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台灣資訊科技產業導入綠色供應鏈管理之研究

A Study of Green Supply Chain Management in Taiwan's Information Technology Industry

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摘要

歐盟 2003 年 2 月 13 日公佈廢電子電機設備（Waste Electronics and Electrical Equipment，WEEE）及電子電機設備中危害物質禁用（Restriction of the use of certain Hazardous Substance in electrical and electronic equipment，RoHS），以及能源使用產品生態化設計指令（Eco-design Requirements for Energy-using Products，EuP）等三大環保指令。對於資訊電子產品進行有關有毒物質禁用及廢棄物回收的要求。國際資訊大廠也隨之帶動產品環保的要求，並將落實到資訊產品當中，顛覆過去資訊產品以安規、可靠度為主的規範，掀起了一連串的綠色產品的改造工程。本研究利用深度訪談研究方法，輔以文獻與環保議題之整理，並探討三個案例公司，涵蓋主動元件、被動元件、電腦機殼、印刷電路板、電源供應器及連接器等六大資訊零組件產業藉以建立資訊科技(IT)產業推動綠色供應鏈管理系統模式，再以個案實證說明推動模式的適用性，及有效降低與解決企業供應鏈(GSCM)之風險與壓力，突破與安然渡過此項非關稅的貿易障礙，提供其他產業後續推動環保相關議題時之參考。

關鍵詞：資訊科技產業、綠色供應鏈管理、環保相關議題、非關稅的貿易障礙

Abstract

On February 13, 2003, the European Union (EU) officially promulgated three major environmental protection directives, including Waste Electronics and Electrical Equipment (WEEE), Restriction of the Use of Certain Hazardous Substance in Electrical and Electronic Equipment (RoHS), and Eco-design requirements for Energy-using Products (EuP), which banned the use of toxic substances in information and electronic products and demanded recycling wastes. A green products reformation was raised as the world-class information and electronics giants followed and put into execution the requirements from EU.

This study adopted in-depth interview methodology alongside reorganization of literature reviews and environmental protection related issues. It, meanwhile, probed into three case companies covering six major information parts and components industries, i.e., active components, passive components, computer housing, PCB, power supply, and connectors. An empirical case study was also implemented to explain the applicability of this model for green supply chain management (GSCM) and to offer a resolution to risks or pressures from enterprise's supply chains in information technology (IT) industry. This study aimed to provide other industries with conducive and handy references in promoting the subsequent environmental protection-related issues, and to overcome the non-tariff trade barrier.

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1. Introduction

Over the last decade, the growing concerns about environmental (‘green’) issues have become an important issue for firms, and there are many institutions, such as non-governmental organizations (NGO), governments, and stakeholders that have forced and driven many companies to improve their environmental performance (Azzone & Bertele, 1994; Noci, 1997; Porter & van der Linde, 1995). The management of environmental issues is significant for both large and small firms (Schaper, 2002). There are many researches on different environmental aspects, such as environmental programs in end-of-pipe disposal programs (Azzone & Bertele, 1994), cleaner technologies of the production process (Nagel, 2003), green purchasing practices (Min & Galle, 2001), total quality management (TQM) and environmental excellence in manufacturing (Klassen & McLaughlin, 1993), developing ‘green’ programs, such as recycling programs with supply chain partners (Noci, 1995), particularly in environmental management initiatives, and designing and developing new ‘green’ products with suppliers (Azzone & Noci, 1996). There are more environmental practices and strategies in operating systems and manufacturing to environmental improvement (Gupta, 1995; Sarkis, 2001), purchasing improvement in decreasing the environmental impacts (Walton et al., 1998), and tight linkage between customer-supplier relationships in facilitating the adoption and diffusion of environmental innovation in the production process (Florida, 1996, & 2001; Simpson, 2004).

The European Union (EU) officially promulgated on February 13, 2003 the three major directives on environmental protection, respectively, 2002/96/EC: Waste Electronics and Electrical Equipment (WEEE), 2002/95/EC: Restriction of the Use of Certain Hazardous Substance in Electrical and Electronic Equipment (RoHS), and Eco-design requirements for Energy-using Products (EuP) to demand manufacturers restrict use of certain hazardous substance and require producers to be responsible for recycling and handling waste of information and electronic products. So motivated, leading international manufacturers in the information technology (IT) industry, such as HP, Dell, and Sony, follow through environmental requirements into IT products. Recently, Taiwan’s government and some environmental promotion institutions, such as IDB, EPA, TEEMA, ITRA, TEMA, BCSD, and EDF, have monitored many firms to improve their environmental performance and led to many original equipment manufacturers (OEMs) and original design manufacturers (ODMs) to help their suppliers to achieve better environmental performance in supply chains in responding to international environmental requirements (TEEMA, 2006). This results in the green supply chain management (GSCM) receiving considerable attention in improving the company’s environmental performance in Taiwan. Some companies have tried to put the GSCM into practice, such as obtaining a third-party certificate like the ISO 14001 certification, and integrating environmental issues into the supplier. Although the information technology industry seems to be more proactive in adoption of the GSCM in Taiwan, compared to other industries, there are still many potential risks and challenges.

This study was conducted by in-depth interview in conjunction with focus group approaches, by reviewing related literatures of environmental issues, and by examining three corporate cases in an attempt to identify the most effective environmental control and managerial method for the IT industry, i.e., implementation of the GSCM practices, while providing references for other industries in their subsequent efforts in introducing environmental specifications and successfully overcoming EU non-tariff trading barriers.

