

Choosing the right approach to green your supply chains

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Abstract

Purpose – Due to the different institutional pressure such as those from market, regulations and competitors, companies have implemented green supply chain management (GSCM). Unfortunately, tens of GSCM practices exist. Whether all companies should implement GSCM and how to achieve both environmental and economic performance are still not clear for many companies. The purpose of this paper is to develop models that can be helpful for companies to identify right GSCM practices and implement GSCM effectively and efficiently.

Design/methodology/approach – Based on about 18 years of study on GSCM with four surveys in China in 2001, 2005, 2012 and 2016, as well as numerous site visits and interviews mainly in China but also in Japan, Germany and Canada, this paper explores institutional drivers as well as opportunities and challenges using theoretical analysis and case studies. GSCM is defined considering a product life cycle. A key three-step GSCM approach is theoretically developed considering opportunities and challenges through life cycle analysis (LCA) of a product and position of a company.

Findings – All companies should implement GSCM practices to avoid risks. To effectively implement GSCM practices, a company should understand the life cycle of its product and its position in the supply chain. A key three-step LCA-based approach can help companies to identify the critical GSCM practices.

Originality/value – A key three-step LCA-based approach for GSCM implementation is originally developed based on theoretical analysis and eight years of study.

Keywords Green supply chain management, Life cycle analysis, Three-step approach

Paper type Research paper

1. Introduction

Due to the increasing external pressure and self-improvement driven, companies have sought ways to improve their environmental performance. However, corporate executives have been at a loss on how to truly reduce their environmental footprint (Hendriks *et al.*, 2018). They lack certainty and confidence that programs they propose and implement can result in true environmental performance improvements (Anvar *et al.*, 2018). By most accounts, expanding organizational environmental improvement efforts to extend beyond their own walls, deep into their supply chains, is where the treasure of reducing ecological burdens exists (Lee and Tang, 2018). Even with the attractiveness of such imagery, the complexities of probing into the supply chain to find environmental



wins can be very draining and has made even the most intrepid executive reluctant. Why upset the status quo for what might be considered a peripheral nicety rather than an imperative competitive practice?

When seeking to green supply chains, the best scenario is one where all members in a supply chain can improve profits, become more eco-friendly, and get recognized for it. Evidence that green supply chain practices can contribute to these outcomes has been trumpeted in the academic and practitioner literature (Feng *et al.*, 2018; Laari *et al.*, 2018). But treading carefully is still the mantra of most organizations. Cooperation with a supply chain may not bring benefits for some companies (Hong and Guo, 2019; Noh and Kim, 2019). Are minor environmental and economic wins of plucking the low-hanging fruit enough? What is required to maintain a fruitful long term organizational and supply chain benefit from green supply chain adoption? Where should organizations and supply chain members concentrate their effort to reduce their supply chain ecological burdens?

To answer these questions above, this paper first examines reasons why organizations should green their supply chains or implement green supply chain management (GSCM) considering different stakeholders in Part 2. Part 3 defines GSCM based a product life cycle and introduces five GSCM practices. Part 4 explores GSCM opportunities and challenges using existing examples. In Part 5, three steps are developed for effective GSCM implementation. Conclusions with a focus on practical implications are introduced in Part 6.

2. Why do organizations care about greening their supply chains?

Pressures from customers, regulators and competitors have caused companies to pay closer attention to how they manage their environmental impacts and eventually pursue environmental innovations (Giri *et al.*, 2019; Mathiyazhagan *et al.*, 2015; Zand *et al.*, 2019; Zhu *et al.*, 2013). Picking the internal “lowest hanging fruit” of environmental improvements has typically been the initial avenue for companies when managing their environmental programs. Companies tend to focus on environmental innovations that provide “win-win,” economic and environmental, opportunities and benefits. Yet, there are deeper and more profound opportunities when companies investigate environmental improvement opportunities outside their organizational boundaries. One such opportunity occurs when companies focus on greening their supply chains or implement GSCM practices (Lee and Tang, 2018; Yalabik and Fairchild, 2011).

Corporate motivations for adopting GSCM are varied. Lee Scott, WalMart’s former chief executive officer released an organization-wide strategy for developing green supply chains, requesting hundreds of top Chinese suppliers to comply with Walmart’s environmental requirements at a “sustainability summit” in Beijing. In addition to seeking economic benefits, GSCM efforts have been critical to improving Walmart’s brand image and name. In developing countries, export and meeting requirements for international customers used to be a key drivers for companies to implement GSCM practices (Zhu and Sarkis, 2007; Zhu *et al.*, 2005).

