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# GREEN SUPPLY CHAIN MANAGEMENT

Product Life Cycle Approach

**PART 1**

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**Basic Concepts  
and Background**

**CHAPTER 1**

Introduction

**CHAPTER 2**

Mathematical Background



# CHAPTER 1

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## Introduction

In this introductory chapter, we review the development and evolution of green supply chain management and its impact on industry.

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### 1.1 Development of Green Supply Chain Management

As the effects of environmental problems on the living conditions of the world's population become more apparent, an emphasis on environmental awareness has become more prominent. The general public has started to pay more attention to the potential consequences of this global environmental problem.

Some of the most pressing environmental issues include ozone layer depletion, global warming, and hazardous wastes. In an effort to mitigate the negative impacts of such environmental problems, many nations have passed laws and regulations and have set environmental standards aimed at reducing industry carbon and greenhouse gas emissions to the atmosphere. Some of these standards include *end-of-life vehicle* (ELV); *restriction of hazardous substances* (RoHS); *waste electrical and electronic equipment* (WEEE); *eco-design of energy-using products* (EuP); and *registration, evaluation, authorization, and restriction of chemicals* (REACH).

In addition, industries have been increasingly creating environmentally friendly products to satisfy consumers' demand for green products. For instance, businesses have lessened the use of raw materials, have begun recycling old products, and have started using renewable energy.

*Supply chain management* (SCM) covers industry planning and control activity that relates to trade, exchange, and logistics management. More importantly, it includes collaboration among suppliers, agents, and new customers. With increasing customer awareness and more stringent regulations, industries have started to integrate environmental factors throughout their organizations. Furthermore, industries have been gradually shifting towards environmentally friendly supply chains by integrating green technologies into their product designs, production, and distribution processes. These efforts, together

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with the desire to incorporate *extended production responsibility* (EPR), have led to the evolution of *green supply chain management* (GSCM).

In 1969, the Coca-Cola Company commissioned a study on life-cycle analysis to assess the environmental impact of its product packages, laying the framework for the *life cycle assessment* (LCA) practiced today. During this period, LCA emphasized reducing the negative environmental impact from production, transportation, and disposal of goods. However, progression in recent years has gradually transformed and integrated this methodology into the entire SCM system.

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### 1.2 Evolution of GSCM from SCM

SCM was first discussed by a group of professional consultants back in the 1980s. This discussion and later developments have made people more aware of SCM (Oliver and Webber, 1982). In his book titled *Competitive Advantage: Creating and Sustaining Superior Performance*, Porter (1985) introduces the concept of value chain. He emphasizes that industry can perform a series of primary and support activities to increase the added value of products, which could in turn add value for customers. The linkages of these activities to add value to the products and services that an organization produces is known as *the value chain*. According to Porter, the support activities include inbound logistics, operations, outbound logistics, marketing, sales, and services.

SCM is recognized as a network of interconnected businesses that form a tight linkage among raw material resources, production, transportation, and distribution of material resources, information, and financial flows for the ultimate provision of goods and services. Consequently, the Global Supply Chain Forum of 1999 defined SCM as, “An integration of procedures from suppliers to consumers to provide products, services and information in order to add the values of the customers and the related roles.” Therefore, the SCM complexity revolves around three factors: (1) products, (2) suppliers, and (3) raw materials.

In terms of sustainability and the international green initiatives, focus is given to the three major issues—dematerialization, detoxification, and decarbonization—which lead to the 4R’s (reduction, redesign, reuse, and remanufacture) in practice. Most industries strive for dematerialization to reduce the amount of materials or time needed to produce and deliver products and services required by the customers. The production of poisonous materials can be the best example of people who suffer from their own actions because they ignore the potentially global effects of such systems such as oil spill or some other poisonous material spill.