1.1 Background of the Study

Information technology industry in Taiwan including information hardware, digital network, mobile devices, and information software seeing ever expansion either in output, value, and market share, has become an emergence one with world-class competition strength. As illustrated in Table 1 for the total production values of Taiwan information industry during 2001~2006 as compiled by Market Intelligence Center (MIC) of Institute for Information Industry (III) of Taiwan in April 2007, the IT industry, the sector of information hardware took up 78.4% of the total value of output while the sectors of digital network, mobile device, and information software far behind at 6.2%, 9.8%, and 5.6%, respectively, in 2006. Therefore, this study focuses on the sector of information hardware as the subject and suppliers from the upper and the lower streams of the information hardware were invited for in-depth interview.

Table 1 Global Production Values of Taiwan's IT Products during 2001-2006

(UNIT: USD 1 MILLION)

Output Value	**2001**		**2002**		**2003**		**2004**		**2005**		**2006**	
	US$1M	%	US$1M	%	US$1M	%	US$1M	%	US$1M	%	US$1M	%
Hardware	42,750	83.7	48,435	82.6	57,105	82.6	69,664	82.6	80,980	81.5	89,656	78.4
Digital Network	3,044	6.0	3.176	5.4	3,348	4.8	4,524	5.4	5,511	5.5	7,169	6.2
Mobile Devices	1,349	2.6	2,911	5.0	4,311	6.3	5,464	6.5	7,770	7.8	11,191	9.8
Software	3,947	7.7	4,134	7.0	4,300	6.3	4,700	5.5	5,200	5.2	6,387	5.6
Total	51,000		58,656		69,124		84,352		99,461		114,403	

Note. Data adapted from MIC of Institute for Information Industry of Taiwan (April 2007) and Wu (2005)

According to the US-AEP (1999), the information and electronics industry dominates the global markets and shifts towards a technologically-advanced economy, and has a huge range of products and services, and this is a heavy pollution industry. Both external and internal forces drive the industry towards GSCM. External pressures include: regulatory threats (product take-back & waste management), advocacy groups (nongovernmental organizations, consumers, investors, shareholders, and commercial customers), while internal forces are linked to management issues, such as risk management, company benefits of GSCM, societal concerns for environmental impacts, and corporate image (US-AEP, 1999).

In the past, most researchers described the GSCM as "merges a firm's environmental management policies and goals with its supply chain management (SCM) programs." The current GSCM issue focuses on the management strategy after enacting the directives in the EU. In order to comply with these EU's directives, Taiwan's government and related institutions have helped the companies to carry out the GSCM practices, such as promoting the "Green Project," setting up the "GP User Group," the information exchange platform like the material composition information distribution by XML, the green component (GC) certification standard, the green product management system, providing a training program to pass the ISO14000 certification, and integrating environmental issues into the supplier. Many companies have begun to transfer their focus from one plant to the whole supply chains. Lewis & Gretsakis (2001) argued that in the future, all companies will need to implement strategies to reduce the environmental impacts of their products and services.

1.2 Purpose of Study

Among three key Directives, RoHS, WEEE, and EuP, the RoHS directive has the most significant impact on the IT industry engaging in the original equipment manufacturing (OEM) or original design manufacturing (ODM) outsourcing. The WEEE directive, wherein only the brand leading manufacturers are significantly affected, and the EuP directive for dealing with issues related to energy saving design and energy R&D, are excluded from the scope of this study.

In compliance with restricted use of six hazard substances, respectively lead, mercury, cadmium, hexavalent chromium, polybrominated byphenyls (PBB), and polybrominated diphynel ethers (PBDE) as specified in RoHS Directive, this study commenced from the five departments of sales, R&D, purchase, quality control, and manufacturing process through the operating mode of GSCM implementation in the IT industry to create effective internal green product standard operating procedure (SOP) within a company in meeting requirements from four primary aspects of product, design, purchase, and inspection. The four aspects that affect the supply chain are discussed in this study. Whereas aspects of inspection and purchase are more significantly correlated with the green supply chain, and meeting the requirements of restricted use of those six hazardous substances in information and electronic products according to the management and inspection requirements set forth in the RoHS directive of the EU, they define the orientation of the study.

2. Literature Review

The literature review is comprised of six sections. Section one examines the road map of international environmental strategies; section two collects environmental directives published in the world, particularly in the EU; section three discusses the environmental specifications formulated by international leading information manufacturers; section four explores into the characteristics of OEMs outsourcing in the IT industry; section five focuses on the literature related to the supply chain management (SCM); and section six discusses the literature of green supply chain management (GSCM).

2.1 International Environmental Protection Strategies Roadmap

Fermented by the formal establishment of WTO (World Trade Organization), the ultimate objective is to achieve the liberalization of the world trade. Meanwhile, protection measures with significant changes, particularly those well-hidden, lower transparency, preventing monitoring and prediction (technical barriers), taken by the leading capitalist states, including USA, Japan, and EU have created very serious barriers to the external trading in the developing countries. While providing a shield to stop invasion of foreign products, the technical barrier is the trade barrier, so far the most concealed movement and the toughest one with which to cope.

2.1.1 Integrated Environmental Strategies of EU

The concept of environmental protection diffuses from an individual nation to the utilization of global resources since countries participating in the 1992 World Summit Meeting signed the *21st Century Action Guidelines* and the *Fifth Environmental Action Plan*. Changes in national environmental strategies gradually shift the focus from the demands of the manufacturing process to address management of the pressure upon the environment of the life cycle of the product in the development of an environment-friendly green product.

