as a useful tool to support the decision-making process, which was defined as a core competence of a firm by Fine and Whitney (1996). The research model will be applied to the empirical study in order to test the model established and give answers to the research questions.

Part II Empirical Part

Chapter 6: Electronic industries in Korea

1. Introduction

From the previous chapters of literature review, the research model of portfolio matrix for supplier involvement strategies is established. The matrix has two dimensions and these are directions of environmentally friendly product development and contribution of supplier input. In order to examine the portfolio matrix, this study has chosen the Korean electronic industry. The main reasons to choose the Korean electronic industry in this study are as follows.

First, the environmental regulations and requirements in global markets relatively are very high and the level of awareness in the industry is quite high.

Second, the Korean electronic industry shows a high level of market share and dominance in certain products including semiconductors, mobile phones, monitors, air conditioners, TV and refrigerators.

Third, the author has extensive experiences in the electronic industry and is well aware of environmental issues in product development and supplier management.

These reasons make this doctoral research attractive for the author and valuable to the industry. More importantly, the feasibility and applicability of this research model in the empirical study is considered with high priority, and the author carefully decided to choose the Korean electronic industry for substantial research output as a result of employing the portfolio matrix.

2. Environmental issues

2.1. Environmental regulations for electronic industries

Electronic industries are recognized as a promising growth engine in the 21st century. They need international collaboration in technology, market, capital, etc. With key technology and development in electronic parts industries, strategies for collaboration with electronic parts industries are the essential elements to maximize the competitiveness in this area.

The market size of the world electronic industries is over 1.2 trillion dollars. About 30.7 percent is in the United States, followed by Japan and China. Korean electronic industries occupy about 3.1 percent of the world electronic market. Table 6-1 and 6-2 shows the market size and production of electronic industries in the world. The market size of world electronic industries expands or contracts depending on the release of new products.

Table 6-1 Market sizes of world electronic industries (million dollar, percent)

	2000		2001		2002	
	Market size	Percentage	Market size	Percentage	Market size	Percentage
Total	1, 356, 368	100.0	1, 217,236	100.0	1, 253,059	100.0
USA	472,257	34.8	374,020	30.7	380,004	30.0
Japan	208,989	15.4	192,102	15.8	194,005	15.5
China	81,660	6.0	91, 861	7.5	105,064	8.4
Germany	63,327	4.7	59,138	4.9	59,649	4.8
UK	62,198	4.6	58,432	4.8	59,547	4.8
Korea	41,228	3.0	38,335	3.1	39,713	3.2
France	40,497	3.0	38,774	3.2	38,605	3.1
Taiwan	25,310	1.9	22,417	1.8	22,950	1.8
Singapore	22,973	1.7	21,218	1.7	21,889	1.7
Malaysia	16,401	1.2	14,054	1.2	14,525	1.2

Source: Yearbook of World Electronics Data 2002, Vol.3.

Table 6-2 Production of world electronic industries (million dollar, percent)

	2000		2001		2002	
	Market size	Percentage	Market size	Percentage	Market size	Percentage
Total	1, 366, 369	100.0	1, 210,341	100.0	1, 247,896	100.0
USA	385,145	28.2	314,965	26.0	318,890	25.6
Japan	263,451	19.3	230,869	19.1	231,984	18.6
China	81,035	5.9	94,539	7.8	110,613	8.9
Korea	76,059	5.6	67,393	5.6	69,861	5.6
Germany	52,622	3.9	48,270	4.0	49,013	3.9
UK	52,203	3.8	47,154	3.9	47,890	3.8
Singapore	47,318	3.5	38,390	3.2	39,916	3.2
Malaysia	44,539	3.3	38,123	3.1	39,216	3.1
Taiwan	50,193	3.7	42,644	3.5	43,699	3.5
France	38,391	2.8	34,692	2.9	35,293	2.8

Source: Yearbook of World Electronics Data 2002, Vol.3.

Environmental regulations applied to the electronic industries are focused on the disposal and recycling of waste, limitation and restriction of hazardous materials, and reduction of energy consumption. Many members in the EU, including Germany, and Japan have legislated for the recycling of electronic products and the restriction of hazardous materials; sanctions are levied if the regulations are not complied with. Therefore, these environmental regulations are a significant burden to the firms that export products to these countries, and have been increasingly dispersed all over the world.

Eco-label

Eco-labeling is one of the measures applied to electric and electronic products. The electric and electronic products under the Eco-labeling system include dishwashers, refrigerators, washers, lamps, etc. Among them, the labeling was first applied to lamps in 1995. The eco-labeling systems were developed.

As of April 2001, standards for the Eco Label were made for 17 product groups including washers, dish washers, refrigerators, PCs, etc. Draft standards for an additional 3 groups, e.g. batteries, waste bags, etc., were developed and reviewed, and those for TVs, tires, and vacuum cleaners are being prepared. Each EU member has specific environmental labeling programs. For example, Germany has implemented Blue Angel that requires governmental organizations to purchase only the products with that label.

The USA introduced Green Seal, an environmental mark under the lead of the private sector. The environmental system does not show trade effect by mandatory standards, but the requirements such as the selection of products in the export thereof, the standard granting environmental label, and the inspection of factories and facilities may weaken export competitiveness. Also a trade wall effect may be caused indirectly under the consumption patterns of products, the assumption of costs for satisfying the label granting standard, and the preference of consumers in each country. Currently, the US environmental mark system is applied to 34 products including tissue, paint, refrigerators, coating paper, vacuum cleaners and washing machines.

Energy Labeling

In September 1992, the EU Committee started the Energy Labeling System to balance the existing appliance energy labeling programs of its members and to promote efficient use of energy. In accordance with the Energy Labeling System, appliances should be labeled with the manufacturer's name, model, capacity, energy efficiency rate, energy consumption, noise level, etc. The EU Committee has developed the standards for 7 product groups, i.e. refrigerators, freezers, washers, tumble dryers, washer dryers, lamps and dish washers, and is expanding it to water heaters, ovens, and air conditioners. The products without the labels are restricted in the market.

The EU has regulated the energy label for washers, washer dryers, and refrigerators since April, 1996 and restricted those kinds of products without the label to be sold since October, 1996. The most representative regulation on appliances is for energy consumption. The European Association of Consumer Electronic Manufacturers (EACEM) has established the regulation on energy consumption for 5 kinds of electric/electronic products, i.e. TVs, VCRs, audios, wireless phones, and chargers. The regulation is not compulsory. The EU declared the plan to make a new compulsory regulation if electric or electronic industries do not comply with the regulation.

The Energy Labeling System was also applied to lamps. Since July 1999, all lamps and fluorescent lamps have been labeled with energy an efficiency rate (7 levels), brand name, supplier address, lamp description, model design, usage, and model test method. Since January, 2001, the selling of all the lamps not complying with the new standard have been restricted.

The Department of Energy (DOE) enacted the National Appliance Energy Conservation Act in 1987 and presents the minimum energy efficiency standards with respect to household appliances (including air conditioners, washing machines, drying machines, refrigerators, electric ovens, dishwashers, gas heaters, TVs, microwave ovens, etc.)

Also, the DOE introduced the Energy Star program in 1992 and applied energy efficiency standards to IT instruments including PCs, controllers, facsimiles, scanners, duplicators, printers, multimedia terminals, microprocessors, power supplies, and software. While this system is operated by a voluntary partnership between the EPA and manufacturers, the government does not give a mandatory provision with respect to the energy efficiency of electric and electronic products, but attracts voluntary civil participations through this program and further invites indirectly to produce energy-efficient products through the differentiation of governmental purchase including the purchase of Energy Star products in electric and electronic products such as PCs in accordance with the administrative orders.

IPP (Integrated Product Policy)

The IPP include action plans of the EU to reduce environmental impacts of products. It was intended to develop a framework to promote the production and consumption of environmentally friendly products. With the increased recognition of the necessity of product-centered integral environmental policy, the IPP was officially discussed at the EU Environmental Minister Meeting in 1999, and Green Paper was adopted on February 7, 2001. In June, 2003, the European Commission adopted it as an official agenda.

The goals of the IPP were to: 1) develop a framework to promote environmentally friendly products; 2) develop environmentally friendly products, as follows.

- Life Cycle Assessment, i.e. the analysis of the life cycles of products and their ecological effects and to portray them in a transparent way.
- Improvement of the ecological properties of products and services based on the whole life cycle.
- Decrease of material flows, i.e. protection of the natural biological, substantial and energetical resources. The consumption of the economies in total and of products along the whole life cycle in particular will become less than a factor 4 to 10 compared with today.
- Prevention of local or regional durable environmental damages which are caused by the withdrawal of materials like soil, water and minerals.
- Prevention of a capacity overload of the environment with ‘mass pollutants’, like e.g. carbon dioxide, nutrients and acidifiers.
- Prevention of a capacity overload of the environment with anthropogenic foreign matters, like e.g. xenobiotica.
- Prevention of a capacity overload of the environment by release/mobilization of

natural pollutants, like e.g. toxic heavy metals.

- Integration of the environmental policy in the range of products in other policies (trade, economy, purchase, development, etc.).
- Ecologization of products and services, of consumption and disposal.
- Prevention of dangers and risks concerning the environment and humans.
- Consideration of the tempo between anthropogenic entries in the environment and the reactivity of the environment.

Significant possibilities can result from reaching these goals: ecological effectiveness; economic efficiency; political acceptance.

Eco-design Requirements of Energy-using Products

The objective of Eco-design Requirements for Energy-using Products (EuP) was to ensure the free movement of energy-using products by developing a framework to take into account environmental aspects at the state of product development, and ultimately to contribute to sustainable development. Energy-using products are defined as products that use energy (electric energy, fossil fuel, recycled fuel, etc.) to work, including those of which parts are individually sold. The final version of the requirements, Framework Proposal, was published on August 1, 2003. The energy-using products marketed in the EU should be developed in accordance with the ecodesign processes specified in the requirements. Upon complying with the requirements, the energy-using products should be marked with a 'CE Mark' to be sold and distributed. In particular the eco-design processes should include the assessment of environmental performance and the development of ecological profiles.

Many major electronic companies, including Apple, AVAYA, Fujitsu Limited, GE, Intel, Lucent Technologies, and Schneider Industry, participated in the meeting held on November 18, 2002 to develop the requirements. Some companies like NOKIA and HP have already opened the environmental information of their products on the Internet. On the other hand, some firms have their own environmental mark certification systems. For example, some electronic companies in Japan apply their own environmental marks to their environmentally friendly products.

WEEE

On June 7, 2001, EU Environment Ministers reached a final agreement with respect to the WEEE Directive (a Directive on Waste Electrical and Electronic Equipment) and RoHS

Directive (a Directive on the Restriction of the use of certain Hazardous Substances in electrical and electronic equipment) that included the response to common environmental problems between members. While WEEE Directive and RoHS Directive have been integrated in the process of discussions, both of them were separated respectively to reflect the demand of European industries.

EU enacted and promulgated on February 17, 2003, the WEEE Directive (a Directive on Waste Electrical and Electronic Equipment). With respect to all electric and electronic products distributed in the EU, manufacturers who produced and sold such products shall be fully responsible for removing, disposing or recycling waste products, and produce products that generate small waste and are easily recyclable in essence from August, 2005 in accordance therewith.

These regulations oblige producers to recover and recycle, in a certain percentage, electric and electronic products not incinerated and reclaimed after used by consumers, which cover wide electric and electronic devices from small household electric appliances to IT and communication devices. The percentage of recovery, reuse, and recycle is determined for major electric and electronic products, and only the electric and electronic products of enterprises that conform to this percentage can be sold in the EU.

EU RoHS (The Restriction of the use of certain Hazardous Substance in Electrical and Electronic Equipment)

EU RoHS (a Directive on the Restriction of the use of certain Hazardous Substances in electrical and electronic equipment) is restricted to inorganic substances including lead, mercury, cadmium and hexavalent chromium, and organic substances including PBB(Pro Brominated Biphenyls) and PBDE(Pro Brominated Diphenyl Ethers) widely used as bromine flame retardants for use in electric and electronic products from January 1, 2006.

Promulgated March 2, 2003, this directive aims to balance the laws and regulations of EU members with respect to the restriction of hazardous substances in electric and electronic products and to contribute to human health, environment-friendly recovery, and disposal of waste electric and electronic products.

Most electronic products are composed of environmentally unfriendly substances, e.g. plastics, Pb, glass, Hg, Cr-6, which have adverse influences on the natural environment.

Table 6-3 Hazardous materials in electronic parts

Hazardous materials	Electronic parts with the hazardous materials
Pb	Switch (Tact), Disk, Cable, Diode, Capacitor, Transistor, Others
Cd	Connector, Plug, Cord, Remote Controller, Capacitor
Cr-6	Screw, Bolts, Pin, Reinforcement
PBB, PBDE	Out-Case Plastic, PCB
Hg	Lamp

Due to the nature of electronic products, various environmental pollutants are discharged from the processes of producing electronic products discharge. Most of the electronic parts in electronic products contain hazardous materials including Pb, Cd, PBB, PBDE, etc. Moreover, electronic products have more parts containing hazardous materials than electric products (see Table 6-5 and 6-6).

Under the rapidly changing technology in electronic products, the product life cycle is decreasing and consequently electronic product waste is increasing. Since most electronic parts contain hazardous materials such as Pb, Cd, PBB, PBDE, etc., collaboration with suppliers to avoid the use of these pollutants is seriously required. As shown in Table 6-6, many hazardous materials are used in electronic parts for stabilizers, paints, connectors, and reinforcements.

Table 6-4 Applications of hazardous materials in electronic parts

Hazardous materials	Applications
Pb	Part Lead Terminal Surface Treatment, Cable Heat-resistance, Stabilizer
Cd	PVC Paint, Stabilizer
Cr-6	Connector
PBB, PBDE	Flame retardant
Hg	Fluorescent lamp

This directive will have an affect on enterprises including the prohibition within the EU territory if the laws and regulations are not conformed to. There will be additional costs for the analysis of hazardous substances, and the increase of raw costs in the conversion into the alternative materials and parts.

Regulation of ozone layer destroying substances and regulations of warning label attachment

Part 6 of the 1996 Clean Air Act of the USA states the regulations for the ozone destroying substances for the protection of the stratosphere. In accordance with these provisions, the ozone destroying substances shall be classified into Class I and Class II substances according to the influence on the destruction of the ozone layer.

Class I substances have a large destructive effect on the ozone layer and have a rapid regulation schedule, while Class II substances are less destructive than Class I substances on the ozone layer and have a looser regulation schedule. The production of Class I substances, including CFC and halogen, shall be suspended until 1999. However, the production of methyl chloroform will be permitted by 20 percent until 2001, but shall be suspended after January in 2002. The trade and use of Class II substances including HCFC will be suspended from 2015, the production of which shall be completely suspended from January 2030. Also, warning labels shall be attached to any container storing or transporting regulated substances pursuant to the Clean Air Act or any product that uses regulated substances in the manufacturing process, and any product with the warning label not attached is prohibited from being imported into the USA. For example, where any container contains, stores, or transports Class II substances such as HCFC, or the same are used in the manufacturing, any product with the warning label not attached will be prohibited to be distributed or imported in the USA.

Recycling regulation related to electric and electronic products in Japan

Japan prepared the Basic Recycling Society Promotion Act to give political priority to the control of waste generation, to reinforce waste management actions, including the imposition of obligations to recover and dispose waste products on industries, along with the enforcement of the relevant laws and regulations including the Packing and Electric Household Appliances Recycle Act and the PC Recycle Act for the purpose of the reduction of various waste discharge, the expansion of recycling, and the prevention of illegal transactions. It seems that this aims not only to attract resource saving through the minimization of waste discharge and the maximization of recycling, but also to respond actively to the control of air pollutant emissions such as dioxin from incineration and reclamation, the prevention water pollution and the security of waste reclaiming ground. The Ministry of Environment of Japan provided legally in the Household Electric Product Recycling Act the obligation of recycling with respect to household electric products in 2004. The subject of the Household Electric Product Recycling Act enforced since April of 2001, includes refrigerators, washing machines, air conditioners and TVs, while manufacturers shall accept and recycle waste electric products and retailers shall accept from consumers and deliver to the manufacturers waste products sold by them. For PC, the regulation of waste discharge with respect to office PC was enforced preferentially from April, 2001, and the regulation of home PC will be enforced from April, 2003. Notebook computers, monitors and PC peripherals were selected as the subject of regulation. Also the prepayment system will be first introduced to reflect the expenses required for the recovery and recycling of home PC on the product purchase price, and the Act provides the goal of a 50 percent recycling rate to be achieved by producers for Desk Top PC, 20 percent or more for notebook computers and 55 percent for monitors (CRT, LCD Display).