One of the most pressing environmental needs is the detoxification of industrial pollutants. Much of the natural resources around

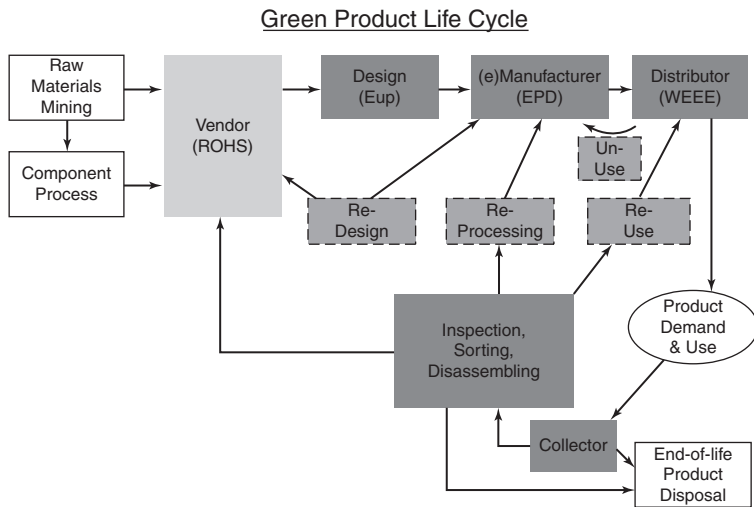
the world have been contaminated by industrial waste and pollutants due to the use of hazardous materials in industrial products. The profound effect of environmental degradation threatens the living conditions of all organisms. In this context, detoxification becomes a more important and serious challenge to individuals, governments, and industries. In addition, carbon emissions from the production of hydrogen to produce power from fossil fuels release greenhouse gases into the atmosphere, resulting in the climate change problem. Hence, decarbonization, also known as de-energization, is necessary to mitigate this problem. To achieve these goals, redesign of a product for reducing energy consumption and ease of disassembly for reuse and remanufacture becomes a necessity.

Given the global green initiatives, new methods have emerged for adopting the practices and standards for analyzing sustainable development in leading enterprises operating in developed countries. These methods generally focus on the three most important aspects of the enterprise, viz., (1) product design, (2) production process, and (3) the organization itself.

In 1994, the Asian Productivity Organization (APO) stated that if Asia was to fully develop, sustainability should be part of a new paradigm to integrate the environmental factors with production. These recommendations have led *green productivity* (GP) to prevail in Asia. The fundamental goal of GP is to develop higher-level production processes to protect society while simultaneously increasing industry product qualities and maintaining profit targets for industry.

Thus, green productivity focuses on enhancing productivity and environmental performance for sustainable developments in industry to achieve a competitive advantage. Wu and Dunn (1995) use environment and energy problems together with Porter's statement on value chain integration to emphasize that industry not only has to increase product value, but it also needs to use the value chain. The main idea is to decrease environmental impact throughout the value chain, from raw materials to the final product. In this case, environmental impact includes reduction in energy use, consumption of natural resources, and pollution-related problems. Although Wu and Dunn do not fully describe the framework of the green supply chain, they tackle pollution produced by industry at different levels in the value chain, as well as postconsumer consumption. The authors point out that there should be an increase in product recycling to increase the further use of raw material and supply. To that end, GSCM should augment the activities of reverse logistic management (which includes decreasing production source, renewing natural resources, recycling materials, cleaning waste material, and managing hazardous substances) to integrate all aspects of environmental management into its domain (see, for example, Pochampally et al., 2009).