To facilitate green products promotion and sustainable consumption, the EU formally adopted a green paper of Integrated Product Policy (IPP). This includes how to improve the environmental performance in the product life cycle and presents a major challenge to both public and private sectors in the EU. Believed to be beneficial for the promotion of the green product, IPP expects all the regulating authorities in the EU to negotiate and work out a package of feasible and consistent economic incentives and tools. The purposes of putting IPP in action include (Europa, 2006):

(1) To cope with impacts upon the environment by products and services and improve efficiency of utilizing resources;
(2) To confirm the structure of integrating current policies of the EU on environment, health, industry, refuses and chemistry;

(3) To achieve the ultimate target of a sustainable development as addressed in the *Fifth Environmental Action Plan*; and
(4) To have continuous improvement on environmental performance of products and services as the working principle of IPP in terms of the viewpoint of the life cycle, market-oriented, and involvements of interested parties.

Each advanced nation has developed the IPP by laying down national policy and business operation to extend the responsibilities of manufacturers and preventive institutional foundation or business strategy. In a word, the disposal of end of life products must be producers' responsibilities. The basis is that the producer plays the role of the original provider of the product or service, and attains the genuine status of sustainable use of resources from product life cycle (PLC) analysis and integrated deliberation of how to provide brand-new products or services.

2.2 EU Environmental Directives

This section centers on the collection of the EU environmental directives, particularly the urgent efforts after WEEE and RoHS directives were promulgated on February 13, 2003.
After the disputes lasted for a decade, the *European Commission* and *the Council of the European Union* finally had the consensus on October 11, 2002 based on the compromise made among the documents of common ground submitted by each member state in June of 2001. Following the publication of the WEEE directive in February 2003, the timetable for each demand is finalized to deliver a strong message to manufacturers in Taiwan that it is time to take action instead of sitting back.

WEEE directive of the EU features that the manufacturers of eletronic and electric products must bear costs incurred from product reclaim, disposal, and recycle. Various materials are tightly incorporated into a product and certain materials, including gold and other precious metals, e.g., hazardous substances of lead, mercury, cadmium, and hexavalent chromium that when reclaimed are prevented from the disposal by a burial or incineration method as do for other refuses. Having hired hands to dismantle and classify WEEE for further disposal involves higher costs and a time-consuming effect. As estimated, the disposal cost of WEEE is six-fold of times of that for the general refuses, and the labor cost takes up 80% of the total cost of disposal.

Most of the manufacturers choose to forthwith search for materials not restricted to substitute those restricted in the RoHS directive. Taking the common topic of lead-free products, the advanced multinational corporations (MNCs) have already developed a package of technologies either for the soldering materials or the parts. There have been many lead-free products introduced into the market in recent years, and Japan has had the fastest pace in doing so.

2.3 Environmental Specifications of International Leading Manufacturers in IT Industry

This Section is divided into two parts, respectively: 1) compilation and description of environmental requirements, and 2) the client's requirements that the leading IT manufacturers have to meet from the international environmental protection regulations.

2.3.1 Environmental Requirements of World Leading IT Manufacturers

Whereas items and contents of the requirements vary by individual client, it becomes vital in understanding the generality among the clients. It is not uncommon for many companies to immediately meet client's requirements without bothering to check out details of those requirements by forthwith incorporating them into their corporate documentation systems or executive instructions, and even directly passing them to their vendors for

compliance, which finally results in internal friction or misunderstanding. Table 2 lists the environmental requirements set forth by international leading manufacturers in the IT industry.

Table 2 Environmental Requirements of World Leading IT Manufacturers

No	World Leading Manufacturers	Environmental Requirements
1	3COM	Environmental Hazards Questionnaire
2	CANON	Green Procurement Standards
3	DELL	6T198、7X435
4	HP	A-5951-1745-1、HP Vendor Environmental Performance Review Questionnaire
5	MICROSOFT	H00594、H00642、H01288
6	IBM	ES 46G3772
7	MOTOROLA	12G02897W18
8	NEC	Green Procurement Guidelines
9	SONY	SS-00259、SS-00254
10	TOSHIBA	Guidelines for Green Procurement: No. 360045308

Related information on environmental requirements to be collected by a company should vary depending on the requirements of an individual client in a primary orientation to focus on limitations prescribed by international laws and directives, client's requirements, and industry-based specifications.

2.3.2 Summary and Description for Client's Requirements

Information on product environmental requirements by clients both at home and overseas so far is essentially collected according to the limits of containment of substance of environmental control as specified in the RoHS directive published by the EU. Although the client's requirements vary, clients established stricter specifications based on the RoHS directive. The most stringent specification is demanded by Fujitsu among clients from Japan in terms of lead, cadmium, mercury, hexavalent chromium, and two types of brominated flame-retardants. Fujitsu completely restricts use of lead, cadmium, mercury, and hexavalent chromium and has a total of nineteen substances banned in the manufacturing process including PBBs, PBDEs, PCBs, PCTs, PCNs, asbestos, chemicals containing nitrogen, ozone destroying substance, CFCs, hexachlorobenzene, aldrin, dieldrin, endrin, Mirex, and recommends the use of substances including methane chloride, HBFC, PFC, trichloroethylene, and carbon tetrachloride.

Hazardous substances restricted for use in the RoHS directive include lead, mercury, cadmium, hexavalent chromium, PBB, and PBDEs. What the electronic industry is going through now is just the first phase one of the green product requirements. Therefore, any manufacturer is facing the risk of significantly reduced market shares unless they map out early out a set of effective control procedures to cope with changed market demands entering from the angle of integral strategy planning.