This Act is characterized to divide the roles of manufacturers (including retailers), consumers, and the government (local government) for recycling. Accordingly, manufacturers (including retailers) shall construct the recovery and recycling system of waste products discharged by consumers, while consumers shall deliver waste products to retailers and manufacturers for the environment-friendly disposal and pay the expenses for recycling. It is provided that the government (local government) shall take actions for recycling including technical and facilities support and publicity.

Recycling regulation related to electric and electronic product in Korea

This system is based on the Act of resource saving and recycling promotion (enforced in January, 2003), the subject of which includes refrigerators, washing machines, air conditioners, TVs, PCs, mobile phones and audios (enforced in 2005). With respect to major regulations, producers shall recover and recycle more than the mandatory recycling amount of each waste product and waste packing, and if any producer has not conformed to this provision, such producer shall assume more than the expenses required for the recycling.

2.2. Trend and implications of environmental regulation in major countries

The environmental regulation of the electronic parts industries in major countries appears in environmental standards, environmental mark systems, mark and packing waste regulations, product taxes (including energy taxes and carbon taxes), and industrial regulation. The reinforcement of regulations like these will increase costs and investments for the preparation of a response system, including the development of environmental technology as well as direct trade effect and then raise raw costs of export, which will result in poorer export competitiveness.

The environmental standard that is a typical type of environmental regulation includes product standard, manufacturing process standard, air, water and noise standard, product standard related to the supervision of the compliance to the standard applied to product testing, product and manufacturing process, and the waste management standard imposed to producers and distributors. For energy tax and carbon tax with respect to energy invested in the production, and superfund tax of the USA imposed on manufacturing and import of oil products and hazardous chemicals, they actually have a similar effect on customs, which will affect product costs.

For labeling, advanced countries are obliged to attach a label approved by the competent authorities in production, sale, distribution, export, and import to regulate the processing and production of hazardous products.

It is expected that the WEEE of the EU will have the most comprehensive influence on production and export. Electronic products discharge pollutants in production because of their nature but may be recycled even after their use. However, as the product life span shortens, because of the rapid speed of technology, waste will inevitably be discharged in large quantities. Specifically as the EU raises the percentage of reuse and recycling, any company that has no recycling point in Europe shall be compelled to recover waste, electric products and transport them to its home country, which will increase its costs.

With respect to hazardous substances regulated by RoHS of the EU, there is a little room until the enforcement of regulation, but it will take much time and effort to secure the processing technology and reliability for the development and application of alternative materials. Specifically given that advanced purchasers already demand purchase guidelines at the level of RoHS regulation to domestic suppliers or OEM businesses, it is a very serious issue that the export itself will be threatened without an active response thereto.

The EU and Japan have already secured and apply to the products the relevant technology including lead free soldering that removes lead completely, regardless of the time point of regulation. They announced they will apply this to all electric and electronic products and demand the same from relevant suppliers. Accordingly, substitute technology for hazardous substances requires new investment and additional time, which will cause the increase of product costs, but the industries will lose the hegemony of competition in the global market if they do not respond actively to the movement of advanced industries.

In Korea, the Korea Electronics Association (KEA) organized the panel meeting with government (Ministry of Trade and Industry), major electronics manufacturers including

Samsung electronics and LG electronics, academics and research institutions since 2003. Having communication channel among each key players, the Korean electronics industry can identify the issues to improve for EU WEEE and RoHS requirements. Even the industry collects and share information with regard to testing results and material requirements under the EU WEEE and RoHS. During this process, the industry can save time and efforts to prepare the legal requirements from international markets and increase competitiveness in the current global electronics market position

2.3. Influence of environmental regulation on enterprise activities

Environmental regulations for the protection of the environment are increasingly extended to consumer products including household electric products and IT devices, which acts as a trade barrier. Any company with relatively poor technology will not meet high environmental standards and abandon the export of products in time. With the environmental standards of the EU, the relevant industries deeply participate and reflect their opinions in its enactment process, which causes relatively adverse conditions to imports. Specifically, the EU reinforces the obligations of manufacturers and importers regardless of items and imposes the obligation to recover and recycle products free of charge.

Table 6-5 Influence of environmental regulation on enterprise activities

Corporate Activities	Prohibition of Hazardous Substances	Collection and Recycling of Disposed Products	Energy Consumption Regulation and Electric Wave Regulation
Purchasing	◎		
Product Design	○	◎	○
Manufacturing	◎	○	
Sales	◎		◎
Collection and Recycling		◎	

◎ : Direct Impact, ○ : Indirect Impact

Accordingly, direct costs of manufacturers and importers will be sharply increased. It is especially evaluated that the obligation of recovery and recycling is generally far more adverse for the businesses out of the area than European businesses, which will lead to weakened competitiveness of the relevant businesses.

On the basis of the subject of regulation, the environmental regulations of each country and international convention may be classified largely into the prohibition of hazardous substances, recovery and recycling of wastes, and the regulation on energy and electric wave. The influence of these environmental regulations on the electric and electronic industries is examined around the supply chain management activities of enterprise as follows:

Prohibition of Hazardous Substances

Major environmental regulations in relation to the prohibition of hazardous substances are distributed in the world, including the EU and USA's restriction on the use of substances that can destroy the ozone layer based on RoHS of the EU and Montreal Protocol, Restriction on batteries that contain heavy metal, Climatic change convention, Regulations on the voluntary reduction of PFCs by the semi-conductor industry, and REACH of EU. Prohibition of hazardous substances and its related environmental regulations can directly affect supply, manufacturing, and sale in the activities of enterprise management.

Supply Stage

Due to the prohibition of hazardous substances and their related environmental regulations, suppliers have a burden to develop and research substances that can be substituted for prohibited substances. Global companies of developed countries, such as SONY, Philips, and IBM, use their own evaluating system of environmental characteristics when they procure raw substances, parts, and expendable substances and when they select cooperative companies (e.g., suppliers, distributors). They have their own green procurement guidelines, reflecting the trends of their country's laws and international environmental regulations, and they impose the guidelines on suppliers as a part of contract condition. Accordingly, if companies keep using hazardous substances specified by different environmental regulations, they might damage the image of companies, and might have a difficult time in advancing into the market.

Manufacturing Stage

At present, Korea is evaluating substances that can be substituted for prohibited substances. It is estimated to take at least 2 or 3 years just for analyzing substances for parts. Therefore, it will be difficult to exclude hazardous substances completely by 2006. The EU is in the process of specifying detection standards of hazardous substances and standardizing a confirmation method; this is led by the EICTA (European Information and Communications Technology Industry Association), an electronic association for 26 leading companies and 3000 small and medium-size companies of 16 member countries. Companies in Korea feel pressured by this trend to eliminate hazardous substances for products. Prohibition of hazardous substances that can destroy the ozone layer, specified in the Montreal Protocol, can affect the manufacturing of electronic products and semi-conductor, can weaken price competitiveness, and can lead to the reduction of exports. Therefore, it is imperative to develop substitute substances for chlorofluorocarbons (CFCs).

To be able to use substituted substances, companies require new processing facilities and substances for parts, which result in additional investment and development expenses. In addition, companies in Korea should respond to global warming through processing improvement and clean fuel use. Most Korean companies purchase manufacturing equipment such as PFC semi-conductors and raw/subsidiary substances from advanced countries. Additional investment to construct new manufacturing lines is expected.

Sales Stage

If the electrical and electronic industry in Korea does not recognize the environment as an important element of product manufacturing, they will lose competitiveness in the market. Before purchasing a product, general consumers evaluate environmental superiority of the product in addition to price, product quality, and design. First, they check the approval label of an environment-related certificate and ask for other environmental information on product.

For example, the Eco-label used by the EU has been controlling the sales of certain products in the EU by regulating the use of prohibited chemicals during the manufacturing process to reduce environmental damage. Consumer protection organizations and environmental groups, as well as eco-labeling companies, are actively promoting eco-labeled products to be environment-friendly. By using the promotion as a strategy to protect the environment, eco-labeled products are steadily increasing. As more environmental information about raw substances and companies is accumulated, the information on the finished electric and electronic products will be published in the future. Based on the environmental information, consumers will make purchasing decision; and this will directly affect the sales of products.

Collection and Recycling of Disposed Products

As examples of major environmental regulations on disposed products, there are the Waste Electrical and Electronic Equipment (WEEE) of the EU and the Japanese Recycling System of Electronic Appliances and PCs. These regulations can influence business activities especially the product designing stage and disposing stage.

Product Designing Stage

To increase recyclability of disposed products, electric and electronic companies need to design biodegradable, environment-friendly products by simplifying product substances and selecting reusable substances. To design a product that can be disassembled easily, companies should simplify the structure of finished a product and standardize a disassembling order. At the product designing stage, it is also important to consider other elements to enable disassembly with standard tools.

Recent electronic products are designed to be light and small in size. Companies should consider additional expenses for a modularized design to lengthen product life and to make upgrading and after service easy by using interchangeable parts.

These environmental regulations would prohibit companies from using ‘clever chips’ which prevent products from being reused. It is required that a certain rate of a finished product should be reused or recycled. If clever chips are used, it will be difficult to meet the minimum recycling requirement. In this case, the manufacturing process for finished products should be changed partially; and this will increase manufacturing costs. As a result, environment-friendly designs will be used to reduce recycling expenses, and light products will be preferred.

Collection and Recycling Stage

With respect to the WEEE of the EU, the regulations are applied to all the electrical and electronic equipment waste before burning or land filling it. Most Korean electrical and electronic products, which are to be exported to the EU, will be affected by the regulations.

In addition, product developers and/or manufacturers should pay for waste collecting expenses of electric and electronic products that are produced after August 13, 2005. Companies are required to attach labels indicating that the WEEE can be applied to the products. They should also provide collateral security to prove it. When the WEEE regulations go into effect, the EU Commission has reported that product price will go up by 1percent on the average and TVs by 2-3 percent. However, the industry itself estimates that prices will be increased about 3 percent.

To establish a recycling system in Europe, it will cost more. By the recycling regulations that require manufacturers to take responsibility for the disposal of their products, the financial burden on companies will be increased in the future. The recycling rate of small electronic products and lighting equipment is much lower than the regulations specified by the EU. Constructing a system of product recovery and recycling is estimated to cost an enormous amount of money. Collection and recycling responsibility imposed by the EU is considered to be unfair to foreign companies exporting to Europe. If appropriate recycling facilities are not established in Europe, collected waste products should be sent to the manufacturer's own country or to a third country, implicating cost for industry.

As a result, the competitiveness of foreign companies exporting to Europe will be weakened. Developed countries, including Japan and America, will not be able to meet the standards of the EU, and their marketing strategy in Europe will also be affected.

Energy consumption regulation and electric wave regulation

The environmental regulation related to energy consumption and electromagnetic radiation shielding includes Energy Consumption Regulation and Electromagnetic Wave Regulation of the EU, Energy Efficiency Regulation and Electromagnetic Wave Regulation (CFR21) of the USA, which shall be considered first in the design stage of products, but most of all seem to have direct influence on the sale of products. Given that various mark systems related to energy efficiency and electromagnetic wave adopt a voluntary participation system of the private organizations and place no differential limitation on foreign businesses, it is difficult to consider the environmental mark system itself as a non-tariff barrier.

However if local buyers avoid the import of products with environmental marks not attached, it may act as a trade barrier; specifically having large influence on the corporate publicity and the raise of image. As it is likely to be used for green marketing, such as the expansion of sales and the launching of new business under the circumstances, it is considered that it will impact directly on the enterprise management.

Positive aspect and implication of environmental regulation

As a result of examining the direct/indirect influence of various environmental regulations on enterprise activities, most environmental regulations that are reinforced around the EU are clearly threatening elements for the survival of the electric and electronic industries. Specifically given that direct regulations on electric and electronic products such as WEEE and RoHS have been increased recently, it is expected that a vast damage of management loss will be caused from the negligence of environment-friendly supply chain management such as environment-friendly design or green purchases.

In light of other aspects, however, the environmental standard of the EU has a positive aspect in that it blocks the products made in countries that cannot meet these standards, while providing a more promising environment to the products of countries that can satisfy these standards. Specifically, the products that satisfy the environmental standard of the EU that is on the world best level can raise their international reputation thereof, which will help them enter into other markets.

With respect to the WEEE Directive of the EU, England, Greece, Spain and Italy lack a recovery system and related basic infrastructure to fulfill mass disposal for the enforcement of the waste electric product directive, unlike countries where recycling facilities have already been operating for several years, independent of the same directive with respect to electronic products, which can act as an element of chance for the domestic enterprises.

If the domestic enterprises develop localized technology and improve the process with respect to substitute substances to deal wisely with the prohibition of hazardous substances, they can have a chance to apply them to the security of environment-friendly substance manufacturing technology and the reduction of raw costs. Also environmental and energy labeling systems of more advanced countries can act as an element of chance. They can raise corporate value by generating niche market and improving corporate image through the active application of labeling, and further raise the corporate competitiveness by achieving dynamic innovation through the voluntary efforts of environmental improvement in this process.

The result of environmental management shown by several advanced enterprises is one of the positive aspects held by reinforced environmental regulation. Enterprises that saved energy or used resources and raw materials more efficiently to reduce costs and expenses introduced management systems including the minimization of wastes and Life Cycle Assessment, which resulted in the increase of their competitiveness.

Since the systems actively promoted actively the generation of new business, the development of new environment-friendly products and the strategic linkage of environment related products and services between demand and supply through the promotion of strategies based on an environmental mindset, and consequentially raised their competitiveness, it is considered that the reinforcement of environmental regulation standards can act an element to increase market value of enterprise.

3. Characteristics of Korean Electronic industries

3.1 Supply chain management in Korean electronic industries

3.1.1. Dependence on long-term transactions

Korean electronic industries generally have collaborative relationships, and they are differentiated by the characteristics of parts, with their suppliers. Moreover, they have consolidated their business with highly efficient suppliers. Meanwhile, these relationships have induced the suppliers to reduce the experience curve consistently and to make a long-term and transaction-specific investment to share profits with their buyers. In Korean electronic industries, transactions are typically ensured for 3 years. The suppliers that show a good performance are able to participate in the development of the next models. Therefore, suppliers can make an investment in the development and planning of ideas for the next products and models. As Dyer and Ouch (1993) pointed out, engineers who worked with a limited number of suppliers for a long period of time are able to efficiently design and develop the next products and models, and consequently the experience curve of the suppliers will be consistently decreased whenever new products or models are developed.

3.1.2. Trust establishment

Korean electronic industries have recognized the necessity of depending on suppliers from the start of their business and have developed the mechanisms to establish mutual trust. The recognition is the result of the partnership, and benchmarking of, with Japanese electronic firms in their early stage of business. In particular they have concentrated on the development of mechanisms to establish the trust between buyers and suppliers as well as the contracts to protect their profit. As Sako (1991) and Smike (1991) asserted, these efforts can be interpreted as the minimization of the risk caused by opportunistic behaviors.

3.1.3. Competition of suppliers for design and manufacturing

For the development of new products and models, Korean electronic industries have involved several proved suppliers from the supplier group in the design and development of components. They have established competition systems, where a supplier competes with one or two competitors, to press them to make a customized investment and to make them recognize that they have to compete against their competitors. These competition systems are called dual sourcing or multi sourcing, which is composed of 3 suppliers at most.

3.2. Strategic partnership

The supplier management in Korean electronic industries seems to be differentiated by the balance of the collaborative relationship with suppliers and the strategic input from suppliers. In the differentiated management, according to the collaborative relationship with suppliers (Gullander *et al*., 2001), the buyer-supplier relationships are divided into arm's length relationship and collaborative relationship (Dobler *et al*., 1996). In the differentiated management according to the strategic input from suppliers (Dyer *et al*., 1996), suppliers are divided into strategic partners and collaborative partners that provide non-strategic but necessary input. The strategic input is the input that has a high value and is customized to buyer products to play an important role in differentiating the buyer products. Therefore, this kind of input needs a high level of communication between buyers and suppliers and multiple function interfaces between engineering and engineering or manufacturing and manufacturing.

These suppliers, called key suppliers, provide design and production services according to the specification of buyers. They are classified into 3 types: full service suppliers, full system suppliers, and design support suppliers. The full service suppliers provide the specifications for design and production services to buyers. These suppliers typically have a responsibility for entire subsystems, and participate in new model planning even before a conceptual stage. They have superior knowledge about their products and processes to buyers and suggest a solution to set appropriate prices and performance goals. They even carry out the relevant tests independently. The full system suppliers design and manufacture complicated assemblies. They have a less influence on the design because they have less technical capability. Since their technical capability is low, they less influence on the product design. Buyers give essential specifications on the performance, interface requirements, spatial restrictions. These kinds of suppliers develop the system for themselves. They also have a responsibility for primary tests, and buyers are fully dependent on the test results carried out by them. They may participate in the meeting with buyers during the conceptual stage, but the buyers decide the detailed specifications of the input. These suppliers have a responsibility for setting detailed design, and making and testing prototypes. However, buyers make essential tests to internally check the performance of the input from suppliers. Communication is not largely made at the conceptual state, but done when prototypes are made.