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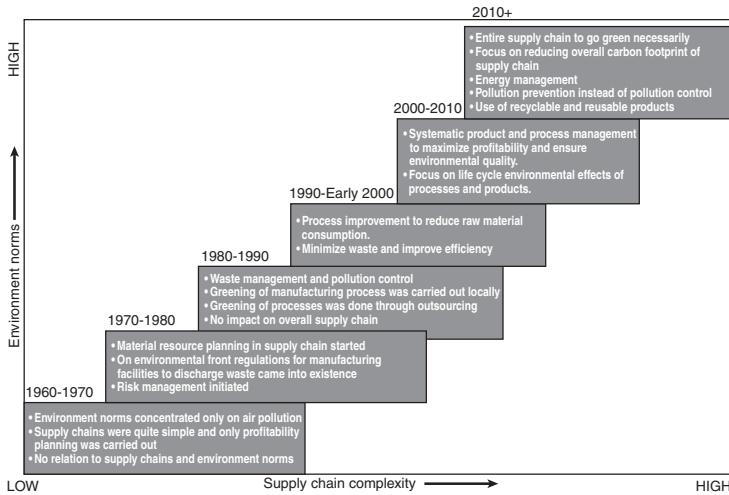
**FIGURE 1.1** Framework of a green supply chain with the involved forward and reverse activities and their corresponding directives.

This concept is adopted in the book by Wang (2009). In particular, Wang points out that market expectations have been an essential motivation to encourage industries to focus on creating and adding value at all levels of the value chain to enhance their competitive advantages. This has led to the establishment of communication channels between customers and suppliers. With the rapid development of Internet technology, such channels can be effectively built through on-line platforms. Thus, organizations must establish reliable databases and effective retrieval schemes to make this information available via search engines.

In this book, we shall discuss the green supply chain in the framework shown in Fig. 1.1, addressing both the forward activities of procurement, design, manufacture, and distribution to the consumer, as well as the reverse activities of inspection, sorting, and disassembly for the purposes of reuse, reprocessing, and redesign for the demand of primary and secondary markets.

### 1.3 Impact of GSCM on Industry

Life-cycle analysis evaluates various aspects of the product system, including technology and its potential impact to the environment, throughout its life cycle. It involves examining all stages of the development of a product or service, from the selection of raw materials, through product outputs and usage, to product processing after use. The most common tool used in life-cycle analysis is called *life cycle*



**FIGURE 1.2** Evolution of the green supply chain.

*assessment* (LCA), which is used to assist designers at the beginning of product design to identify techniques that ensure that the product components and designs are attuned to environmental standards.

Standards must be set when conducting an LCA of the amount of energy and natural resources utilized, the amount of emissions caused by air and water pollution, and the waste products resulting from consumption of the product output.

Although the theory of GSCM was developed in the 1990s, due to numerous challenges, most industries did not begin to adopt GP until 2000 or even later. Figure 1.2 shows the evolution of green supply chain technologies. One can see in the course of development that while consciousness concerning the environment increased, the complexity and scale of GSC technologies also increased. Each country has varying environmental protection standards integrated into its own regulatory system. Furthermore, these laws need to be acceptable to industries for them to be adopted in *original design manufacturing* (ODM) and *original equipment manufacturing* (OEM). The impact of GSCM on industries will be discussed in the next section.

### 1.3.1 Impact of GSCM on Industry Tactics

The effect of GSCM on industry is significant, in that the green procurement system is built to control suppliers, especially for ODM, so that they satisfy environmental protection standards for their products. For example, in order to satisfy the ELV standards, automobile companies collaborated and created the International Material Data System (IMDS), which ensures that the materials used by OEMs and their suppliers meet international standards.

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In the electrical and electronics industries, suppliers use green procurement procedures and documentation to specifically control the use of various hazardous materials. However, GSCM aims to satisfy the “green requirement” for ODMs throughout the entire SCM. One famous example that can be referred to is the event of SONY, in which, because of the forbidden metal Cd found in the connectors of their play stations, their cargo was not allowed to enter the harbor of Holland, which caused enormous damage to both the products as well as the reputation. Thus, SONY developed SS-00259 technical standard (SONY, 2004) to restrict all of their component suppliers to follow a standard flow in partnership, in order to ensure that no toxic material will ever appear along their supply chain.