2.4 Characteristics of OEM in the IT Industry

According to Zhau (2000), the IT industry once was taken as one of the industries which allowed Taiwan to penetrate into the global market with OBM. Only 37% of PCs

manufactured and exported by domestic makers in 1988 contributed to OEM, while the remaining 63% were based on OBM. However, upon entering into the 90s, at least 61% of the PCs exported by domestic makers were based on the OEM, sharing 73.90% of the total output of the information hardwares in 1997 (Hung et al., 2002). Taiwan's OEMs (original equipment manufacturers) and ODMs (original design manufacturers) have become the largest supply partners of the world's major IT firms (Yu and Hsu, 2002).

2.5 Supply Chain Management

According to Chen & Chen (2001), the supply chain management employs a series of effective methods to integrate planning and control of production-related materials between the vendor and the end-user, taking interests of all members in the passage including vendors, manufacturers, warehouse and sales outlets into consideration to satisfy the customer service level expected in the passage through consistent control and planning among the members, thus to make the optimal use of resources and minimize the cost of the general system.

2.5.1 Development Background of Supply Chain Management

The evolution of the supply chain management was originated during the 70s when enterprises tried to transform transportation into logistics with the primary objective of integrating transportation and warehousing to cut down the inventory level. At the time, predicted production dominated the production plan and gave birth to Material Requirement Planning (MRP) to solve issues related to control and demand of materials for the process and to purchase raw materials from the upper stream of the trade. Reduction of total cost became the primary objective of the business world upon entering into the 80s. Accordingly, Just In Time (JIT) production, Kanban Management (signboard management), Total Quality Control (TQC), and other strategies to improve production efficiency and lower production cost were highly welcome. Manufacturers shifted from their original plans of mass production into customized production based on the orientation of customer needs due to changes in market structure when customer needs headed for diversification in the 90s. How to come up with a quick response to a customer, shorten the lead time of a new product, lower transportation costs, provide a justified price, and promptly make a delivery to where specified by the customer have become issues most concerned by the business world. Therefore, integrated vendors and customer needs through the supply chain management become critical for an enterprise in seeking sustainable development.

During the period of 2000 through 2006, Quick Response (QR) and efficient replenishment have been operated for Vendor Management Inventory (VMI) to develop the supply chain for general consumer products. The basic idea is to provide the right product in the right quantity, at the right time and place, and with the lowest cost.

Whereas there is a trend toward specialization and global outsourcing of electronics products, the OEM/ODM of IT industry in the long and complex global supply networks will be subjected to extremely high impacts from the future requirements of the green supply chain management after RoHS directive became enforceable on July 1, 2006.

2.5.2 The Significance of Supply Chain Management

According to the definition of the Council of Supply Chain Management Professionals (CSCMP) of the USA, "supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. Kalakota and Whinston (1997) believed that the supply chain is basically a business process to link the manufacturer, retailer, customer, and vendor into a chain by

pooling technologies and resources of all the loops in the chain into a virtual organization for the development and distribution of products; the purpose is to effectively deliver the products from the production line into the hands of the customer. The supply chain also functions to provide early warning of any changed demands among multiple cooperation units in the chain, and thus to earn profits by coordinating the business process among organizations. Ellram (1991) argued that the supply chain management is a method to handle the material planning and integrated control between the vendor and the end-user taking into consideration the benefits for each and all members in the passage, and the management of the supply chain seeks the optimal utilization of the existing resources through joint management and consistent planning among the members in meeting the level of customer service in the passage. The word 'chain' is somehow a short name; actually the process allowing flow of materials always appears in the structure of a 'network.'

To sum up those expert viewpoints as described above, the supply chain management is the overall and optimal business means to leap over the barriers of business organizations to attempt eliminating wastes in the business process by sharing operation resources or information. A series of efficient methods is employed to integrate suppliers, manufacturers, warehouses, and sales outlets for the goods to be produced in the accurate quantity and distributed at the right time to the right place for customer satisfaction and minimized costs for the entire system.

2.6 Green Supply Chain Management (GSCM)

In the past, most researchers stated that the GSCM "merges a firm's environmental management policies and goals with its supply chain management (SCM) programs." The current GSCM issue is discussed to focus on the management strategy after enacting the EU's directives, such as WEEE, RoHS, and EuP. GSCM is implemented in order to comply with these directives of the EU.

In South East Asia, greening the supplier is a relatively new concept and most companies there prefer to go for and achieve the objectives in greening of their supply chains through the mentoring method, relationship building, and networking. In this region there are many MNCs and other large manufacturing firms. Therefore, greening of the suppliers is absolutely necessary in order to achieve the greening of the manufacturing process and toward sustainable development of this region (Rao, 2002). Rao found that in Taiwan, there are many large firms/industry leaders, such as the information and electronic OEMs/ODMs (called the central firms) which coordinate the transaction between upstream suppliers (called satellite firms) and downstream buyers to work together to implement high levels of advanced environmental management practices, and to improve environmental performance.