On the other hand, non-strategic but necessary inputs are typically supplied from independent suppliers. They are neither customized nor contributable to product differentiation. This kind of input is standardized, so that the necessity of buyer-supplier collaboration is low. The supply chain management of Korean electronic industries is characterized by complete exclusiveness; that is, no interaction between the supply chains of competitors. This kind of supply chain management in Korean electronic industries has not only forced suppliers to make a relationship for specific investments and to concentrate on the business activities with primary customers, but also has prevented suppliers from making opportunistic behaviors. About 2 or 3 suppliers are selected as long-term contractors. Moreover, suppliers are fully dependent on buyers in the development of technology and do not have opportunities to obtain knowledge from various customers as they have a transaction only with their primary buyer. Therefore, buyers have taken the initiative in product development. Dyer *et al*. (1996) defined this kind of relationship as a durable arm's length relationship, differentiated from the arm's length relationship. Making transactions with several multinational corporations like Samsung Electronics and LG Electronics, Korean electronic industries have obtained supplier's goodwill.

4. Conclusion

The Korean electronic industry generally has collaborative relationships and differentiates supplier management by the characteristics of parts. The supplier management in the Korean electronic industry seems to be differentiated by the balance of the collaborative relationship with suppliers and the strategic input from suppliers. In the differentiated management, according to the collaborative relationship with suppliers, the buyer-supplier relationships are divided into arm's length relationship and collaborative relationship. In the differentiated management, according to the strategic input from suppliers, suppliers are divided into strategic partners and collaborative partners that provide non-strategic but necessary input.

In the supplier management, Korean electronic companies have a collaborative relationship with the strategic partners supplying strategic input and a durable arm’s length relationship with the suppliers supplying non-strategic input.

This study carried out interviews with development managers from Korean electronic companies to find a closely coordinated relationship between buyers and suppliers in environmentally friendly product development. In reality, Korean electronic companies had a partnership with several primary suppliers and allocated limited roles to other minors. With tightly scheduled development programs, buyers force suppliers to achieve their goals and develop prototypes in line with the programs. If this kind of program is correctly managed, suppliers will help buyers to reduce lead-time and drive design processes.

Supply chain management in the Korean electronic industry reflects the collaborative and long-term relationship in terms of strategic competitiveness for buyers and suppliers respectively. Traditionally, the Electronic industry has lead exports that were based upon a well-networked supply chain. The main buyers have a limited number of suppliers for producing key parts. Thus, it was not surprising to observe that the buyers and key suppliers work together to develop key parts of products. However, there are certain levels of arms’ length relationships with suppliers for mass produced parts and products. It characterizes the supply chain management in the Korean electronic industry and demonstrates the strategic relationship in terms of product development. More importantly, in order to develop environmentally friendly products, the buyers and suppliers work strategically together. Even though there is some level of difference when major Korean electronic manufacturers (i.e. buyers) apply environmental strategies to suppliers, the buyers demonstrate similar patterns of strategic relationships with suppliers as mentioned above because the buyers take benchmarks each other, and even share key suppliers for main products.

Chapter 7: Empirical Analysis of K Electronics

1. K Electronics' Activities for Environmentally Friendly Product Development

K Electronics, founded in 1969, has practiced responsible management by using human resources and cutting-edge technology, based on the management philosophy, "contribution to the society by creating the best products and services with human resources and technology." K Electronics started its environmental management system, in June 1992, announcing the "Environmental Policy" to prevent environmental accidents and achieve sustainable improvement, and declared "Green Management" in May 1996. The K Electronics' corporate policy of making green management the top priority of all corporate activities has led to bold and continuous measures. Such measures include developing green technologies and green products, reducing waste and maintaining accident-free workplaces based on the five pillars of green management. These include greening of management, products, processes, workplaces and communities. Green Management is K Electronics' willingness to take environment, safety, and health into account as key elements in business activities and, ultimately, to enhance the quality of life and preserve the environment of the earth. It is also the commitment to take all social responsibilities by implementing management practices in consideration of safety and health, developing environmentally friendly products, using resources and energy efficiently, making workplaces safer and healthier, and achieving the co-development of customers and communities. To attain these goals, K Electronics has consistently upgraded Green Management Programs. As a result, the company has received local and international safety and environmental certifications, such as ISO 14001 and Environmentally Friendly Enterprise Certification, for its achievement of environmentally friendly product development and advanced process innovation. It became recognized as a world leader in environment and safety by holding the Guinness World Record for having the safest workplace in the world.

K Electronics has made a consistent effort to develop environmentally friendly products by adding "environment" to considerations for product development in addition to performance, cost, quality, and design, and taking into account the environmental aspects of products as well as assemblability, disassemblability, recyclability, and serviceability from the whole life cycles from acquisition of raw materials to production, distribution, use, and disposal of products. For example, all K Electronics VCR models are made with lead-free soldering. The K Electronics' TFT-LCD monitor and PDP TV are the first among those made in Korea to acquire the environmental labeling certificate Type III – a label that tells consumers those environmentally friendly materials and parts are blended into the product (The Ministry of Environment Korea, 2004).

LCA (Life Cycle Assessment)

LCA is a scientific tool to quantitatively evaluate the environmental aspects of products in the whole life cycle. K Electronics has used the LCA to identify environmentally unfriendly points of products and improve them. The LCA was applied to: microwaves in 1995; TVs, monitors, refrigerators, air conditioners, and washers in 1997; desktop PCs, notebook computers, DRAM chips, and ICs in 1998; laser printers in 1999; and vacuum cleaners in 2000. The problems identified by the LCA studies are corrected, and the results of the LCA studies are fed into SPEED (Simplified LCA Program for Effective Eco-Design) to help designers take into account environmental aspects throughout the life cycle of products.

DfA/D/R/S: Design for Assembly/ Disassembly/ Recycling/ Service

DfA/D/R/S is a tool for assessing and improving assembly, disassembly, recycling and service of products. It was first applied to: washers, TVs, and refrigerators in 1995; microwaves in 1996; vacuum cleaners in 1997; monitors in 1998; printers, PCs, vacuum cleaners, air conditioners, VCRs in 1999; and cellular phones in 2000. To speed up and facilitate implementation, the tool is integrated with the 3D-CAD System and Products Data Management (PDM) System. With the LCA software, it is used in the stage of product design to improve the environmental features of products. The Design for Cost (DfC) Module is also under development to save costs.

Environmental Marks (Environmental Labeling, Energy Mark)

K Electronics' laser printers received the Korea Environmental Labeling in 1999. In particular, ML-6060, one of the K Electronics laser printers, which got the labeling in 2000, is characterized by dramatic energy savings, less ozone generation (only 1/50 less than traditional models), and much lower noise. Its solid-frame-type toner cartridge prevents any leakage of used toners. In recognition of these environment-friendly features, the Ministry of Environment and The Maeil Business Newspaper granted K Electronics "The Green Marketing Award" in 2001.

With the certification of environmental labeling applicable in foreign countries, K Electronics' exports are well recognized for their excellence in the global market. In particular, TCO 95 and TCO 99, environmental labeling certifications in Sweden were given to K Electronics' monitors in recognition of its contribution to the environment.

K Electronics has achieved many energy marks. In particular, all of the washers received the 1st grade of Energy Efficiency Rating Standards in Korea. PCs, monitors, facsimile machines, TVs, VCRs, DVD players, and audios earned Energy Savings Label. The US EPA also awarded K Electronics' monitors, PCs, printers, and washers its Energy Star Mark.

For the development of environmentally friendly products, K Electronics specifies the requirements for the consideration of environmental aspects in "Product Development Guides," which is the top-level guide in K Electronics. Moreover, the rules for meeting the requirements are specified in "Product Pollutant Control Rules," "Environmental Response Product Assessment Rules," and "Green Purchase Management Regulations."

Environmentally Friendly Packaging Materials

Recycling of Used Styrofoam

In order to recycle the Styrofoam used as shock-absorbing materials, K Electronics is carrying out studies on "recycling of used Styrofoam using physical processes." These studies aimed at reusing the used Styrofoam as shock-absorbing materials rather than recycling it into other types of products. The process is characterized by the maintenance of the physical properties of Styrofoam using an unheated compressor.

Reduction in Use of Packaging Materials

Computer simulation is used to identify any fragile areas in products and thus optimize the structure of packaging materials for the best shock absorption, ultimately reducing the use of Styrofoam packaging materials. In particular, this technology reduced the amount of Styrofoam used for AS-410 air conditioner packaging from 180g to 148g, a reduction of 18 percent.

Environmentally Friendly Packaging Materials

K Electronics has made a great effort to replace conventional packaging materials with environmentally friendly materials. For example, in Korea the ML-6060 printer first adopted honey pad paper shock absorbers instead of Styrofoam, reducing 10 percent of the total packaging volume. M5317 PC and NL15MO LCD monitors use corrugated pad paper shock absorbing materials.

2. Analysis of Portfolios for Supplier Involvement: Case Studies

As already shown in Chapter 5, the portfolio matrix suggested in this study reviews the strategic framework and possible options for supplier involvement in environmentally friendly product development. Besides conceptual rightness, it is very important to investigate the strategic significance and practical feasibility of a model. Therefore, this study reviews the supplier involvement portfolio using the proposed model, which combines ecodesign directions and supplier contributions on two-dimensional coordinates.

This study applies to environmentally friendly product development in 6 different business sections for refrigerators, monitors, semiconductors, VCRs, air conditioners, and printers. The products selected for this study are all those developed by K Electronics as environmentally friendly products from 1997 to 2003, and are all introduced in 'Green Management Best Practices', which is published annually by K Electronics Headquarter.

The studies of the 6 business sections were carried out using published literatures, reports, and interviews. A questionnaire was newly developed and conducted for the interviews. Moreover, the data obtained from face-to-face interviews were re-checked via telephone interview (see Appendix 1).

Like other electronic firms in Korea, since K Electronics has made much of the partnership with suppliers, and has closely cooperated with those that make a high contribution to product development, it has two different managements of suppliers. One is to have a cooperative partnership with suppliers with a high contribution to product development in environmental aspects. The other approach is to keep transaction with a small number of competing suppliers, which make a relatively smaller but still necessary contribution to environmental aspects of products.

Table 7-1 Summary of the products analyzed in this study

Product	Market		Initial Driver for environmentally friendly product development	Environmentally friendly aspect	Development direction	Suppliers involved
	Range	Customer				
Refrigerator	Global	Consumer Market	International regulation (for Global Warming)	Minimum energy consumption	Development of high-efficiency compressor	HB Company
					Development of high efficiency evaporator	W Company H Company
			International regulation (for Ozone depletion)	Complete replacement of CFC	Use of environmentally friendly refrigerant	D Company
					Use of environmentally friendly insulation material	HP Company
Monitor	Regional (EU)	Consumer Market	Green Marketing (with Eco Label)	Eco Label	Use of homogeneous resin	J Company
			Regional regulation (for Energy saving)	Minimum energy consumption	Use of energy-saving circuit	SK Electronic S Electric
Semiconductor	Global	Industry Market	International regulation (for Lead and Halogen compounds)	Prohibition of hazardous materials	Lead-free soldering material	S Company
					Use of halogen-free PCB	E1 Company S Electric E2 Company
					Use of halogen-free EMC	H Chemical
VCR	Regional (EU)	Consumer Market	International regulation (WEEE)	Recyclablility	Reduction of parts	S Electronic
Air conditioner	Regional (Domestic)	Consumer Market	Regional regulation (Expanded producer Responsibility)	Recyclablility	More compact-size	D Company
					Reducing packaging	EK Company S Chemical
Laser Printer	Regional (Domestic)	Consumer Market	Regional regulation (Expanded producer Responsibility)	Recyclablility	Use of environmentally friendly packaging materials	HK Company

The Table 7-1 shows the cases. As the Table 7-1 presents, the initial drivers for developing 6-selected product are evoked by the relevant international and national regulations. When the international legislation such as WEEE and RoHS is planned to be effective, the K Electronics well in advance strategically plan to design and develop the main products with key suppliers together because it would be not possible to solve environmental problems including lead soldering without their early involvement. When K Electronics identified the environmental regulation and legislation will be a threat factor as well as an opportunity factor. In other words, if K Electronics has developed capabilities well prior to relevant environmental regulations implementation, it will give a huge opportunity for K Electronics compared to competitors in global and domestic markets. Thus, K Electronics took a quick move to adapt their main products more environmentally friendly way to meet legal requirements. Having this in mind, let us go back to the main theme of this thesis (i.e. supplier involvement in environmentally friendly product development). The portfolio model is designed in previous chapter 5 and applied here to analyze the level of suppliers' involvement in environmentally friendly product development.

3. Case 1: Refrigerator

3.1 Directions of Environmentally Friendly Product Development

3.1.1. Complete Replacement of CFCs

According to the Montreal Protocol on Substances That Deplete the Ozone Layer, some advanced countries, including the U.S.A and Japan, have totally prohibited the use of CFC refrigerants and foams in refrigerators since 1995. In Germany, refrigerators using natural refrigerants and glowing agents have been developed since 1995. As a result, refrigerators using R600a and cyclopentane, as a refrigerant and foam, respectively, have been marketed and other European countries also shifted to R 600a.

Since Korea is categorized as a developing country, Korean manufacturers are exempted from the prohibition of the use of CFC materials by 2005. However, K Electronics started replacing CFCs with HFC-134a, as a refrigerant, and using cyclopentane, as a forming agent, respectively in 1996, and have solely used those environmentally friendly materials in all refrigerators since 1997, in order to compete in the international market. Moreover, the natural refrigerant, R-600a, has been used for the models designed to export to Europe.

3.1.2. Minimum Energy Consumption

Since the United Nations Conference on Environment and Development in 1992, K Electronics has consistently made an effort to reduce the emission of CO_2 gas and control the hazardous materials with high GWP[11], in order to enhance energy efficiency of products. Since HFC-134a has an ODP of 'Zero' but has high GWP, electronic manufacturers should develop alternative materials and achieve better energy efficiency of their products.

11) Global Warming Potential

Table 7-2 Environmental properties of refrigerator refrigerants

Refrigerants	Molecular formula	ODP[12]	GWP	Inflammability
CFC 12	$CC\ell_2F_2$	1	8100	No
HFC 134a	$C_2H_2F_4$	0	1300	No
R 600a	$CH(CH_3)_3$	0	3	Yes

As a result of great efforts, K Electronics was successful in dramatically lowering the energy consumption of refrigerators by using a high-efficiency compressor and cooling system. Such features earned K Electronics' refrigerators the status of Class A in European Energy Efficiency Rating, also boosting exports.

Table 7-3 Comparison with competitors

	K Electronics	Foreign competitor	Korean competitor	Remarks
Refrigerant	R600a	R600a	R134a	
Foam	Cyclopentane	Cyclopentane	Cyclopentane	
Cooling	No-frost	Frost	No-frost	
Compressor	1	2	1	
Control	Electronic	Electronic	Semi-electronic	
Display	Digital	Digital	LED[13]	
Energy consumption (kWh/month)	32	42	57	Based on ISO 8561
Energy class	A	B	B	

According to the EU's Eco Labeling for refrigerators, the energy efficiency index should be 45 percent or below and noise should not exceed 42 dB(Class A). The content of refrigerant should also comply with the standards. Manufacturers should provide appropriate information to customers.

K Electronics developed a new cooling system, H.M.Cycle (High-efficiency Multi-evaporator Cycle), which used non-CFC refrigerants and minimized the energy consumption of a refrigerator. The system aimed especially at replacing conventional

12) Ozone Depletion Potential
13) Light-Emitting Diode

refrigerants with non-CFC materials and improving energy efficiency of a refrigerator.

The system used a new compressor that allowed the refrigerator and freezer compartments to work independently and introduced a new evaporator, SOFT (Split, Oval Fin & Tube), improving the heat exchange rate by 30 percent and the defrost capability by 12 percent. The SOFT evaporator had a cross disposition oval refrigerant tube and a separate fin evaporator, so it improved heat exchange, and thus, reduced power consumption by 3percent. Moreover, it was 30percent smaller than conventional evaporators. With the energy consumption of 32 kWh/month, K Electronics' refrigerators achieved Energy Class A, as specified in ISO 8561 standard. In particular, the smaller size of the evaporator increased productivity two times, from 4 to 8 units per person, and enabled modular assembly.