Also using SCM, Dell can estimate its Supply Chain Carbon Output (InfoWorld website). Dell demands that all first-level suppliers sign the Electronic Industry Code of Conduct (EICC), and encourages these suppliers to conform to these standards by being certified. The EICC establishes standards and regulations for corporate social responsibility in the electronic industry’s global supply chain. These regulations are developed from reviews of basic standards, which involve laborers and employers, safety, environmental responsibility, system management, and ethics (Dell website).

### 1.3.2 Impact of the Green Supply Chain on Industrial Administration

In order to achieve the goal of GSCM, industries must gather all existing material systems, information management systems, and process operation systems, and integrate all the green requirements into tasks and procedures to achieve greening. For this purpose, industries strive through the GSCM system to evaluate the green performance of suppliers, assess the quality of green products, and direct overall management of suppliers. In addition, industry leaders use *information technology* (IT) to assist other industries to solve the problems and challenges of applying GSCM. Efforts have been made to ensure that the overall supply chain conforms to the standards of GSCM through management systems, production processes, technique standards, verification of work, and analysis of product components. Some of the benefits of introducing GSCM into industry are discussed in the following subsections.

#### **Increased Interaction Between Client and Supplier**

With increasing customer awareness and regulatory norms, organizations with greener supply chain management practices increase client interaction to gain understanding of their clients’ needs and wants, providing opportunity for future product development. Clients also encourage suppliers to strengthen their design capability and

production control process in order to meet requirements based on standards.

### **Collaboration Between the Company and the Supplier to Create Innovative Product Design**

In the development of green products, innovation is needed, such as identifying substitute materials (e.g., non-lead material fabrication and non-halogenic plastic material and fabrication), creating energy-saving designs, and upgrading energy-transforming efficiency. All of these tasks rely on collaborative and innovative design efforts between the industry and its suppliers.

### **Requirement for Suppliers to Provide Environmental Information**

To ensure that products conform to environmental standards, information on products and their suppliers should be based on the content of a survey that the collaborative suppliers are required to provide.

- In order to satisfy the recycling rate and the recovery rate that the WEEE standard has set, the supplier must accomplish a survey regarding information on the location of the hazardous component, the amount and component *bill of manufacturing* (BOM) form, the means of transportation, and the weight of the product, in order to analyze the disassembling rate and the possibility of recycling. In addition, this information helps recycling companies to increase the recycling rate of waste products of the electronic and electrical machinery components.
- In order to understand the potential environmental impact of the production of goods, the brand company can use SCM to ensure that suppliers cooperate in providing information on the material component and content of the product.

### **Collaboration Between the Company and the Supplier in Creating Green Product Design**

In order to meet standards for green product design, companies must collaborate with suppliers in developing product design. For example, the company should inform its suppliers of the product requirements to meet certain environmental standards, such as developing non-lead products and non-halogenic products, or to provide postconsumer plastic materials.

### **Auditing the Suppliers' Green Performance**

Companies should also set up a green audit management or environmental audit management system to ensure that suppliers satisfy the product requirement. This allows the supplier to gain understanding

of the industry's environmental strategy or the green standards for the product to which the company is adhering, so that the supplier is able to assist the company in achieving its target *corporate social responsibility* (CSR).

### **Challenge of Increased Prime Costs**

To satisfy the standards of green purchasing for the company, suppliers need not only send products to one laboratory for testing and supply test results but should also provide and install their own testing equipment (e.g., XRF) and controlling systems (e.g., QC 080000, ISO 9000, ISO 14000, OSAS 18000). Moreover, some of the tools for integrating information systems (e.g., ERP, PLM, CAD, CRM) are costly, which can lead to an increase in the cost of production.