2.6.1 Development Background of Green Supply Chain Management

According to Hart (1995, & 1997), firm wants to move toward sustainable development that must be implemented through three stages of environmental strategy. The first stage is pollution prevention that focuses on minimizing or eliminating waste before it has been created, and the second stage is product stewardship that focuses on minimizing not only pollution from manufacturing, but also all environmental impacts throughout the full life cycles of products such as life-cycle analysis (LCA), and design for environment (DfE). The third stage is clean technology that focuses on replacing current product and processing technologies with new, cleaner ones. Pollution prevention, product stewardship, and clean technology all move a company toward sustainability (Hart, 1995 & 1997). Beamon (1999) pointed out that the evolution of environmental management policy from the 1970s to the mid 1980s stage was a risk management, and it focused on waste management and pollution control; the stage from the mid 1980s to the early 1990s was pollution prevention, and it

emphasized process improvement to reduce material use, minimize waste, and improve efficiency; from the mid 1990s stage, it leaned towards life cycle management and industrial ecology, and focused on systematic product and process management to maximize profitability and ensure environmental quality, and life cycle environmental effects of processes and products. The 2001 stage focused on sustainable development, and it should make efforts to develop green industries that are environmentally friendly, engage in green production that does not threaten or pollute the environment, and promote green consumption that protects the environment in order to maintain sustainable world.

2.6.2 The Definition of Green Supply Chain Management

According to Bowen, Cousins, Lamming, & Faruk (2001), the green supply chain may be facilitated by cross-functional team working. They believed that five generic supply management capabilities may facilitate the implementation of green supply. These include (1) integrating into cross-functional team working, (2) collaborating with suppliers toward environmental improvement, (3)understanding of environmental issues among purchasing managers and how they affect building supply management capabilities to implement green supply, (4) using the technical skills and competencies for purchasing personnel in building green supply capabilities, and (5) having existing detailed purchasing policies and procedures as a key resource for green supply. Many researchers suggested various definitions for GSCM. Table 3 indicates that the summary of the definitions of GSCM are as follows.

Table 3 Definition of Green or Environmental Supply Chain Management

Researcher(s)	Definition
Beamon, 1999	The traditional supply chain is defined as an integrated manufacturing process wherein raw materials are manufactured into final products, via distribution, retail, or both, then delivered to customers. The full integrated, extended supply chain contains all of the elements of the traditional supply chain, but extends the one-way chain to construct a semi-closed loop that includes product and packaging recycling, re-use, and/or remanufacturing operations (p.337).
Bowen et al., 2001	The term “green supply” indicates supply management activities (such as cooperative recycling and packaging waste reduction) that are attempts to improve the environmental performance of purchased inputs, or of the supplier that provides them. Two main types of green supply can be identified. The first is termed “greening the supply process”, while the second is “product-based green supply” (p.175).
Zsidisin & Siferd, 2001	Environmental supply chain management (ESCM) for an individual firm is the set of supply chain management policies held, actions taken, and relationship formed in response to concerns related to the natural environment with regard to the design, acquisition, production, distribution, use, reuse, and disposal of the firm’s goods and services (p. 69).
Rao, 2002	The concepts pertaining to greening the supply chain or supply chain environmental management (SCEM) are usually understood by industry as screening suppliers for their environmental performance and then doing business with only those that meet

	the regulatory standards (p. 632).
Wang et al., (2004)	Green supply chain management is the sustainable development model for modern enterprises and it is from cradle-to-reincarnation. They argued that the major elements involved in the green supply chain include green design, green material selection, green manufacturing, green packaging, green marketing, green consumption, and green recycling.
Hervani et al., (2005)	Green supply chain management (GSCM) is described as "Green Supply Chain Management = Green Purchasing + Green Manufacturing/ Materials Management + Green Distribution/ Marketing + Reverse Logistics." They represented a framework (system model) based on one activity "Implementation and Operation of GSCM/PMS" (p.334). GSCM should promote the sharing of environmental responsibility and lend itself to achieving a reduced environmental burden caused by industry (p.336).

Note. Data adapted from Chiou et al., (2007) & Seuring (2004)

2.6.3 Significance of Green Supply Chain Management

In the GEMI's (2001) research, it pointed out that there are two types of business value, including reducing costs and increasing revenues, which can be obtained from integrating and improving the environment, health, and safety (EHS) performance in the supply chain. In the reducing cost part, it includes reducing the (1) direct costs of operations, (2) hidden and indirect costs, (3) contingent costs, and (4) increasing the image and relationship costs and benefits. In the impacts on revenue, it includes increasing the (1) image and relationship costs and benefits, (2) superior product benefits, and (3) marketing benefits. So, better supplier's EHS management can have both bottom line impacts (reducing costs) and top line impacts (increasing revenues). According to Business for Social Responsibility (BSR) (2004), suppliers' efforts in good environmental performance will result in some advantages: (1) cost reduction, (2) greater operational efficiency, (3) enhanced value to customers, (4) increased sales, (5) positive media attention, and (6) positive ratings from socially responsible investment groups.

Regarding contribution to the increasing environmental legislative pressures by many developed countries such as Japan, the EU, and the US, many firms have attempted to modify their products or services to conform to these regulations and directives by improving their environmental performance. Amongst all, the EU's three major environmental protection directives of the Waste Electrical and Electronic Equipment (WEEE), the Restriction of the Use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS), and the Energy-using Products (EuP), and above all, the starting adoption on July 1, 2006 of the RoHS directive has had the greatest impact on IT industry, particularly as global major production base of these products for original equipment manufacturers (OEMs) or original design manufacturers (ODMs) in Taiwan. They should be more proactive in implementing the GSCM and ban the use of toxic substances to meet the requirements of the RoHS directive.

3. Methodology

This part is divided into five sections. Section one describes the type of study; section two explains the sources of data; section three shows how the information was collected; section four clarifies the study method used in in-depth interviews.