The refrigerators with the SOFT evaporators were introduced in domestic and foreign journals. The patents for H.M.Cycle are now pending (33 patents in Korea and 16 foreign countries). The Ministry of Science and Technology granted the KT Mark (Korea Good Technology Mark) to refrigerators with SOFT evaporators in recognition of its technological advancement.

3.2. Contributions of Suppliers

3.2.1. High Efficiency Compressor Development

To realize the H.M.Cycle, K Electronics needed to develop a high efficiency compressor. HB Company in Korea participated in the development. The high efficiency compressor (the input of the supplier), was based on new technology (i.e. gray box). The supplier developed the high efficiency compressor with the concept given by K Electronics.

The HB Company was a new supplier, which took responsibility for input design, and took part in the development of the high efficiency compressor from the concept stage. In addition, the supplier positively negotiated about the refrigerator specifications with K Electronics. And also, the supplier took the initiative in the high efficiency compressor development by influencing on the product specification through addressing new technology development (i.e. fully developed).

In conclusion, it could be said that the development of the high-energy efficiency refrigerator was an evolutionary improvement (i.e. reduction of impact during use by lowering energy consumption) in the environmentally friendly product development, and the high efficiency compressor, the input of the HB Company, made a high contribution to the development. Therefore, involving the supplier in the development of the environmentally friendly refrigerator could be considered as the “exploitation strategy” of K Electronics.

3.2.2. High Efficiency Evaporator Development

To realize the H.M.Cycle, it was necessary for K Electronics to develop a high efficiency evaporator. The development required a new cylinder, which was a part of the high efficiency evaporator, with larger volume by 65-70 percent without a change in outer size. W Company and H Company in Korea, which had supplied cylinders to K Electronics, participated in the development of the new cylinder. These suppliers were the members of the supplier community, which was run by K Electronics. The supplier community of K Electronics was organized to keep the partnership between suppliers and improve the mutual good by promoting information exchange and cooperative development.

The cylinder, the input from the suppliers, was “necessary but not strategic”, and was based on simple technology, which does not require high quality skills or engineering performance (i.e. white box). These companies developed and manufactured the cylinder on the basis of the detailed specifications given by K Electronics.

Since K Electronics took responsibility for the design of the cylinder, they had less influence on the product specifications. K Electronics needed the manufacturing capability of these companies, and the contribution of the suppliers on the product specifications was limited to their present capability. The suppliers took part in the development of the cylinder from the prototyping stage. The key reason that K Electronics decided to allow their involvement was the cost and the protection of classified information. In other words, K Electronics could manufacture the high efficiency evaporator at a lower cost by outsourcing cylinder manufacturing, while preventing the critical technical information of the evaporator from being disclosed. K Electronics took the initiative in the cylinder’s development. K Electronics had maintained business relationships with them, and induced them to compete with each other to get benefits in the aspect of cost (i.e. partnership sourcing).

It could be concluded that the high-energy efficiency refrigerator development was an evolutionary improvement (i.e. reduction of material usage by reducing volume) in the environmentally friendly product development, and the cylinder, the input of the W Company and H Company, made a small contribution to the development. Therefore, involving the suppliers in the development of the environmentally friendly refrigerator could be considered the "manufacture-driven strategy" of K Electronics.

3.2.3. Applying Environmentally Friendly Refrigerant

In 1996, K Electronics successively replaced CFCs with HFC-134a and R600a (isobutene) as a refrigerant, in order to meet the environmental requirements of the global market, especially the EU market. K Electronics developed refrigerators for which R600a, an environmentally friendly refrigerant (e.g. a natural refrigerant), could be used. K Electronics had obtained the refrigerant from D Company.

The refrigerant, the input of D Company, was "necessary but not strategic", and based on complicated technology, which required high quality skills or engineering performance, though the chief ingredients were opened (i.e. gray box). And also, the supplier owned the patent for R600a, so K Electronics totally depended on the company.

Contrary to other materials or parts of a refrigerator, the refrigerant had a large effect on the related components. In particular, R600a itself had high pressure, and thus, the compressor, heat exchanger, and valves in a refrigerator should endure the pressure. The D Company had made an effort to minimize the effect of the refrigerant on the related components and to ensure the stability of quality. It was, therefore, difficult for K Electronics to change the supplier of the refrigerant to another company, due to the possible difficulty in the stability of quality. The D Company developed the refrigerant suitable for the K Electronics' refrigerator with the critical specification given by K Electronics.

As an existing supplier of K Electronics, the D Company took part in the development of the environmentally friendly refrigerant from the concept stage. The supplier influenced the product specifications through consistent communication with K Electronics, in order to ensure the stability of quality of the input (i.e. collaborate). Thus, the D Company took the initiative in the development of the environmentally friendly refrigerant through supplier interaction.

In conclusion, it could be said that the development of the refrigerator, applying the environmentally friendly refrigerant, was an evolutionary improvement (i.e. selection of low-impact materials by applying clean materials) in the environmentally friendly product development, and the environmentally friendly refrigerant, the input of the D Company, made a high contribution to the development. Therefore, involving the supplier in the development of the environmentally friendly refrigerator could be considered as the "exploitation strategy" of K Electronics.

3.2.4. Applying Environmentally Friendly Insulation Material

In order to meet the international regulations on substances harmful to the ozone layer, K Electronics replaced the CFC 11 with cyclopentane as a forming agent for insulation material. Cyclopentane was an environmentally friendly forming agent, while CFC 11 was a sort of substance harmful to the ozone layer. HP Company supplied the hard polyurethane blended cyclopentane as a insulation material for the refrigerator. The hard polyurethane blended cyclopentane was co-developed by the B Company and P Company, and HP Company, which was a local corporation of the P Company in Korea, had produced it.

The hard polyurethane blended cyclopentane, the input of HP Company, was "necessary but not strategic", based on complicated technology which required high quality skills or engineering performance, though the chief ingredients were opened (i.e. gray box). And also, the supplier was the sole vendor, which could exercise the patent for the hard polyurethane blended cyclopentane in Korea, so K Electronics totally depended on the supplier. In addition, the hard polyurethane blended cyclopentane was optimized to K Electronics' refrigerators by obtaining the critical specification from K Electronics. Therefore, it was not easy for K Electronics to change HP Company with other suppliers.

Figure 7-1 Supplier involvement strategies in the environmentally friendly product development (Refrigerator)

Directions of environmentally friendly product development		
	High efficiency evaporator development	High efficiency compressor development Applying environmentally friendly refrigerant Applying environmentally friendly insulation material

Contribution of supplier input

As a new supplier of K Electronics, HP Company took part in the development of the environmentally friendly insulation material from the concept stage. The supplier influenced the product specifications through consistent communication with K Electronics, in order to ensure the stability of quality of the input (i.e. collaborate). Moreover, HP Company led the development of the environmentally friendly insulation material through supplier interaction.

It could be concluded that the development of the refrigerator, applying the environmentally friendly insulation material, was an evolutionary improvement (i.e. selection low-impact materials by applying clean materials) in the environmentally friendly product development, and the environmentally friendly insulation material, the input of the HP Company, made a high contribution to the development. Therefore, involving the supplier in the development of the environmentally friendly refrigerator could be considered the “exploitation strategy” of K Electronics.

Figure 7-1 showed the result of the application of the relationship between the directions of environmentally friendly product development and the contribution of supplier input in the development of the environmentally friendly refrigerator to the portfolio matrix for supplier involvement strategies.

4. Case 2: Monitor

4.1. Directions of Environmentally Friendly Product Development

K Electronics' monitors had ranked top in the global market (sales of 3 trillion won in 1999). Besides its brands, K Electronics had produced OEM products for world-class monitor sellers, such as IBM, Compaq, Dell, HP, Siemens, etc., showing the high quality of the monitors.

During the financial crisis in Korea during the late 1990s, K Electronics had to make every effort to keep superiority over low-price monitor manufacturers and had to keep up with other advanced ones. Moreover, the green consumerism, especially in the European market, forced the company to focus on the development of environmentally friendly products.

Responding to these changes, K Electronics set a goal of obtaining all international environment marks, applicable to monitors in 1998, in order to cope with international environment issues actively and strengthen product competitiveness.

4.1.1. Obtaining TCO Mark

TCO, the Swedish confederation of profession employers, was organized to protect the rights of office workers. The organization was the cradle of the regulation of hazardous electromagnetic radiation (MPR[14] I, MPR II). The regulation started with TCO 92, and was revised to TCO 95 and TCO 99. In the latest TCO 99, not only quality but also environmental aspects were taken into account.

- MPR I, MPR II: Regulation of hazardous electromagnetic radiation
- TCO 92: MPR I, MPR II + Regulation of energy consumption
- TCO 95: TCO 92 + Ergonomics of monitors + Fundamental ecology standards
- TCO 99: TCO 95 + Reinforcement of ergonomics + More stringent ecology standards (e.g. Receiving ISO 14001 certification, establishing collecting and recycling)

Obtaining the TCO mark meant that the monitor had good quality in, not only performance, but also environmental aspects. As a result of elaborate market research and efforts, K

14) Measure and Proof Radiation Board

Electronics obtained the TCO 99 mark on November 1, 1998 for the first time in monitor industries across the world. This helped K Electronics enjoy a competitive advantage over its rivals.

4.1.2. Obtaining White Swan Mark

The White Swan Mark, made by 5 countries in Northern Europe consisting of Norway, Sweden, Denmark, Finland, and Iceland, applied to electronics as well as other types of products. While the TCO Mark took into account the quality and environmental aspects of a product, the White Swan Mark focused more on the environment.

- Most of environmental regulations in TCO Mark - Regulation of recyclability - Regulation of energy consumption by size - Prohibition of hazardous materials

The strengthening of the EU's environmental regulations made K Electronics' monitor division select strategic models for obtaining the mark. K Electronics finally decided to focus their efforts for the mark on LCD monitors. K Electronics obtained the White Swan Mark in February, 1998.

Although the mark was not well known, even in the European market during the time, the differential feature ultimately contributed to the increase in sales. Since Northern Europe was a high-end market, where high-priced products were mostly sold, the customers in this region attached importance to both quality and environmental friendliness. By offering differential features and obtaining those environmental marks, K Electronics could greatly improve the image of its monitor brand and the company itself.

Table 7-4 Monitor sales in Sweden (1998)

Purchaser	Product	Sales(Units)	Total amount
A	15 inch LCD Monitor	5,000	$4,000,000
B	15 inch LCD Monitor	400	$300,000
C	15, 17 inch LCD Monitor	300	$300,000
D	15 inch LCD Monitor	1,500	$1,500,000
Total		7,200	$6,100,000

4.1.3. Minimum Energy Consumption

With the exception of a few special purpose models, all K Electronics monitors complied with E2000 in Europe, the most stringent regulation in the world. In particular, the 15-inch monitor model successfully lowered stand-by energy consumption by 40 percent - from 2.5W to 1.5W. The 17-inch monitor model operated on only 75W of electricity, which is 25 percent less than the 100W consumed by previous models.

4.2. Contributions of Suppliers

4.2.1. Using Homogeneous Resin

To satisfy the needs of customers for better recycling, K Electronics used homogeneous resin in the monitor's body, so that they were more easily recycled and more resistant to outside impact and inside heat. K Electronics acquired the homogeneous resin from J Company in Korea, which was one of its affiliates.

The homogeneous resin, the input of the J Company, was based on technically complicated new technology (i.e. black box). It specifically had better heat resistance as a highly practicable resin and contained cadmium and lead below 50 ppm[15] and 200 ppm, respectively. The supplier co-developed the homogeneous resin with the concept given by K Electronics.

Since K Electronics itself did not have the ability to develop the homogeneous resin for its monitor body, it totally depended on J Company in the development of the homogeneous resin. Most resin suppliers were large-sized global companies so K Electronics could not fully control them. These suppliers had made proactive responses to environmental pressure in order to get an opportunity in advance. As a late starter, the J Company had an intention to grope for other opportunities in the market through its cooperation with K Electronics. These two companies had co-developed the homogeneous resin for the monitor body for 3-4 months until they obtained a satisfactory quality. The supplier played a decisive role in determining the properties of the plastic materials of the monitor body, so it took responsibility for the input.

As an existing supplier, J Company influenced the product specifications through consistent communication with K Electronics to satisfy K Electronics needs (i.e. collaborative). The

15) Parts Per Million

supplier was involved in the co-development of the homogeneous material from the concept stage. The supplier took initiative in the co-development of the homogeneous resin through supplier interaction.

It could be concluded that the co-development of the monitor, using the homogeneous resin, was a revolutionary improvement (i.e. optimization of end-of-life system by applying monomaterials) in the environmentally friendly product development, and the homogeneous resin, the input of J Company, made a high contribution to the development. Therefore, involving J Company in the co-development of the homogeneous resin could be considered the "partnership development strategy" of K Electronics.

4.2.2. Applying Energy Saving Circuit

K Electronics improved the performance of the energy saving circuit in a monitor so as to lower the energy consumption at the sleeping mode. The new energy saving circuit reduced power consumption from 2-3W to 1W by modifying the frequency at the sleeping mode. For this, K Electronics worked with new suppliers, SK Electronic and S Electric in Korea.

The new energy saving circuit, the input of SK Electronic and S Electric was "strategic" and was based on simple engineering capability, since they just assembled the parts supplied from the second vendors (i.e. white box). These suppliers developed and manufactured the energy saving circuit on the basis of the detailed specifications given by K Electronics.

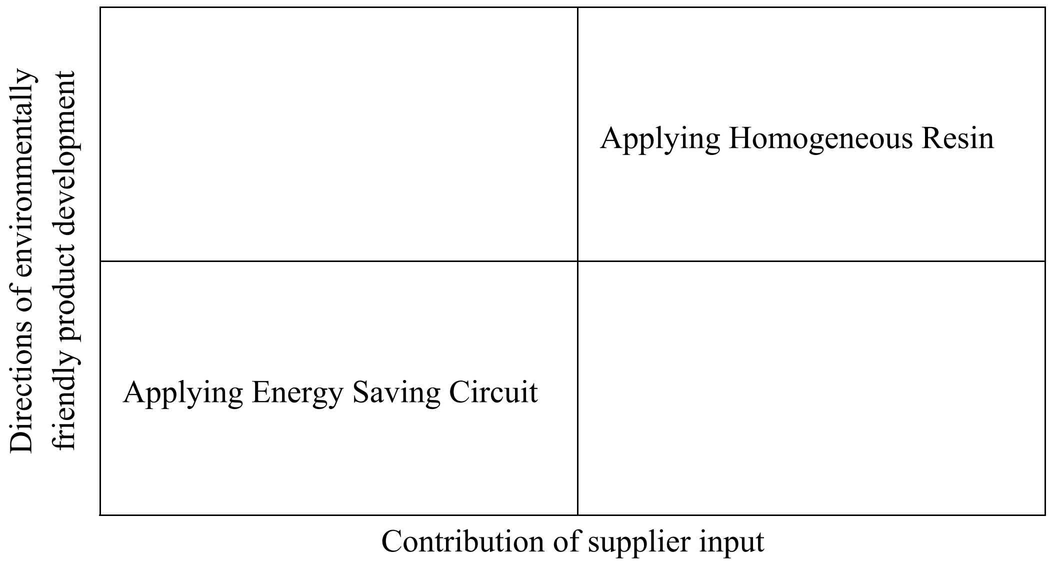
Since K Electronics took responsibility for the design of the energy saving circuit, SK Electronic and S Electric had less influence on the product specifications. K Electronics needed the manufacturing capability of these companies, and the contribution of the suppliers to the product specifications was limited to their present capability. The companies took part in the development of the energy saving circuit from the prototyping stage. It should be noted that K Electronics requested for SK Electronics and S Electric to use transformers and controllers made by G Company and CB Company, which were important parts to determine the performance of the energy saving circuit.

SK Electronic and S Electric took part in the development from the prototyping stage. K Electronics took the initiative in the development of the energy saving circuit, and SK Electronic and S Electric participated in the development through partnership sourcing.

In conclusion, it could be said that the development of the monitor applying the energy saving circuit was an evolutionary improvement (i.e. reduction of impact during use by lowering energy consumption) in the environmentally friendly product development, and the new energy saving circuit, the input of SK Electronic and S Electric made a small contribution to the development. Therefore, involving SK Electronic and S Electric in the development of the energy saving circuit could be considered the “manufacturer-driven development strategy” of K Electronics.

The Figure 7-2 shows the result of the application of the relationship between the directions of environmentally friendly product development and the contribution of supplier input in the development of the environmentally friendly monitor to the portfolio matrix for supplier involvement strategies.