### **1.3.3 Intensification of Competition by GSCM**

As organizations face the challenges of adhering to environmental protection regulations, many domestic and international industries are finding opportunities in green product development. These include searching for new raw material supplies, developing new processes, and expanding new markets. This industrial strategy is similar to the shift from the so-called "red ocean strategy" (i.e., low-price competition in existing markets) to a "blue ocean strategy" (i.e., developing new market opportunities). These results prove Porter's analysis of competition:

- Attempt to get out of present factory competition;
- Increase the barrier facing the new competitor when trying to become involved in the burgeoning market;
- Pose competition to rivals.

Furthermore, Porter's analysis can be extended. Rather than considering the situation from the point of view of competition, GSCM can be viewed from the point of view of collaboration, thereby creating more opportunities in the global industry. A strategic alliance both upstream and downstream can lead to the expansion of a much bigger energy industry. This allows an enterprise to gain understanding of its customer needs and to actively devote its efforts to the development of green products. However, the enterprise needs to expand its supplier base in order to strictly adhere to standards set to ensure quality control and to allow price negotiation.

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## **1.4 Summary and Conclusion**

Supply chain management facilitates interaction among the supplier, the shipping industry, the customer, the retail merchant, the quality

controller, and the manager of the final product. This interaction may change from the upstream or the downstream side depending on the influence of the enterprise on the supply chain. The enterprise can enhance the relationship within the supply chain through effective communication to avoid misunderstanding. Thus, the enterprise serves as the linkage that facilitates interaction in the supply chain.

With increasing interest and development in the areas of green procurement, technology, and product development, local enterprises have already adopted some initial measures. The challenge, however, is how to effectively implement and manage this initiative in order to achieve significant results. Figure 1.3 shows an implementation procedure for extending the supply chain that includes activities focusing on operations analysis, measurement, and continuous improvement. All of these major issues will be discussed in this book, and their value will be measured against corresponding performance.

In summary, as environmental protection continues to grow as a global concern, organizations are paying more attention to ensuring that green standards are adhered to at all levels of the value chain, from manufacturing, through social welfare, to sustainability of the product development system. The green value chain framework is built based on future trends and environmental requirements for a sustainable design. For related issues of development along the life cycle of a product, the reader is referred to the handbook published by the Global Green Supply Chain Group (2007).

This book is organized into four parts: “Basic Concepts and Background” (which includes this chapter and Chapter 2, which introduces

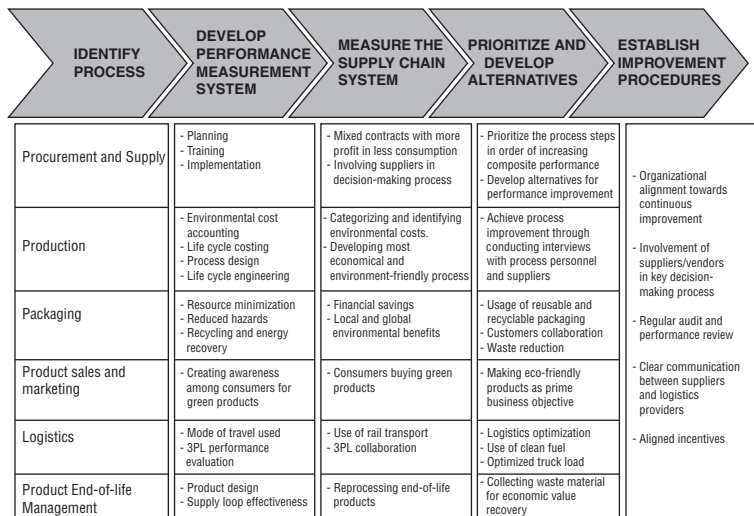


FIGURE 1.3 Development of a GSCM system with the related issues.

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the basic mathematical background needed to follow this book), “Green Engineering Technology” (which is mainly concerned with the engineering issues of developing a GSC), “Green Value Chain Management” (which considers GSC from both sides of demand and supply as a closed-loop system including the roles indicated in Fig. 1.3) and “Green Policy and Information Management System” (which discusses information support for such system to be found on the Internet).

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