3.1 Type of Study

As discussed in literature review, the GSCM presents a new topic of management to be desperately constructed by the information industry. However, perception of legal requirements in environmental protection of production by business owners in the supply chain of information electronics in Taiwan so far is limited only to the RoHS Directive, and those owners appear to be quite naive on other related laws, regulations, and policies. Given with the premises, promotion of related strategies on production environmental requirements will have to face much unpredictable resistance in the future. The subjects of the study are the first tier suppliers in the IT industry, and an in-depth interview was conducted which included a semiconductor device (packaging fabs), passive industry (resistance, capacitor, and inductance), computer casing (case and metal works), PCB, power supply, and adapter. Participants for the interviews were selected from the listed companies, OTC, or international leading manufacturers.

3.2 Data Sources

A comprehensive collection of secondary data included international environmental strategies and legal requirements, international environmental protection directives, environmental regulations from international IT leading companies, information industry analysis and documentations, and supply chain management literature reviews. Primary data were conducted from in-depth interviews and a focus group seminar for this study.

3.3 Data Collection

Demonstrative information application programs and projects from the information industry promoted by the Department of Industrial Technology (DIT, 2006), MOEA, and financial statements disclosures of listed companies and over the counter (OTC) as published by MOEA were relied upon for collecting information on the roadmap of environmental strategies and legal requirements, environmental directives, and environmental constraints of the leading manufacturers in the world, supply chain management documentations supported by data available from in-depth interviews, and a focus group seminar for analysis.

3.4 In-depth Interview

Before conducting the in-depth interview, data from documentations, investigation reports, news coverage, and studies already published or disclosed were collected to have an initial understanding of the certain structure and history of the information industry as a whole. The preparation helped in getting get more sensitive in the transition of the historical background, identify the critical interviewee, and suggest key issues that should be focused on during the interview.

4. Data Analysis and Discussion

This section is comprised of three sections. Section one deals with the data analysis of an in-depth interview; section two describes the industrial characteristics of the case company; and the final section discusses and summarizes the results and findings.

4.1 Data Analysis for In-depth Interview

This Section touches the analysis based on the information available from an in-depth interview. According to a quantitative survey of 2005 by the sector of the information industry in the environmental program owned by the Department of Industrial Technology (DIT), Ministry of Economic Affairs (MOEA) of Taiwan, as shown in Figure 1, the electronic passive device takes the lead at 22.1%, followed by mechanism device (computer casing), 17.3%; adaptor, 11.8%; electronic active device, 8.8%; subsystem (power supply), 7.4%; and PCB, 4.4% in the percentage of the industry by the sector surveyed as shown in Figure 1. The sum of the distribution of those sectors surveyed is 71.8%, showing that the subjects of the interview are justified to represent the IT industry.

In this Section, the background, roadmap, and future competition edges of six sectors, respectively, active device semiconductor, passive device, computer casing, PCB, power supply, and adaptor are analyzed to identify the correlation between the upper and the lower streams of the supply chain in information technology industry, thus to understand difficulties, recommendations, and coping measures in implementing the GSCM practice.

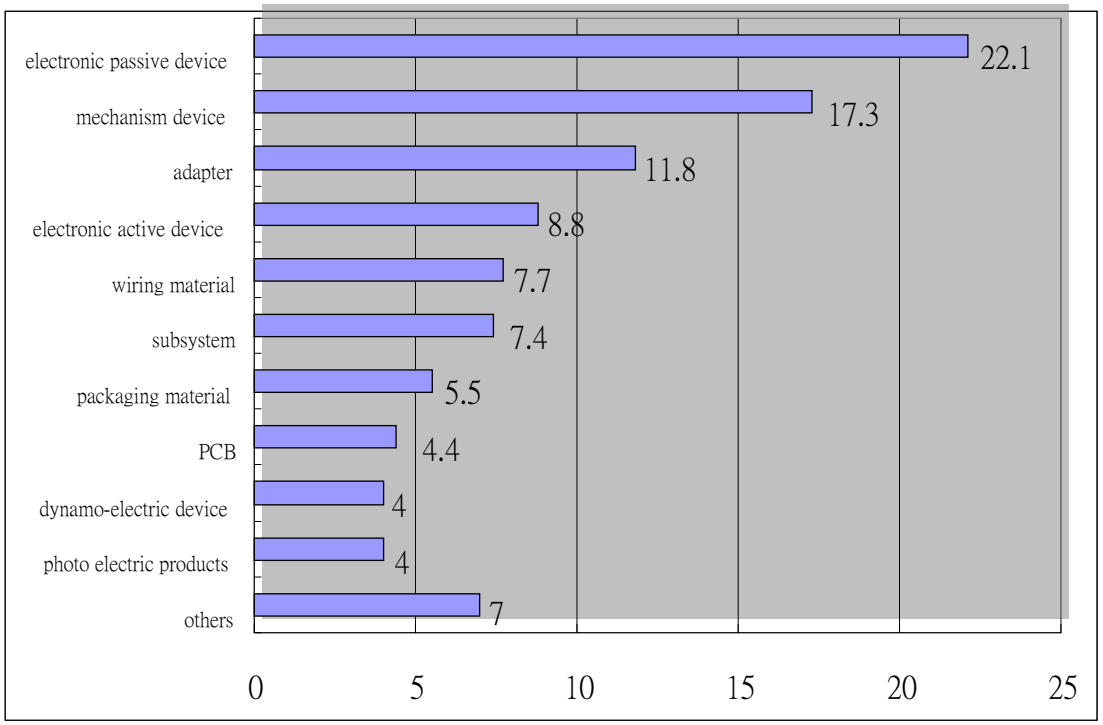

Figure 1 Quantitative Investigation of Distribution Percentage of Electronic Industry by Sector in 2005