Figure 7-2 Supplier involvement strategies in the environmentally friendly product development (Monitor)



5. Case 3: Semiconductor

5.1. Directions of Environmentally Friendly Product Development

Global lead-free regulations are constantly being more strengthened. In particular, the RoHS regulation in the EU will prohibit electronic manufacturers from using 4 kinds of heavy metals (lead, mercury, 6-chrome, cadmium) and halogen compounds[16] from 2006. To cope with the regulations, K Electronics developed memory module products for which lead and halogen compounds were not used at all. The products were characterized by the application of completely lead-free plating materials and solder pastes and the world's first exclusion of halogen compounds from package molding compounds and circuit boards.

K Electronics started basic research for the semiconductors in 1998, and organized a "Lead-free Product Task Force Team (TFT)" for developing lead-free semiconductor packages and module products in February 2000. Furthermore, "Green Product TFT" was formed in October 2002 to develop environmentally friendly semiconductor products without lead and halogen compounds. As a result of the cooperative efforts of associated departments, K Electronics finally succeeded in developing a "lead and halogen-free semiconductor" in May 2002. The "Lead-free Product TFT" identified lead-used processes in semiconductor manufacturing and developed alternative materials. Applying new materials, the "Lead-free Product TFT" analyzed all of possible problems and made great efforts to solve them. The "Green Product TFT" had studied to exclude lead and halogen compounds from semiconductor products, leading to the development of "lead and halogen-free semiconductor".

5.1.1. Lead-free Soldering

Typical lead-used processes in semiconductor manufacturing were electroplating, soldering, and module production. In traditional processes, the alloy of tin and lead had been used for all of these three processes. K Electronics developed a new process using lead–free plating materials and solder pastes. In the three processes, the alloys, tin and lead, have been replaced with new alloys of tin and bismuth, or tin, copper, silver.

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16) Highly toxic and corrosive. Has a large influence on the human body and the environment. Composed of F, Cl, Br, I, or At, which is in the group 7b of the periodic table.

Table 7-5 Replacement of soldering materials

Application	Replacement
Plastic Package (Lead Plating)	SnPb → Sn-Bi (Bi content : 2 ~ 6 wt percent)
Ball type Packages (Solder Ball)	SnPb → Sn-3.0Ag-0.5Cu
Module Products (Solder Paste)	SnPb → Sn-3.0Ag-0.5Cu

5.1.2. Halogen-Free EMCs[17] and PCBs[18].

In the semiconductor industry, halogen compounds had been typically used for package molding compounds and PCBs Lead-free products had been developed by several semiconductor manufacturers. However, it was K Electronics that succeeded in developing the world's first halogen-free semiconductors.

5.2. Contributions of Suppliers

5.2.1. Lead-Free Soldering Materials Development

In response to the environmental regulations in the EU (i.e. RoHS), K Electronics had applied lead-free soldering materials. K Electronics had acquired the lead-free soldering materials from S Company in Japan. The supplier had made a proactive response to environmental pressure in order to get an opportunity in advance. K Electronics had fully depended on the supplier for the lead-free soldering materials, since S Company owned a joint patent for the material with Iowa University. In particular, K Electronics had to solve the problem of replacing lead with silver that raised the process temperature in its plant and thus, had an adverse effect on other compartments.

The lead-free soldering materials, the input of the S Company, were "necessary but not strategic", and based on complicated technology which required high quality skill or engineering performance, though the chief ingredients were opened (i.e. gray box). The supplier developed the lead free soldering materials with the concept given by K Electronics.

The S Company influenced the product specifications through consistent communication with K Electronics, so as to meet the optimum process condition of K Electronics (i.e.

17) Epoxy Molding Compounds
18) Printed Circuit Board

collaborate). As an existing supplier of K Electronics, the S Company took part in the development of the semiconductor, applying lead free soldering materials from the concept stage. Thus, the supplier took the initiative in the development of the lead free soldering materials through supplier interaction.

It can be concluded that the development of the semiconductor, applying the lead-free soldering materials, was an evolutionary improvement (select low-impact materials by applying clean materials) in the environmentally friendly product development, and the lead-free soldering materials, the input of S Company, made a high contribution to the development. Therefore, involving the supplier in the development of the environmentally friendly semiconductor could be considered the "exploitation strategy" of K Electronics.

5.2.2. Applying Halogen-Free PCBs

To respond to the RoHS regulation, K Electronics had used the PCBs without bromine and antimony. The PCB, as a sort of a standardized product, could be bought from many suppliers. K Electronics obtained it from many suppliers, including E1 Company, S Electric, and E2 Company.

The input of these suppliers was "necessary but not strategic", and based on simple technology (i.e. white box). They acquired the detailed specifications from K Electronics. The key technology for halogen-free PCBs was to exclude halogen compounds from pre-pregs and PSRs (Photo Sensitive Resists) in the PCB. Thus, it was important to note that the they should acquire halogen-free pre-pregs and PSRs from their vendors, such as D Ink, H Chemical, D2 Company, and M2 Company, as designated by K Electronics.

K Electronics took responsibility for the product design. They had less influence on the product specifications. K Electronics needed the manufacturing capability of these suppliers, and the contribution of the suppliers on the product specifications was limited to their present capability. The reason that K Electronics involved these suppliers in the environmentally friendly product development was their cost and manufacturing capability.

The suppliers participated in the development from the prototyping stage. K Electronics took the initiative in the development, and E1 Company, S Electric, and E2 Company participated in the development through partnership sourcing. Thus, K Electronics motivated them to compete with each other to get benefits.

In conclusion, it could be said that the involvement of the suppliers in the development of the semiconductor, applying the halogen-free PCB, was an evolutionary improvement (i.e.

selection low-impact materials by applying clean materials) in the environmentally friendly product development, and the halogen-free PCB, the input of these suppliers made a small contribution to the development. Therefore, involving those suppliers in the development of environmentally friendly semiconductor could be the “manufacturer-driven development strategy” of K Electronics.

5.2.3. Applying Halogen-Free EMCs

To respond to the RoHS regulation, K Electronics had used the EMCs without bromine and antimony. The halogen-free EMCs were supplied from H Chemical in Japan. The halogen free EMCs, the input of the supplier, were “necessary but not strategic”, and based on complicated technology, which required high quality skill or engineering performance (i.e. gray box). K Electronics had fully depended on the supplier. H Chemical developed the halogen free EMCs with the concept given by K Electronics.

H Chemical took responsibility for an input design and took part in the development of the halogen free EMCs from the concept stage. Moreover, the supplier positively negotiated about the specifications of the semiconductor with K Electronics. The company also took the initiative in the development of the semiconductor applying the halogen-free EMCs by influencing on the product specifications through addressing new technology development (i.e. fully developed).

It could be concluded that the involvement of the suppliers in the development of the semiconductor, applying the halogen free EMCs, was an evolutionary improvement (selection low-impact materials by applying clean materials) in the environmentally friendly product development, and the halogen-free EMCs, the input of the suppliers, made a high contribution to the development. Therefore, involving those companies in the development of the environmentally friendly semiconductor could be considered the “exploitation strategy” of K Electronics.

Figure 7-3 shows the result of the application of the relationship between the directions of environmentally friendly product development and the contribution of supplier input in the development of the environmentally friendly semiconductor to the portfolio matrix for supplier involvement strategies.

Figure 7-3 Supplier involvement strategies in the environmentally friendly product development (Semiconductor)

Directions of environmentally friendly product development

Applying Halogen-free PCB	Lead-free Soldering Materials Development Applying Halogen-free EMC

Contribution of supplier input

6. Case 4: VCR (Video Cassette Recorder)

6.1. Directions of Environmentally Friendly Product Development (Less number of parts used)

For the EU WEEE, K Electronics has designed VCRs so as to facilitate disassembling and recycling of used ones. To achieve this goal, K Electronics reduced 60 parts (from 810 to 750) by simplifying the block circuit: that is, integrating the video and audio ICs.

6.2. Contributions of Suppliers

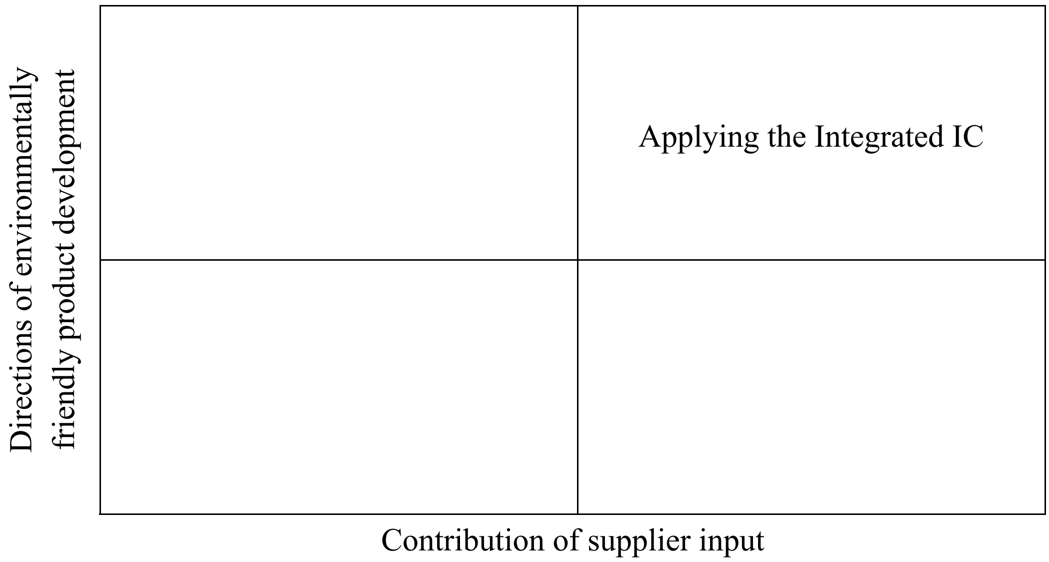
K Electronics could dramatically reduce the number of parts used for VCRs by integrating internal ICs. S Electronics in Japan participated in the development. The supplier recognized the needs of K Electronics at its presentation of new product development. As a result of consistent efforts and communication with K Electronics, they succeeded in developing the integrated IC.

The integrated IC, the input of these companies was “strategic”, and based on highly complicated technology, which required high quality skill or engineering performance (i.e. gray box). S Electronics developed the integrated IC with the concept given by K Electronics.

The decisive reason that K Electronics decided to involve the suppliers was their highly qualified technology and customization. K Electronics has maintained their partnership with these companies from the beginning of their business and over 70 percent of associated parts are supplied from these suppliers. The supplier took responsibility for the input design and took part in the development of the integrated IC from the concept stage. Also, S Electronics positively negotiated about the product specifications with K Electronics. Moreover the supplier took the initiative in the development of the integrated IC by influencing the product’s specification through addressing new technology development (i.e. fully developed).

In conclusion, it could be said that the involvement of S Electronic in the development of the VCR, applying the integrated IC, was a revolutionary improvement (i.e. new concept of development by integrating functions) in the environmentally friendly product development, and the integrated IC, the input of the supplier, made a high contribution to the development. Therefore, involving the supplier in the development of the environmentally friendly VCR could be considered the "partnership development strategy" of K Electronics.

Figure 7-4 Supplier involvement strategy in the environmentally friendly product development (VCR)



The Figure 7-4 shows the result of the application of the relationship between the directions of environmentally friendly product development and the contribution of supplier input in the development of the environmentally friendly VCR to the portfolio matrix for supplier involvement strategies.

7. Case 5: Air Conditioner

7.1. Directions of Environmentally Friendly Product Development

7.1.1. Size and Weight Reduction

The Ministry of Environment in Korea obliged the pre-assessment of recyclability of electronic products in 1994. Subsequently, electronic manufacturers in Korea had to take into account environmental aspects of 5 kinds of electronic products, including air conditioners, from the product development stage. K Electronics started to apply the technology for improvement of recyclability to product design and development. As a result, the company developed an environmentally friendly, high efficiency (Class 1) home air conditioner that applied the environmentally friendly refrigerant, R 410a and developed and produced world's first new type compressor for R 410a. The new compressor was smaller in size by 30 percent than traditional compressors, reducing 15 percent of the cost of materials. The size reduction of the compressor could be achieved by developing a high-efficiency, low-noise, heat exchanger, fin with outer diameters of 7 mm and 9.52 mm. The heat exchanger fin improved the efficiency of energy consumption and reduced the size of air conditioners. Applying the heat exchanger fin reduced over 1 billion won of the cost of materials in 1998.

7.1.2. Reduction in Packaging

Reducing packing materials saved natural resources and reduced waste. The Ministry of Environment in Korea legislated the Act on the Control and Recycling of Packaging Waste in 1993, and the Regulations on Product Packaging and Packaging Materials in 1995. According to these, manufacturers and importers of electronic products had to attain their objective of packaging waste reduction by using less, or collecting and recycling plastic packaging materials. The objective was the sum of the rate of the reduced amount of plastic packaging materials in the year in question based on that in 1994, and the rate of collected and recycled, or disposed packaging materials in the year in question.

Table 7-6 Objectives of packaging waste reduction

	After January 1998	After January 2000	After January 2002
Objective	Over 0 percent	Over 30 percent	Over 50 percent

Source: Ministry of Environment (Korea)

K Electronics changed the packing box for air conditioners to an open-type package, which covers only the top and bottom parts of the product. K Electronics identified the fragile areas of the product to arrive at an optimal shock absorbent structure by computer simulation and thus reduced the amount of EPS (Expanded polystyrene) foam used for packaging. The amount of EPS foam packing for the air conditioner was reduced by 18percent, from 180g to 148g, by using computer simulation technology. It satisfied packaging requirements while being more environmentally friendly.

7.2. Contributions of Suppliers

7.2.1. More Compact Size

Responding to more stringent environmental regulations of the government for home appliances size and weight reduction, K Electronics started to develop the high efficiency, reduced-sized compressor for air conditioners. To achieve the development, K Electronics needed to develop a smaller fin used for the air conditioner compressor. The D company in Korea took part in the development of the new fin. The important reason that K Electronics selected the D company was the cost and the protection of classified information. The D company started it business with employees, outsourced from K Electronics in 1999, under the condition that it would acquire human resources, technology, and equipment from K Electronics and it would be treated as a department of K Electronics for a 3-year incubation period. Therefore, it could be said that D Company had the same technology and development capability as K Electronics.

The new fin, the input of the D Company, was “necessary but not strategic”, based on well-known technology (i.e. white box). The supplier developed and manufactured the fin on the basis of the critical specifications given by K Electronics.

The D Company took responsibility for the input design, and took part in the development of the fin from the post-concept stage. K Electronics needed the design and manufacturing capability of the supplier, and received proposals about the specifications from the supplier. The D Company took the initiative in the development of the fin by addressing its own technology (i.e. fully development)

It could be concluded that the involvement of the D Company, in the development of the air conditioner applying the new fin, was an evolutionary improvement (i.e. reduction of material use by reducing volume) in the environmentally friendly product development, and the smaller fin, the input of the suppliers, made a high contribution to the development.

Therefore, involving the supplier in the development of the environmentally friendly air conditioner could be considered the "exploitation strategy" of K Electronics.

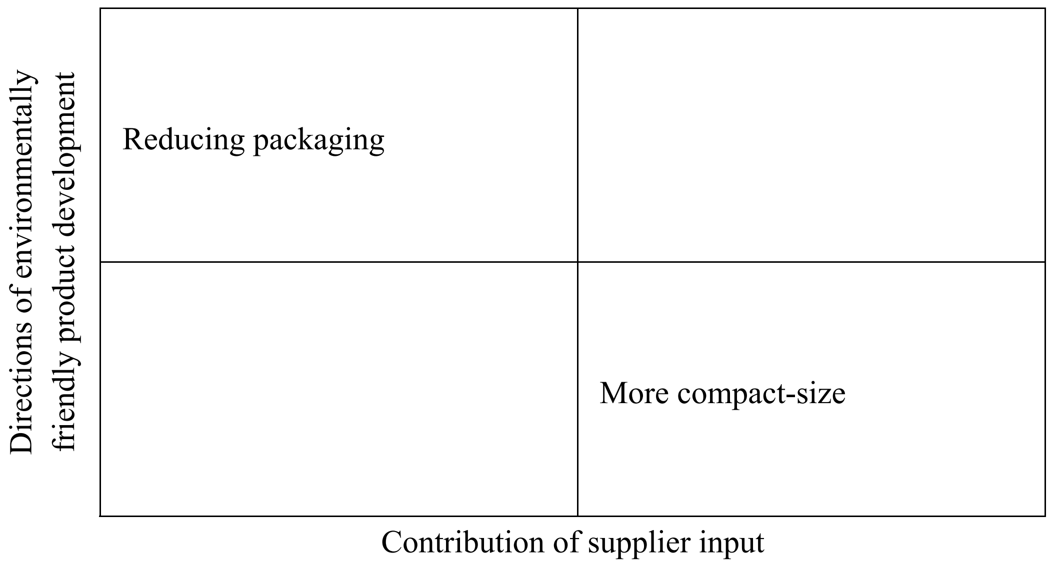
7.2.2. Reducing Packaging

To respond to the regulations of package waste and satisfy the needs of customers, K Electronics made an effort to reduce the amount of packaging materials without deteriorating the functions. The EPS foam packing, open-type package, was supplied from EK Company and S Chemical.