Note. Data from an Environmental Program Planning Project Closing Report by DIT at the MOEA, R.O.C. (2006)

4.1.1 Analysis of Impacts from Six Sectors upon the GSCM

According to an analysis of the data availed from literature research, and an in-depth interview, there are two types of manufacturers affected by the promotion of the green supply

chain in the IT industry, one that has its manufacturing process affected and another that is not. The lead-free manufacturing process respectively in sectors of a semiconductor, passive device, adapter, and PCB is directly affected; the manufacturing process of the computer casing sector is not affected; and the sector of the power supply shares the same form of the correlation between the upper and the lower streams in the supply chain as that of the information industry. Based on these characteristics of the manufacturing process affected by the green supply chain.

4.2 Analysis of the Industrial Characteristics of the Case Company

(1) Characteristics of Outsourcing

Three case companies given in the experimental study are all engraining in OEM manufacturers. Company A is engaged in the manufacturing of the peripherals and components; Company B, in the assembly of desktop and server systems; and Company C, in the assembly of notebook and server systems.

(2) Characteristics of Parts Purchase

The purchase of the spares of Companies A, B, and C is done in two types. The first type features transaction by lot through requisition, price negotiation, purchase, acceptance, and payment. For the same type of product, the prospective seller varies by transaction. The transaction is usually done in e-commerce for upgrading the horizontal exposure through the involvement of the open electronic market (for the access to more supply candidates and information on quotation) to get the better pricing conditions of the spares. The second type is to establish and maintain a long-term close work relation with a vendor. The price negotiation is done periodically and less frequently to complete the transaction with the cycle of intensive order placement and taking the delivery. When done in e-commerce, the e-purchase in the tight supply chain network is taken including estimated purchase order and production capacity exchange to effectively facilitate the supply chain, and shorten both of the supply cycle and lead time.

4.3 The results and Findings of the Study

Based on the review of the case in-depth interview, findings and analysis of the implementation of the green supply chain in the IT industry, the researcher summarized the key factors to the success and the difference in implementing the GSCM practice by case companies as below. The research findings showed eight significant issues for implementing the GSCM practices through in-depth interviews to case companies A, B, and C including the following task.

(1) Environmental pressure from the international leading IT companies affects the motivation of GSCM implementation. It is found that the impacts from the pressure of environmental laws are far less than that from their clients to case companies A, B and C.

(2) Authorization from top management affects the willingness to get involved in the GSCM. In general, the organization operation in the information industry heads for the mode of centering on the business entity. The top management of the firms usually considers assigning specific senior staff to work together for the promotion of the GSCM project only when attempting to fend off the pressure from the client.

(3) Transaction partnership relationship affects the results of the case companies to introduce the GSCM into the organization. So far, the key tone of the GSCM undertakings in the information industry has been gradually shifted from related works with the vendors in the chain to the compliance of environmental laws with design for environment and containing non-toxic materials of the products. This relationship has upgraded from transaction partnership to the green partnership.

(4) Capability in manufacturing process affects the timetable in implementing GSCM. The requirements of specification demanded by the international leading manufacturers are constantly updated due to the failure to introduce the international specifications related to lead-free soldering, and the issues derived from the introduction of the lead-free process are more complicated than expected. Accordingly, the proficiency in lead-free process technology becomes a key factor that affects the promotion of the GSCM by the case companies.

(5) Integrated database affects the speed in transmission of cross-functional organizational information. Currently there is a pending and unified standard format for the declaration of the restricted use of hazardous substance in compliance with the RoHS directive in the world. As a result, all electrical and electronic products' manufacturers have to spend massive labor hours in filing the declaration since the types of restricted substance and the declaration specification vary depending on the client and the market.

(6) Standard operating procedure (SOP) affects maintaining the operation of the GSCM. It is found in this study that constant communication with vendors is a must, including the release of a set of consistent green purchase requirements, definition of a uniform survey procedure and forms, instructions of operation and how to complete the forms, presentation of green purchase to the vendors, conducting internal control and audit of green purchase to the key vendors, the indices of responding ratio of vendor to the checklist, and training the frontline seeded staff members to answer questions raised by vendors.

(7) Supplier management by categories contributes to higher risks in the GSCM. Getting the rated vendor control in place proves to be the best option for reducing control risks in the promotion of the GSCM as evidenced in industrial characteristics of company B with its upper stream suppliers. Supplier management into classification can help facilities with the implementation of the GSCM and effectively control the risks of the supply chain as a whole.

(8) Second tier supplier management helps to improve the proficiency of the GSCM. According to the information furnished by company B, second tier supplier management proposed by company B is a very tough mission particularly in the information industry; however, it provides the optimal management to verify the compliance with the *RoHS* directive by effective control of the sources of incoming materials and raw materials of suppliers.

5. Contributions of the Research

This section reviews the contributions of the study in academic aspect, and managerial practices as follow:

(1) For academic aspect:

The study first describes the international environment protection efforts status quo and the specifications of environmental products demanded by the client, followed by a collection of the viewpoints on the conventional supply chain management and a documentary research of green product injected with the practical aspects in the information industry to explore the introduction of the green supply chain into the information industry.

(2) For managerial implications:

The findings of this study contribute to the managerial practices in three aspects, respectively, building up corporate image (CI), the factors of technical environment, and the welcoming of the new green era by the enterprises.

(I) Building up CI:

The coming of the new generation means the arrival of the green era. In contrast to the terminal disposal in the past, the enterprise by promoting the green supply chain management in pushing out environment-friendly products is building up a new green corporate image.

(II) Factors of Technical Environment:

Any barrier in the development of green technology will affect the green supply chain management in an enterprise, and this would result in inefficiency in the supply chain management. An enterprise, while introducing the green technology into its organization, will therefore, take factors of compatibility and difficulties of the technology into consideration.

(III) Welcoming the new green era:

The 21st Century presents critical challenges to the enterprises. Therefore, findings of this study may be referred by enterprise and professional managers in realizing the scope of the enterprise affected by the green supply chain management while facing the challenges of environmental issues.

(3) The mode for Introduction of GSCM for the Business:

In general, any manager, in order to measure up any activities of his organization, would like to simplify any complicated issues. To secure successful introduction of the green supply chain, crucial factors are described as follows in three phases:

(I) Integrating Phase:

As illustrated in Table 4, the integrated framework of green products will allow the formation of the activities of the entire chain of value for the information industry. While promoting the green supply chain, the corporate or enterprise coping configuration and strategies must be first formulated before laying down the specifications. The spirits of the specifications will pivot around two things: vendor green supply chain management and client green product.

Table 4 Framework of Integrated Green Products

<table>
<tr><td colspan="4">RoHS</td><td colspan="2">WEEE</td><td colspan="4">EuP</td></tr>
<tr><td colspan="10">Green Product's Environmental Strategy of the Industry</td></tr>
<tr><td colspan="5">Green Supply Chain Management Specifications for Green Supplier</td><td colspan="5">Green Product Specifications for Customers</td></tr>
<tr><td colspan="2">Supplier Selection</td><td colspan="2">Supplier Management</td><td>Supplier Mentoring</td><td>Risk Control and Management</td><td colspan="2">Customer's Relation Management</td><td colspan="2">Customers' Requirements & Specifications</td></tr>
<tr><td>Design</td><td colspan="2">Confirmation</td><td>Purchase</td><td>Incoming</td><td>Production</td><td colspan="2">Sales</td><td>Service</td><td>Reclaim</td></tr>
<tr><td>R&D</td><td colspan="2">Parts Engineering</td><td>Supplier Screening</td><td>Incoming Inspection</td><td>Lead-free Process</td><td colspan="2">Delivery Inspection</td><td>Product Service</td><td>Product Reclaim</td></tr>
</table>

(II) Introduction Phase:

Before establishing the introduction mode of the green supply chain management including standards, consensus, and platform, two prerequisites are called for: the authorization from the management and the organization for the promotion.

- Establishing the standard:

  Establishing a justified standard, plus the practice of process technical specifications will successfully follow through ISO specifications and SOP requirements to help achieve the first step for the introduction of the green supply chain.

- Establishing the consensus:

  With the standard established, it takes the consensus to jointly follow and promote while confirming the coverage of the green supply chain, and strict selection

and assessment the qualified green supply partners, and win-win cooperation relationship.

- Establishing the platform:

  To continue pushing forward the green supply chain, it must build up an information platform to facilitate integrated green data while eliminating the repetition of internal information and increasing the transparency of trans-organizational information.

(III) Implementing Phase:

User demands must be always satisfied in any business activities whatsoever. The promotion of the green supply chain is never an easy task and it takes the corporate-wide mobilization. IT and planning staff members must do their best in playing a supportive role to meet and satisfy user demands before claiming a successful promotion of the green supply chain.

6. Conclusions and Future Research

Lastly, there are some conclusions in this research, and the suggestions for the future research directions are as follows:

6.1 Conclusions

Taiwan's IT industry now plays an extremely important role in the global hi-tech manufacturing system, and Taiwan has become the world's second largest manufacturer of information hardware. This study is to investigate the GSCM practices in the IT industry in Taiwan. Currently, implementation of the GSCM for the industry in Taiwan is not yet matured and popular, while traces of the few efforts can be seen here. Clinched by the pressure of fast response today, the enterprise must quicken its pace in promoting the mechanism of the GSCM so to improve competition edges by creating an integral GSCM mechanism in the course of the implementation.

Besides, there is evidence that shows some Asian countries, such as Japan, South Korea, and even China, have had their environmental protection laws and regulations in the information and electronic industry. Taiwan has played an important role in the OEM/ODM outsourcing of the IT products. Therefore, it is urgent that Taiwan's government should speed up establishing related environmental laws for the IT industry.

6.2 Future Research

Future research could be pursued along several directions. It is hoped that in the future many more firms will be in-depth interviewed in order to strengthen generalization competence to facilitate a successful implementation of the entire GSCM. In addition, future research should try to verify the configuration of this study by quantitative methods, such as conducting survey questionnaires. Since only a few firms are implementing the GSCM at present, this study has to adopt the approaches of the case study and focus group.

Data collection and research subjects of a future study can include the Taiwanese manufacturers located in China, and have a comparative and gap analysis between Taiwan and China in the GSCM practices. Finally, there is much more room for discussion for improvement in relation to integrated trans-platform information systems, which are the main barrier in implementing the GSCM. A collaboration and good communication relationship, without different information formats and information system, could result in the so-called information sharing between manufacturers and their suppliers.

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