The open-type package, the input of these companies, was "necessary but not strategic" based on the complicated technology of K Electronics, which was worked out by computer simulation (i.e. white box). These suppliers obtained a complete design from K Electronics.

K Electronics took responsibility for the design. K Electronics needed the manufacturing capability of the suppliers and the suppliers had almost no influence on product specifications. They participated in the development of the open-type package from the prototyping stage. K Electronics had maintained business relationships with them, and motivated them to compete with each other to get benefits in the aspect of cost (i.e. partnership sourcing).

Figure 7-5 Supplier involvement strategies in the environmentally friendly product development (Air conditioner)



In conclusion, it could be said that the involvement of the suppliers in the development of air conditioner, applying the open-type package, was a revolutionary improvement (i.e. new concept development by optimizing function of packaging) in the environmentally friendly product development, and the open-type package, the input of the suppliers, made a small contribution to the development. Therefore, involving the suppliers in the development of the environmentally friendly air conditioner could be considered the "leadership development strategy" of K Electronics.

The Figure 7-5 shows the result of the application of the relationship between the directions of environmentally friendly product development and the contribution of supplier input in the development of the environmentally friendly air conditioner to the portfolio matrix for supplier involvement strategies.

8. Case 6: Laser Printer

8.1. Directions of Environmentally Friendly Product Development (Using Environmentally Friendly Packaging Materials)

Responding to local environmental regulations and EU WEEE regulations, K Electronics has been focusing its efforts to replace packaging materials with environmentally friendly materials. For example, K Electronics' laser printer was the first in Korea packed using a beehive-shaped paper shock absorbent that weighs 10percent less than the conventional shape.

8.2. Contributions of Suppliers

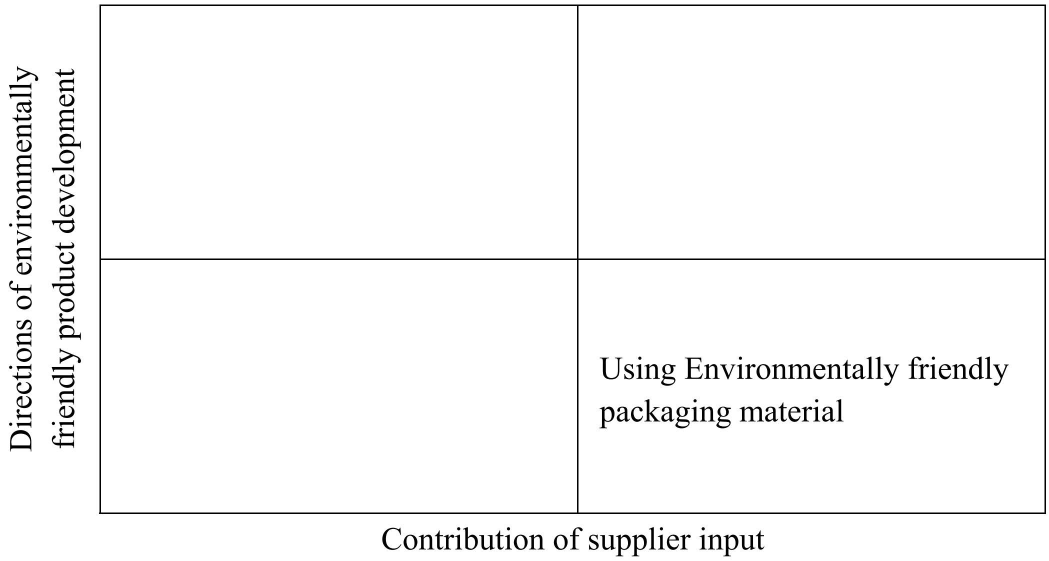
K Electronics replaced packaging materials with corrugated cardboard from EPS foams. HK Company in Korea took part in the development of the beehive-shaped paper packaging. The reason that the supplier could have joint involvement was its good technology, quality, and customization.

The beehive-shaped, paper, shock absorbent packing, the input of HK Company, was “necessary but not strategic”, and based on highly complicated technology (i.e. gray box). The supplier developed the beehive-shaped paper packaging with critical specifications given by K Electronics.

The HK Company took responsibility for input design, and took part in the development of the beehive-shaped paper packaging from the concept stage. Moreover, the supplier positively negotiated about the specification of packaging material with K Electronics. Moreover, the supplier took the initiative in the development of the beehive-shaped paper packaging by influencing product specification through addressing new technology development (i.e. fully development).

It could be concluded that the involvement of the HK Company in the development of the laser printer applying the beehive-shaped paper packaging was an evolutionary improvement (i.e. selection of low-impact materials by using renewable materials) in the environmentally friendly product development, and the beehive-shaped paper packaging, the input of the supplier, made a high contribution to the development. Therefore, involving the supplier in the development of the environmentally friendly laser printer could be considered the “exploitation strategy” of K Electronics

Figure 7-6 Supplier involvement strategy in the environmentally friendly product development (Laser printer)



The Figure 7-6 shows the result of the application of the relationship between the directions of environmentally friendly product development and the contribution of supplier input in the development of the environmentally friendly laser printer to the portfolio matrix for supplier involvement strategies.

9. Conclusion

This chapter reviews the practical application of the portfolio matrix suggested in this study. To prove the feasibility of applying the portfolio matrix for supplier involvement strategies, it was necessary to position the cases in each sector of the matrix and analyze its strategic significance. First, the directions of environmentally friendly product development were based on the Ecodesign Strategy, proposed by Van Hemel in Chapter 4. When collecting the data on the suppliers' contributions, this study focused on the contribution of suppliers' input to environmentally friendly product development, described in Chapter 5. It is important to note that characteristics of targeted products such as easy-to-develop one, level of products complexity, level of suppliers' inputs may produce different environmentally friendly product development directions. In addition, the portfolio model gives an important analysis on the environmentally friendly product development as a result of early supplier involvement.

Figure 7-7 Summarizes the positioning of the cases

Directions of environmentally friendly product development	Contribution of supplier input: Small	Contribution of supplier input: High
Revolutionary	**Air conditioner** (Reducing packaging)	**Monitor** (Applying Homogeneous Resin) **VCR** (Applying integrated IC)
Evolutionary	**Refrigerator** (High efficiency evaporator development) **Monitor** (Applying energy saving circuit) **Semiconductor** (Applying Halogen-free PCB)	**Refrigerator** (High efficiency compressor development) **Refrigerator** (Applying environmentally friendly refrigerant) **Refrigerator** (Applying environmentally friendly insulation material) **Semiconductor** (Applying lead-free soldering material) **Semiconductor** (Applying halogen-free EMC) **Laser printer** (Applying environmentally friendly packaging material) **Air conditioner** (More compact-size)

Chapter 8:
Further Discussions and Conclusions

1. Introduction

The research for this study was undertaken to develop the supplier involvement portfolio matrix, which showed why and how the strategies for the involvement of suppliers in environmentally friendly product development were differentiated. It was hoped that the strategies should be differentiated according to the direction of environmentally friendly product development and the contribution of supplier input. Since being created by just modifying the traditional supplier involvement portfolios without the support of empirical evidence, the model suggested in this study might still not be enough to satisfy strategic practitioners. In this study, therefore, empirical analysis was taken to show the applicability of the new supplier involvement portfolio matrix model.

As a matter of fact, there were a few studies on the strategies for supplier involvement in environmentally friendly product development. Therefore, this study started with the establishment of theoretical foundation for the strategies through literature research. After that, a model was suggested to differentiate the strategies, and an exploratory study was undertaken.

The exploratory study needed empirical data, which was acquired by investigating a developer (a manufacturer) and suppliers in the environmentally friendly product development. Moreover, the investigation of some suppliers was associated with the information that was hardly disclosed including the production cost and supplier network. The case study approach allows the researcher to draw key features out of the data, while at the same time allowing the contextual richness of the material to remain (Smith *et al.*, 2002). This allows the research to uncover contextual factors that explain and influence the observations from the cases. In addition, this research was cooperated with the case (K Electronics), as a result the study was feasible to carry out with maintaining a high standard of data quality.

The core research question of this study was why and how differences occurred in strategies for involving suppliers in the development of environmentally friendly products. This was also subdivided into three parts: What factors differentiates the strategies?; How do the factors differentiate the strategies?; What are the differences in the strategies? To determine the answers of these research questions, 6 important cases of the electronic products by K Electronics were offered. This chapter describes the findings, obtained from analyzing the cases, as a conclusion.

2. Research Question and Conclusions

2.1 What factors differentiate the strategies?

Supplier involvement was important for environmentally friendly product development.

As shown in the 6 cases of ecodesign, the involvement of a supplier in environmentally friendly product development widely ranged from the concept stage to the prototyping development stage. Such involvement occurred when a supplier had a critical capability that a developer (manufacturer) did not have as a core competence. The critical capability varied depending on suppliers. In the exploitation or partnership development strategies, it was technical capability (e.g. patents, new technology, etc.). In the manufacturer-driven development or leadership development strategies, it was the manufacturing capability considered quality or cost (e.g. quality reliability, cost-effective product manufacturing, etc.). The critical capability of a supplier played a very important role in the development of environmentally friendly products. Most of the suppliers in the manufacturer-driven development or leadership development strategy were easily controlled by a developer (manufacturer) and participated in the development through the channel of power of the developer (manufacturer). However, those in the exploitation or partnership development strategy were not easily controlled, and needed a systematic strategy based on the collaboration and communication between the supplier and the developer (manufacturer) (see Appendix 2).

The strategy for supplier involvement was dependent on the direction of environmentally friendly product development and the contribution of supplier input.

This study hypothesized that the involvement of suppliers in the ecodesign is not a “one-size-fit-all”, but differentiated. To prove the hypothesis, the suppliers involvement was studied as a decision-making for the environmental analysis/assessment, generation of environmentally oriented ideas, and evaluation and selection of ideas in the process of environmentally friendly product development, suggested by Bakker (1995) (see Chapter 4). This study found that the supplier involvement strategy was dependent on the direction of environmentally friendly product development and the contribution of supplier input. Analyzing the 6 cases of ecodesign also showed that one or more ecodesign strategies were applied to an environmentally friendly product development, and the suppliers offering the input associated with the strategies took part in the development. Therefore, it was necessary for a developer (manufacturer) to establish supplier involvement strategies taking into account the direction of environmentally friendly product development and the contribution of supplier input when involving a supplier in environmentally friendly product development. It should be noted that such a strategic approach in supplier involvement was required to develop an environmentally friendly product effectively and efficiently. For example, if the manufacturer-driven development strategy was applied to a supplier suitable for the partnership development strategy, a developer (a manufacturer) would focus, not on in its core competence, but allocate the resources to control an uncontrollable company. Therefore, a developer (a manufacturer) should establish supplier involvement strategies differentially by the direction of environmentally friendly product development and the contribution of supplier input (see Appendix 3).

2.2 How do the factors differentiate the strategies?

The more revolutionary the direction of environmentally friendly product development was, the higher the role of a developer (a manufacture) in the development of environmentally friendly product was.

When setting the strategy for supplier involvement, a developer (manufacturer) determined the direction of environmentally friendly product development and then estimated the feasibility of the involvement of associated suppliers. In these processes (see Chapter 5), firstly a developer decided the direction of environmentally friendly product development and then assessed feasibility of the environmentally friendly product development strategy by analyzing the suppliers' information. Analyzing the cases before, it was found that most of the development of environmentally friendly product was concentrated on evolutionary improvement. This has two reasons. First, developers focused on the development of environmentally friendly product with less uncertainty because going to the revolutionary improvement meant taking a risk. Second, manufacturers concentrated on making a quick response to regulations. While evolutionary improvement mostly meant a response to urgent regulations, revolutionary development was an answer that was not associated with laws and regulations. In the situation where regulations were an important force, therefore, they focused on the response to regulations.

What should be emphasized here was that developers played a more important role as the direction of the development of environmentally friendly products was more revolutionary. When supplier input made a high contribution and the development of environmentally friendly products was revolutionary, the manufacturer preferred co-development. When supplier input made a small contribution and the development of environmentally friendly products was revolutionary, the developer had the stronger initiative and leadership in the environmentally friendly product development. When supplier input made a high contribution, the developer (manufacturer) had a stronger intention to share the risk and profits with suppliers in the development of environmentally friendly product. On the other hand, when supplier input made a small contribution, the developer took the whole responsibility for the risk of the development of the environmentally friendly product (see Appendix 2 and 3).

The contribution of supplier input differentiated the characteristics of the input (in the aspect of products).

The strategy for supplier involvement in the development of environmentally friendly product was dependent on the characteristics of the input. In this study, the characteristics of the supplier input (products) were analyzed from the aspect of the product's complexity and the specifications provided.

When the supplier input made a high contribution, the product complexity was usually high (i.e. in the black box or gray box). On the other hand, when the supplier input made a small contribution, the product complexity was low (i.e. in the white box). The high product complexity meant that the supplier was able to keep long-term business through a product differentiation characterized "hard to copy".

In the manufacturer-driven development and leadership development strategies, the product complexity mostly came into the white box; in the exploitation strategy, into the gray box; in the Partnership Development strategy, into the gray box or black box. As the supplier input made a small contribution, the product complexity came into the white box. As the supplier input made a high contribution, the product complexity was in the gray box or black box. In the case of more compact-sized air conditioner development, however, the complexities of products from supplier are unique from other cases included in the exploitation strategy. In the past, D Company was a part of K Electronics, the supplier later on was set-up as an independent one. But K Electronics still relied highly on the supplier. K Electronics had the whole range of knowledge for the supplier, even if it depended highly on supplier. Thus, this case was unique, which began from the beginning of the relationship between K Electronics and D Company.

When the supplier input made a small contribution, the specifications provided from the developer was detailed and concrete. In one case, the developer provided the detailed drawings and even molds for the development (See the reducing packaging in the case of air conditioner). When the supplier input made a high contribution, however, the developer just provided the product concept or critical specifications, allowing them the discretion in the input of development. The abstraction of the specification provided was highest in the leadership development strategy; the next highest abstraction was in the manufacturer-driven development, exploitation, and partnership development strategies in that order (see Appendix 2).

The contribution of the supplier input differentiated the characteristics of the input (in the aspect of services).

The characteristics of the supplier input (services) were analyzed in the aspects of the responsibility for design, the supplier's influence on specifications, and the point when a supplier took part.

It was found that the design responsibility was given to the supplier when the input made a high contribution. The responsibility for design was given to the manufacturer when the input made a small contribution. When the input made a small contribution, the supplier had an influence in the range of its current capability, or made no influence, on specifications. On the other hand, when the input made a high contribution, the supplier's influence on the specifications was characterized by 'collaborative' or 'negotiate'. In the leadership development strategy, the supplier had no influence on specifications. In the manufacturer-driven development strategy, the supplier had an influence in the range of its current capability on specifications. In the exploitation and partnership development strategy, the supplier's influence on the specifications was characterized by 'negotiate' or 'collaborative.' The supplier's influence on specifications was highest in the leadership development strategy; the next highest influence was in the manufacturer-driven development, exploitation, and partnership development strategies in that order.

Especially, the supplier's influence on specifications had a close association with who provided new information in the development of an environmentally friendly product. In the exploitation strategy, the upstream partner provided the environmental information. In the leadership development and manufacturer-driven development strategies, the downstream partner offered the information. In the partnership development strategy, both the upstream and downstream partners provided the information. (See Chapter 4)

When the supplier input made a high contribution, the supplier participated in the development from the concept stage. When the supplier input made a small contribution, the supplier took part in the development after the concept stage. The point of time when the supplier participated in the development was earlier as the input made a higher contribution. In the partnership development and exploitation strategies, the involvement was made before the concept stage. In the manufacturer-driven development and leadership development strategies, the involvement was made at the detailed design stage. Therefore, the supplier took part in the development of environmentally friendly products earlier as the input made a high contribution (see Appendix 3).

The contribution of the supplier input differentiated the initiative of the development.

When the input made a high contribution, the supplier took the initiative of the development. However, when the input made a small contribution, the developer (manufacturer) itself led the development.

In the leadership development strategy, the manufacturer took the initiative through 'in-house'. In the manufacturer-driven development strategy, the developer took the initiative through 'partnership sourcing'. In the exploitation strategy, the supplier took the initiative through 'fully developed.' In the Partnership Development strategy, the supplier took the initiative through 'supplier interaction.' (see Appendix 4)

2.3. What are the differences in the strategies?

The supplier interface management was dependent on the strategy.

Analysis of the supplier management activities showed that the supplier interface management and project management were dependent on the strategy, while the development management and product management were not. This seemed to be linked to the limit of this study: the 6 cases were obtained from 6 business divisions in a single electronic company, K Electronics. Differences were found in the project management and the supplier interface management, which were related to the business unit strategy, but there were no differences in the development management and the product management, which were managed in the level of cooperate strategy. In other words, K Electronics had operated the development management and product management based on its product development rules. For more meaningful results, the analysis of the development management and product management need comparing with case studies of other companies.

The supplier interface management was analyzed from the aspects of the pre-selection, supplier motivation, and necessary supplier capability. Except for several cases in the exploitation strategy, existing suppliers were pre-selected in all strategies. This seems to be because the supplier management of K Electronics, and the Korean electronic industry in a wide meaning, focuses on the partnership. This finding implies that K Electronics had a collaborative relationship with its suppliers, and makes much of the role of the supplier in the development of environmentally friendly products. In particular, K Electronics' CEO emphasized a philosophy called the 'Artistic Purchase' in the supplier management. The 'Artistic Purchase' was to revaluate the role of suppliers by regarding the purchasing activities as a core of competitiveness. The purchase could be achieved by revaluating the status of suppliers. K Electronics had reset the status of purchase by involving it from the product planning stage, and encouraged suppliers to make an effort for self-development by having a business relationship with only a small number of high quality suppliers. In the aspect of the supplier motivation, similar findings, as in the pre-selection, were obtained. In the exploitation strategy, the developer (manufacturer) could not find a special incentive to supplier motivation, and thus, the development of an environmentally friendly product was fully dependent on the input from suppliers. In the manufacturer-driven development and leadership development strategies, however, the business scale given to the suppliers was the incentive. In the partnership development strategy, the incentive was the opportunity for new business or customer-specific assets, based on a win-win idea.

As the supplier input made a higher contribution, higher technical capability such as patents, design capability, and development capabilities were needed as a necessary supplier capability. When the input made a small contribution, manufacturing capability was important. This seemed to be linked to the characteristics of the input (products) and the supplier (see Appendix 4).

The project management was dependent on the strategy.

The project management was analyzed from the aspects of planning activities and execution activities. In planning activities, when the supplier input is relatively small, the criteria to select suppliers is cost and price.. However, when the supplier input is bigger, the affiliates, the partners with high quality technology or the suppliers with patents, took part in the product development.

In execution activities, the leading department is relying on the contribution of the supplier input. As the input made a higher contribution, the development department took initiatives to lead the development of environmentally friendly products. When the input made a small contribution, the purchase department played a higher role. These facts seemed to be linked to the necessary supplier capability for the supplier interface management. Therefore, when the input made a high contribution, technical capability was required from the supplier, and, thus, the development department could lead in the development of an environmentally friendly product. When the input made a small contribution, manufacturing capability was required from the supplier, and, therefore, the purchase department had the initiative. However, the strategies were not different in the collaboration between the 1st tier suppliers and between the 1st and 2nd tier suppliers (see Appendix 4 and 5).

2.4. Additional finding

While analyzing the cases in this study, an additional finding was obtained, which was not associated with the main research questions: in some contributions of supplier input, there was a difference between the traditional product development and the environmentally friendly product development. For example, as shown in Figure 8-1, in the cases of the refrigerator refrigerant, foam materials, lead-free soldering, halogen-free EMC, and packaging materials, the contribution of the supplier input was small in the traditional product development, while high in the environmentally friendly product development. This finding implies that the environmental consideration changes the relationship with suppliers, and the needs for collaboration in the supplier chain is growing in ecodesign.

It may imply that supplier involvement in product development in Korean electronics industry at least will be increasingly important, and its input and contributions will be bigger and influential in order to meet and reflect international and national environmental regulations and requirements.

Figure 8-1 The effect of the environmental consideration on the contribution of supplier input.

Traditional product development	
Air conditioner (Reducing packaging) Refrigerator (High efficiency evaporator Development) Monitor (Applying energy saving circuit) Semiconductor (Applying halogen-free PCB) Air conditioner (More compact sizing) Refrigerator (Applying environmentally friendly refrigerant) Refrigerator (Applying environmentally friendly insulation material) Semiconductor (Applying Lead-free soldering material) Semiconductor (Applying halogen-free EMC) Laser printer (Applying environmentally friendly packaging material)	Monitor (Applying monomaterial resin) VCR (Applying integrated IC) Refrigerator (High efficiency compressor development)
Environmentally friendly product development	
Air conditioner (Reducing packaging) Refrigerator (High efficiency evaporator Development) Monitor (Applying energy saving circuit) Semiconductor (Applying halogen-free PCB) Air conditioner (More compact sizing)	Monitor (Applying monomaterial resin) VCR (Applying integrated IC) Refrigerator (High efficiency compressor development) Refrigerator (Applying environmentally friendly refrigerant) Refrigerator (Applying environmentally friendly insulation material) Semiconductor (Applying Lead-free soldering material) Semiconductor (Applying halogen-free EMC) Laser printer (Applying environmentally friendly packaging material)
Small	High

Contribution of supplier input

3. Further Discussions

In the previous section, this study undertook the findings to the research questions and one of the important additional findings as a conclusion. The findings also implied some managerial thinking. These implications are discussed in the followings.

3.1 Strategic approach to supplier involvement

Purchasing literature in the area of supply chain management over the last decade has emphasized analyzing buyer-supplier relationships because of their significant role in the success of individual firms. Inter-organizational practices such as supplier involvement have become important in the manufacturing industry, partly due to the cost pressure caused by decreasing price levels and partly due to firms' concentration on their core competencies.

"Organizational buying is dramatically shifting from a transaction oriented to a relational oriented philosophy, and will shift from a buying process to a supplier relationship process" (Sheth and Sharma, 1997, p.92).

Because of this shift, much of the past research on buying behavior will become obsolete (Sheth and Sharma, 1997). Efficient management of the supply base has become a challenge (Trent and Monczka, 1998). The supplier involvement in product development has been regarded as an effort to enhance its efficiency and effectiveness. In particular, many researchers have shown the importance of supplier involvement in environmentally friendly product development as a strategy to reduce environmental impacts throughout the life cycle of a product (Steve *et al*., 1999; Noci, 1997; Green *et al*., 1996).

The studies, until now, have just emphasized the importance of supplier involvement in environmentally friendly product development, but mostly failed to look at the necessity of different strategies by the type of involvement. It can be, therefore, said that the different supplier management and the strategic approaches for supplier involvement, proposed by Wynstra and Pierick (1999) and Dyer *et al*. (1996), are critical considerations for environmentally friendly product development.

This study elaborated the portfolio matrix as a decision-making model for establishing supplier involvement strategies in environmentally friendly product development. The portfolio matrix showed that the strategy for supplier involvement in environmentally friendly product development was not a “one-size-fit-all”, but dependent on the direction of environmentally friendly product development and the contribution of supplier input. These strategies would be used as a useful tool to support the decision-making process, which was defined as a core competence of a firm by Fine and Whitney (1996). It is the academic contribution of this study.

3.2 Factors differentiating the strategy for supplier involvement

This study suggested the direction of environmentally friendly product development and the contribution of supplier input as factors differentiating the strategy for supplier involvement. These factors were derived from reviewing the environmentally friendly product development processes and literature, that is, by both practical and theoretical approaches.

For the practical approach, it was first necessary to discuss the stages where suppliers were involved in the process of the environmentally friendly product development. In most of the current, practical environmentally friendly product development processes, developers first decided the direction of environmentally friendly product development, analyzed the given conditions of the firms to identify feasibility of the development, and then decided the supplier involvement. In this process, the factors for the supplier involvement in environmentally friendly product development was obtained from the questions; which direction of environmentally friendly product does the developer have, and which suppliers does the developer have to involve. Other studies before have focused on the design stage in environmentally friendly product development; for example, a supplier early involvement of in product development (Sanders *et al.,* 2001) and the importance of supplier involvement in design (Dobler, 2000). Reviewing a variety of environmentally friendly product development processes suggested by researchers (Bakker, 1995; ISO, 2001; POEM, 2000; PWC, 1999, Promising Approach, 1997; EcoDesign, 1997; Philips ecodesign, 1997), however, this study found that the environmentally friendly product development processes widely ranged from product planning to modification, and the supplier involvement occurred in various stages, including environmental analysis/assessment, generation of environmentally oriented ideas, evaluation and selection of ideas, and overall environmental evaluation/assessment. Therefore, this study claimed that it was necessary to take into account the supplier involvement expanding the scope to various stages of the environmentally friendly product development process, rather than setting limits to the design stage. It was, of course, clear that the design process was the best point for supplier involvement to solve and control the environmental problems of products (Dobler, 2000). Considering the various types of supplier involvement, the effectiveness and efficiency by supplier management, and the environmental friendliness regarded as an additional quality of product, it was required to establish the strategies of supplier involvement in a wide range from design to engineering stages.

For the theoretical approach, it was also necessary to discuss the theoretical feasibility of applying the factors. Oslund (1994) suggested the level of specialized knowledge and the capability of approaching external knowledge in a firm's control as the factors affecting the success of product development. Heidenmark (2001) presented the environmental regulations, market pressure, organizational characteristics, and supplier chain as the factors affecting the decision-making in environmentally friendly product development. In addition, many researchers claimed that it was necessary to have a differential approach because the objectives of projects and their relative importance varied depending on the different levels of innovation (Handerson and Clark, 1990; Wheelright and Clark, 1992; Griffin and Page, 1996; Luthardt and Morchel, 2000). Gullander *et al.* (2001) suggested six factors: the degree of product innovation, the product architecture (modular or integral), the product complexity, the cooperation pattern, the organization for integrated product development, and the risk of undertaking. These studies concluded that the decision-making in product development was made by the factors linked to the product and the organization. According to this theoretical basis, it could be said that the factors differentiating the strategies for supplier involvement, suggested in this study, were in line with the theories. Therefore, this study selected the direction of environmentally friendly product development as the factor linked to the product and the contribution of supplier involvement as the factors linked to the organization.

The factor, the direction of environmentally friendly product development, was linked to the level of innovation of the environmentally friendly product to be developed. In this study, the cluster of ecodesign strategy, proposed by Van Hemel (1998), was used to analyze the direction of the environmentally friendly product development. In particular, this factor was significant for a developer (manufacturer) having responsibility for product development, in the position that it was linked with the complexity and uncertainty in product development, and could lead to mutual collaboration and control for sharing responsibility with suppliers (Pfeffer and Salancik, 1978; Wynstra and Pierick, 1999).

In addition, the factor of the contribution of supplier input, was related to the level of contribution of the products or services from suppliers to environmentally friendly product development. Studies of the supplier involvement in product development have been conducted in the aspects of the asset specificity (Williamson, 1979) and the buyer-supplier relationship (Clark and Fujimoto, 1991; Appleby and Twigg, 1988; Kamarth and Liker, 1994; Asanuma, 1989; Roy and Potter, 1996; Wynstra and Pierick, 1999). However, these studies had a constant trend. In the early studies, focus was given to the potential contribution of suppliers from the viewpoint of buyers. However, more recent studies shifted the focus to the actual contribution of suppliers. As Gullander *et al*. (2001) pointed out, this trend showed the supplier involvement at a more practical and actual perspective. This factor was decided to determine how important the product was, and how helpful the service for the environmentally friendly product development was. Therefore, based on the actual contribution of suppliers, this study approached the aspects of asset specificity and the buyer-supplier relationship.

3.3 Differentiation of supplier involvement strategies

In order to prove the feasibility of the portfolio matrix for supplier involvement strategies, this study analyzed the cases for each division of the matrix. However, it was necessary to discuss the findings of the analysis from the aspects of product characteristics, supplier characteristics, and product development initiative, in order to understand the differentiation of supplier involvement strategies.

In the product characteristics, it was found that the suppliers had a higher part in the development, as the product complexity was higher. This finding supports the relationship between the product complexity and the supplier involvement, which was suggested by Clark and Fujimoto (1991), Kamath and Liker (1994), and Wynstra and Pierick (1999). In addition, the findings about the specifications also was in line with the study results of Kamath and Liker (1994), Dyer *et al* (1996), and Kojima (1998): As the buyer had more partnership with suppliers, the specifications provided were more abstract, but the suppliers played the role of full service supplier[19] or full system supplier[20].

In the supplier characteristics, it was found that the suppliers had more design responsibility and had a higher, and more collaborative, influence on specifications, as the contribution of the input was higher. This finding was in line with the conclusion of Appleby and Twigg (1988): If a supplier had full responsibility for product design, it also had responsibility for input and quality. It was also shown that the supplier involvement was made at an earlier stage as the supplier input made a higher contribution. These results support the findings of Wynstra and Pierick (1999): It was necessary to consider critically the different supplier management and the strategic approach for supplier involvement to increase in the efficiency and effectiveness of environmentally friendly product development than just

19) Takes responsibility for the whole subsystem. Even participates in new model planning before the concept design state. Has much better knowledge of its products or processes than its buyer, and provides a solution to meet the requirements for cost and quality. Makes a test independently, and even has responsibility for testing other vendors' parts.

20) Designs and manufacturers complex assemblies. Has less technical capability, having a smaller influence on design. However, acquires critical specifications from its developer (manufacturer), and resolves requirements and special limitations. Develops systems independently, and has responsibility for testing.

emphasising the importance of the supplier early involvement.

For the supplier management and purchasing activities, this study found that the pre-selection in the supplier interface management was made among the existing ones in all strategies except for the Exploitation strategy, showing the close association with the dependence of suppliers on the manufacturer. This finding was in line with the study of Cox *et al*. (2001): As shown in the power regime between a buyer and supplier, a supplier highly depended on a developer (manufacturer) in mutual dependence or a buyer dominant relationship, while a supplier was not dependent on a developer (manufacturer) in a supplier dominant relationship. According to the recent moving of the relationship with suppliers to a collaborative, non-market transaction (Imrie and Morris, 1992), the findings showed the importance of the developer (manufacturer) in environmentally friendly product development.

The result was also found in the motivation of supplier involvement. In the Exploitation strategy, the developer (manufacturer) did not have a special incentive for supplier motivation. Therefore, the environmentally friendly product development was fully dependent on the supplier input. Outsourcing and supply chain development were often motivated by cost, which was one reason why firms had paid attention to the efficient management of supplier relationships (Virolainen, 1998; Matikainen, 1998). One of the requirements for supplier involvement and its motivation was the information sharing between the firms (Munday, 1992; Tomkins, 2001). From the management point of view, information on activities was important when analyzing and developing a firm's operations. Thus, it was necessary to consider how to motivate supplier involvement for environmentally friendly product development in the exploitation strategy and other strategies. It was beyond this research boundary, but this research finding could be a sound basis for further development.

In project management, the supplier participates earlier when the input made a higher contribution, as also shown in the supplier characteristics. This finding was in line with the study of Ragatz *et al*. (2002): The benefits of supplier involvement in environmentally friendly product development could be a result from sharing product design and specifications with suppliers at the early stage of product development and utilizing the special technology of the supplier.

In addition, the product development initiative was also dependent on the contribution of supplier input. This finding was in line with the study of GEMI (2001): If suppliers made a small contribution to product differentiation, they focused on a lower price of unit input and less administration cost rather than a technical contribution.

More importantly, the portfolio matrix suggested in this study focused on the power regime between developer (manufacturer) and supplier in the supply chain. Hall (2000) pointed out that the dominant power of a developer (manufacturer) led environmentally friendly product development. As shown in the portfolio matrix, however, a developer (manufacturer) had to involve suppliers strategically in the environmentally friendly product development, when considering that the strategies for supplier involvement were not uniform and collaboration was differentiated since many suppliers did not have the same type or level of pressure in the supply chain. As a result, the supplier involvement should be based on the channel of power in the Leadership Development and Manufacturer-driven Development strategies, because values flowed to the dominant side in the relationship. Supplier involvement should be systematically based on the strategic partnership in the Partnership Development strategy. On the other hand, a developer (manufacturer) focused on the use of suppliers in the Exploitation strategy, because suppliers interrupted the flow of values in the supply chain.

Analyzing the cases with the portfolio matrix in this study found that the needs for collaboration in the supply chain are growing. This finding was in line with the suggestion by Boons and Groene (1996): When making an effort to minimize the environmental impacts of products, it was necessary to make a change in the operation of each business in the supply chain and the interaction with other firms, and that by Heiskanen *et al* (1998): Environmentally friendly product development increased the needs for collaboration in the supplier chain.

This study also showed that the product characteristics and the supplier characteristics were differentiated by the supplier involvement strategies, and the findings were in lines with other researchers' studies on the type of supplier involvement in product development. In particular, the portfolio matrix overcame the disadvantage of many models or classifications of the types of supplier involvement that were static or inflexible and not able to show how to manage the supplier involvement, according to focusing just on the characteristics of products (Wynstra and Pierick, 1999). By taking into account the power regime, this study could describe the diversity of the supplier involvement strategies according to the flow of values between the manufacturer and suppliers.

4. Research Limitations and Further Implications

This study discovered some new findings, but also has several limitations. First, the cases of the Korean electronic industry were analyzed to prove the practical feasibility of the portfolio matrix. Not surprisingly, the feasibility of the portfolio matrix should be applied to other nations and industries. From a theoretical point of view, a sound positive finding is limited in the Korean case. Thus, it is necessary to test the matrix model for academics to develop sound and acceptable models in other cases. Therefore, it is not certain that it can be applicable to the global electronics industries. Second, the portfolio matrix applied only to a single electronic company, K Electronics. Although each business division of K Electronics was independently operated, it was impractical to analyze, in detail, the supplier and product management, related to the corporate policy, such as the development management and product management.

In order to prove the validity and reliability of the portfolio matrix and get more reliable answers to the research questions, it is necessary to expand the cases to other industries in different nations. This further study may prove whether the portfolio matrix is feasible only to the local industry or not. In addition, the cases of several corporations, not a single one, should be analyzed in order to study the differences and strategy differentiation according to the corporate policy. It may result from the methodological choice in this research, i.e. case study approach. If other research methods, including quantitative methods and more case studies are employed, it may produce globally applicable outcomes.

As mentioned in the main text, business experience is not a one-size-fit-all approach. It intrinsically indicates that the more complex the challenge and the situation, the more collaboration was required. This means that the portfolio matrix suggested in this study might not explain the global industry, but the matrix model can be an important clue in explaining the experimental market. As a matter of fact, to gain true, long-term green competitive advantage – and reduce overall costs and increase eco-efficiency – global companies need to take a more holistic approach to optimizing their supply chains. Thus creating an adaptive supply chain approach is critical today in a volatile economic and technological environment. As a further research, this study suggests that the portfolio matrix model be examined under the concept of adaptive supply chains in the aspects of integrated networked value. When global companies decide to make or buy new or existing products, the portfolio model can give pre-requisite answers on how to organize suppliers in different types of products and technological standards. In particular, how product functionality and complexity influence environmental supply chain management. Thus, more academic research is necessary to test and prove the applicability of the portfolio matrix model in other corporate cases in different industries and nations.

In order to develop the outcomes of the study further, following issues can be expanded for further studies. First of all, when corporations decide to make or buy in environmental supply chain management, what factors should be reflected for the decision in different industries and nations other than Korean electronic industry?

Secondly, this study found that the supplier involvement strategy is dependent upon the direction of environmentally friendly product development. In order to understand and apply to product development or project development at the corporate level, the question of how the supplier involvement strategy can be developed under corporate strategy or policy should be answered.

Thirdly, this study also identified that a different level of strategic relationship between buyers and suppliers exist in the Korean electronic industry. In order to explain each side of the strategic relationship, it is necessary to answer the question of 'what are the main concerns of suppliers and buyers in terms of strategic competitiveness?

The issues as shown above are equally important to academics and industries. It is expected that the initial outcomes of this study will bring more substantial outcomes of strategic involvement of suppliers within supply chain management from a variety of industries and nations as a result of academic and practical findings.

Appendices

Appendix 1: Interviewees in K Electronics

<table>
<tr><th>Section</th><th>Environment & Safety</th><th>Development</th><th>Purchase</th></tr>
<tr><td>Headquarter</td><td>Mr. J. Whang</td><td>Dr. J. Kwak</td><td>Mr. J. Eum</td></tr>
<tr><td>Refrigerator</td><td>Mr. J. Jang</td><td>Mr. B. Byung
Mr. B. Kim
Mr. J. Lee
Mr. H. Maeng</td><td rowspan="3">Mr. K. Ok</td></tr>
<tr><td>Monitor</td><td>Ms. Y. Jung</td><td>Mr. B. Lee</td></tr>
<tr><td>Semiconductor</td><td>Mr. J. Song
Mr. H. Lee
Mr. D. Jun</td><td>Mr. N. Kim
Mr. T. Park</td></tr>
<tr><td>VCR</td><td rowspan="3">Ms. Y. Jung</td><td>Mr. H. Park
Mr. K. Park
Mr. T. Kim
Mr. B. Sung</td><td>Mr. K. Lee</td></tr>
<tr><td>Air conditioner</td><td>Mr. D. Kim
Mr. D. Sung</td><td rowspan="2">Mr. K. Ok</td></tr>
<tr><td>Laser Printer</td><td>Mr. W. Cho
Mr. D. Sung</td></tr>
</table>

Appendix 2: Characteristics of product and supplier in portfolio matrix

Strategy	Product	Ecodesign Direction	Input Characteristics		Supplier Characteristics			Development Initiative	Supplier Input Contribution
			Product Complexity	Specification Provided	Design Responsibility	Supplier's Influence on Specifications	Stage of Supplier Involvement		
Partnership Development	**Monitor** (Homogeneous Resin)	Optimization of end-of-life system (Apply monomaterials)	Black Box	Concept	Supplier	Collaborate	Concept	Supplier-driven (Supplier Interaction)	High
	VCR (Integrated IC)	New concept development (Integration of functions)	Gray Box	Concept	Supplier	Negotiate	Concept	Supplier-driven (Fully Developed)	High
Leadership Development	**Air conditioner** (Reducing packaging)	New concept development (Functional optimization)	White Box	Complete design	Customer	None	Prototyping	Buyer-driven (Partnership sourcing)	Small
Exploitation	**Refrigerator** (High efficiency compressor)	Reduction of impact during use (Low energy consumption)	Gray Box	Critical specification	Supplier	Negotiate	Concept	Supplier-driven (Fully Developed)	High
	Refrigerator (Environmentally friendly refrigerant)	Selection low-impact materials (Clean materials)	Gray Box	Critical specification	Supplier	Collaborate	Concept	Supplier-driven (Supplier Interaction)	High
	Refrigerator (Environmentally friendly Insulation Material)	Selection low-impact materials (Clean materials)	Gray Box	Critical specification	Supplier	Collaborate	Concept	Supplier-driven (Supplier Interaction)	High
	Semiconductor (Lead-free soldering Materials)	Selection low-impact materials (Clean materials)	Gray Box	Concept	Supplier	Collaborate	Concept	Supplier-driven (Supplier Interaction)	High
	Semiconductor (Halogen-free EMCs)	Selection low-impact materials (Clean materials)	Gray Box	Concept	Supplier	Negotiate	Concept	Supplier-driven (Fully Developed)	High
	Laser printer (Environmentally friendly packaging Material)	Selection low-impact materials (Renewable materials)	Gray Box	Critical specification	Supplier	Negotiate	Concept	Supplier-driven (Fully Developed)	High
	Air conditioner (More compact-size)	Reduction of material usage (Reduction of volume)	White Box	Critical Specification	Supplier	Negotiate	Post-concept	Supplier-driven (Fully Developed)	High
Manufacturer driven Development	**Refrigerator** (High efficient evaporator)	Reduction of material usage (Reduction of volume)	White Box	Detailed Specification	Customer	Present capability	Prototyping	Buyer-driven (Partnership sourcing)	Small
	Semiconductor (Halogen-free PCB)	Selection low-impact materials (Clean materials)	White Box	Detailed Specification	Customer	Present capability	Prototyping	Buyer-driven (Partnership sourcing)	Small
	Monitor (Energy saving circuit)	Reduction of impact during use (Low energy consumption)	White Box	Detailed Specification	Customer	Present capability	Prototyping	Buyer-driven (Partnership sourcing)	Small

Appendix 3: Each case study on supplier management and purchasing activities - Development Management

Strategies	Product	Development Management	
		Influential Department	Base of decision making
Partnership Development	**Monitor** (Homogeneous Resin)	Product Development	Corporate provision of product development
	VCR (Integrated IC)	Product Development	Corporate provision of product development
Leadership Development	**Air conditioner** (Reducing packaging)	Product Development	Corporate provision of product development
Exploitation	**Refrigerator** (High efficiency compressor)	Product Development	Corporate provision of product development
	Refrigerator (Environmentally friendly refrigerant)	Product Development	Corporate provision of product development
	Refrigerator (Environmentally friendly Insulation Material)	Product Development	Corporate provision of product development
	Semiconductor (Lead-free soldering Materials)	Product Development	Corporate provision of product development
	Semiconductor (Halogen-free EMCs)	Product Development	Corporate provision of product development
	Laser printer (Environmentally friendly packaging Material)	Product Development	Corporate provision of product development
	Air conditioner (More compact-size)	Product Development	Corporate provision of product development
Manufacturer-Driven Development	**Refrigerator** (High efficient evaporator)	Product Development	Corporate provision of product development
	Semiconductor (Halogen-free PCB)	Product Development	Corporate provision of product development
	Monitor (Energy saving circuit)	Product Development	Corporate provision of product development

Appendix 4: Each case study on supplier management and purchasing activities - Supplier Interface Management

Strategies	Product	Activities of Supplier Interface Management			
		Monitoring Supplier market	Pre-selecting Suppliers	Motivating Supplier	Necessary Supplier's Capability
Partnership Development	**Monitor** (Homogeneous Resin)	Yes	Existing Supplier	Relation-Specific Investment	Supplier's Patent
	VCR (Integrated IC)	Yes	Existing Supplier	Business Opportunity	Design Capability
Leadership Development	**Air conditioner** (Reducing packaging)	Yes	Existing Supplier	Business Volume	Manufacturing Capability
Exploitation	**Refrigerator** (High efficiency compressor)	Yes	New Supplier	None	Design Capability
	Refrigerator (Environmentally friendly refrigerant)	Yes	Existing Supplier	None	Supplier's Patent
	Refrigerator (Environmentally friendly Insulation Material)	Yes	Existing Supplier	None	Supplier's Patent
	Semiconductor (Lead-free soldering Materials)	Yes	Existing Supplier	None	Development Capability
	Semiconductor (Halogen-free EMCs)	Yes	Existing Supplier	None	Development Capability
	Laser printer (Environmentally friendly packaging Material)	Yes	New Supplier	None	Design Capability
	Air conditioner (More compact-size)	Yes	New Supplier	None	Manufacturing Capability
Manufacturer-Driven Development	**Refrigerator** (High efficient evaporator)	Yes	Existing Supplier	Business Volume	Manufacturing Capability
	Semiconductor (Halogen-free PCB)	Yes	Existing Supplier	Business Volume	Manufacturing Capability
	Monitor (Energy saving circuit)	Yes	Existing Supplier	Business Volume	Manufacturing Capability

Appendix 5: Each case study on supplier management and purchasing activities - Project Management

<table>
<tr><th rowspan="4">Strategies</th><th rowspan="4">Product</th><th colspan="6">Project Management</th></tr>
<tr><th colspan="2">Planning</th><th colspan="3">Execution (Coordination)</th></tr>
<tr><th rowspan="2">Selecting Suppliers</th><th rowspan="2">Stage of Supplier Involvement</th><th rowspan="2">Leading Department</th><th colspan="2">Cooperation</th></tr>
<tr><th>between 1st tiers</th><th>between 2nd tiers</th></tr>
<tr><td rowspan="2">Partnership Development</td><td>Monitor
(Homogeneous Resin)</td><td>Affiliated Company</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>VCR
(Integrated IC)</td><td>Partner having superior technology</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>Leadership Development</td><td>Air conditioner
(Reducing packaging)</td><td>Supplier having cost competition</td><td>Prototyping</td><td>Development /Purchasing</td><td>None</td><td>None</td></tr>
<tr><td rowspan="8">Exploitation</td><td>Refrigerator
(High efficiency compressor)</td><td>Supplier having superior technology</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>Refrigerator
(Environmentally friendly refrigerant)</td><td>Supplier having patent</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>Refrigerator
(Environmentally friendly Insulation Material)</td><td>Supplier having patent</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>Semiconductor
(Lead-free soldering Materials)</td><td>Supplier having superior technology</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>Semiconductor
(Halogen-free EMCs)</td><td>Supplier having superior technology</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>Laser printer
(Environmentally friendly packaging Material)</td><td>Supplier having superior technology</td><td>Concept</td><td>Development /Design</td><td>None</td><td>None</td></tr>
<tr><td>Air conditioner
(More compact-size)</td><td>Supplier having cost competition</td><td>Post-concept</td><td>Development /Purchasing</td><td>None</td><td>None</td></tr>
<tr style="display:none"></tr>
<tr><td rowspan="3">Manufacturer-Driven Development</td><td>Refrigerator
(High efficient evaporator)</td><td>Supplier having cost competition</td><td>Prototyping</td><td>Development /Purchasing</td><td>None</td><td>None</td></tr>
<tr><td>Semiconductor
(Halogen-free PCB)</td><td>Supplier having cost competition</td><td>Prototyping</td><td>Development /Purchasing</td><td>None</td><td>Yes</td></tr>
<tr><td>Monitor
(Energy saving circuit)</td><td>Supplier having cost competition</td><td>Prototyping</td><td>Development /Purchasing</td><td>None</td><td>Yes</td></tr>
</table>

Appendix 6: Each case study on supplier management and purchasing activities - Product Management

Strategies	Product	Product Management			
		Extending Activities		Restrictive activities	
		Providing information	Suggesting alternatives	Evaluating product design	Standardization or simplification
Partnership Development	**Monitor** (Homogeneous Resin)	Yes	Yes	Yes	Yes
	VCR (Integrated IC)	Yes	Yes	Yes	Yes
Leadership Development	**Air conditioner** (Reducing packaging)	Yes	Yes	Yes	Yes
Exploitation	**Refrigerator** (High efficiency compressor)	Yes	Yes	Yes	Yes
	Refrigerator (Environmentally friendly refrigerant)	Yes	Yes	Yes	Yes
	Refrigerator (Environmentally friendly Insulation Material)	Yes	Yes	Yes	Yes
	Semiconductor (Lead-free soldering Materials)	Yes	Yes	Yes	Yes
	Semiconductor (Halogen-free EMCs)	Yes	Yes	Yes	Yes
	Laser printer (Environmentally friendly packaging Material)	Yes	Yes	Yes	Yes
	Air conditioner (More compact-size)	Yes	Yes	Yes	Yes
Manufacturer-Driven Development	**Refrigerator** (High efficient evaporator)	Yes	Yes	Yes	Yes
	Semiconductor (Halogen-free PCB)	Yes	Yes	Yes	Yes
	Monitor (Energy saving circuit)	Yes	Yes	Yes	Yes

Appendix 7: Interview Schedule

1. **Overview of the environmentally friendly product development**

<table>
<tr><td rowspan="2">Product Name</td><td rowspan="2"></td><td colspan="4">Interviewee</td></tr>
<tr><td>Department</td><td></td><td>Name</td><td></td></tr>
<tr><td colspan="6">• Details of the environmentally friendly product development</td></tr>
<tr><td colspan="6">• Backgrounds of the environmentally friendly product development</td></tr>
<tr><td colspan="6">• Performance of the environmentally friendly product development</td></tr>
</table>

2. Business Conditions

2-1. What business conditions of the product does the business division have (in terms of growth opportunities, protection for the innovation, scale of market, competition, and the position in production/distribution system)?

2-2. What development strategies does the business division have?

2-3. What buyer-supplier relationship in the product development does the business division have?

3. Supplier management and purchasing activities in the environmentally friendly product development

3-1. Development management

3-1-1. Which department in the business division is the most influential in the environmentally friendly product development?

3-1-2. How does the business division decide to involve the supplier in the environmentally friendly product development?

3-2. Supplier interface management

3-2-1. How does the business division monitor the supplier market?

3-2-2. How does the business division pre-select suppliers to cooperate in environmentally friendly product development?

3-2-3. How does the business division motivate suppliers to build up/maintain specific knowledge or develop certain products?

3-2-4. How does the business division exploit the technical capability of the supplier?

3-3. Project Management

3-3-1. How does the business division determine specific develop-or-buy solutions?

3-3-2. How does the business division select suppliers for involvement in the development project?

3-3-3. How does the business division determine the extent (workload) and the stage of supplier involvement?

3-3-4. Which department in the business division leads the coordination with suppliers?

3-3-5. Does the business division coordinate development activities between different first tier suppliers?

3-3-6. Does the business division coordinate development activities between first tier suppliers and second tier suppliers?

3-4. Product management

3-4-1. Does the business division provide information on new products and technologies being developed or already available in supplier markets?

3-4-2. Does the business division suggest alternative suppliers, products and technologies that can result in a higher quality of the final product?

3-4-3. Does the business division evaluate product designs in terms of part availability, marketability, lead-time, quality and costs?

3-4-4. Does the business division promote standardization and simplification of designs and parts?

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