Regulatory forces have had even more direct influences on GSCM practices adoption. For example, the European Community introduced two GSCM-related directives, namely, the Waste Electrical and Electronic Equipment Directive (WEEE) and the directive on restrictions of the use of certain hazardous substances in electrical and electronic equipment (RoHS). WEEE extended producers’ product responsibility to consumers. This extension required producers and exporters of electrical and electronic products to shoulder responsibility for end-of-life (EOL) treatment of their products, requiring that they integrate strategic infrastructural decisions relating to reverse logistics (closing-the-loop) management of their products. RoHS extended producers’ responsibility in the opposite supply chain direction, toward suppliers. RoHS requires electrical and electronic products to avoid using six categories of hazardous substances. Companies try to meet regulatory

requirements and commercial needs through their GSCM practices (Hitchcock, 2012). Companies in developed and developing countries both have struggled to overcome regulatory environmental regulations, but they may implement GSCM practices due to awareness of environmental regulatory pressure. For example, Japanese small- and medium-sized companies implement GSCM practices are mainly due to domestic pressure, while Chinese companies care more about international pressure (Zhu *et al.*, 2017).

Interestingly, GSCM practices have also had profound influence on greener and more ethical practices on companies in developing countries, such as China. This diffusion of greener practices through international partners especially partners operating in China has become quite common (Zhu and Liu, 2010). For example, US customers have made efforts to manage Chinese suppliers to be green, and some of them seek help from local governments and non-governmental organizations (Plambeck *et al.*, 2012). At the same time, Chinese companies have initiated GSCM practices to respond to both domestic and international pressures (Zhu, Cordeiro and Sarkis, 2012). Actually, GSCM practices by international competitors are one critical mimetic driver for Chinese companies (Zhu, Tian and Sarkis, 2012).

Even with these various motivational reasons, companies still cast doubt on the value of GSCM. Implementing these GSCM practices is not a trivial operational task; implementation requires substantial resource and manpower commitment. This situation brings about an important initial question: Are GSCM practices universally worthwhile for companies to pursue? Even though GSCM practices can result in improved environmental performance, reduced costs and lessened disruption and reputational risk, the resulting economic payback remains unclear (Zhu and Sarkis, 2004). Without definite and clear economic gains and mandatory regulations, why would or should companies seek to implement GSCM practices?

Whether and how GSCM practices can be implemented in a cost-effective manner is also a question for many companies. Life cycle costs may provide some insights (Walker, 2008). By focusing on an overall life cycle perspective picture, companies will tend to less myopically focus on the low-hanging fruit. Myopic, piecemeal efforts tend to be problematic and short-term focused; a broader perspective will bear sweeter and larger fruit in the long run.

3. What are GSCM practices?

We know that one-size-fits-all is not appropriate for GSCM practices adoption. Companies have implemented different scopes and depths of GSCM practices. The product life cycle helps frame a definition for GSCM practices, as shown in Figure 1. A few GSCM studies

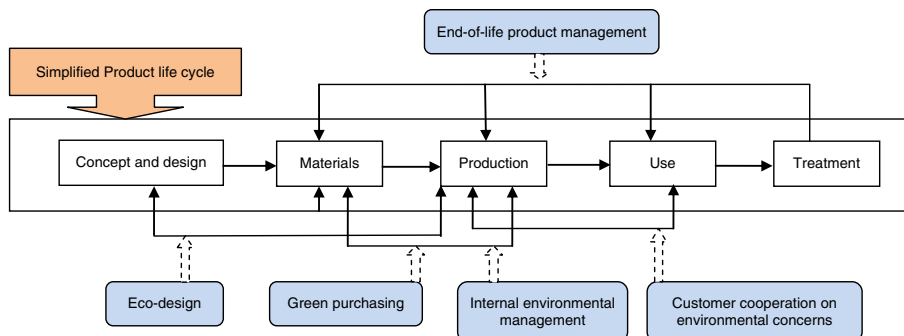


Figure 1.
Product life cycle and
green supply chain
management practices

examine logistics issues (Sheu, 2008; Sheu *et al.*, 2005; Teixeira *et al.*, 2018). Following most GSCM studies, this study identifies five dimensions from a product life cycle perspective, which can help companies carefully plan for GSCM. These dimensions include green purchasing, internal environmental management practices, eco-design, customer collaboration on environmental concerns and EOL product management (Zhu *et al.*, 2005, 2008). These five GSCM dimensions have been commonly accepted (Fahimnia *et al.*, 2015; Maditati *et al.*, 2018).

Green purchasing integrates environmental concerns into materials selection and supplier management. For example, General Motors sums up the value of GSCM: “Working together with our suppliers, we can accomplish much more to improve the environment than General Motors can alone.” Green purchasing practices can reduce environmental burdens by monitoring and collaborating with suppliers (Min and Galle, 1997). Nokia uses questionnaires as a small-scale environmental audit of its suppliers, focusing on Nokia sourced components. Automobile manufacturers such as General Motors, Ford and Toyota require suppliers to achieve certified environmental management systems. Herman Miller, a furniture manufacturer and service provider, holds conferences and workshops for suppliers to promote the awareness of its environmental procurement policies.

Internal organizational environmental management efforts such as cleaner production and energy consumption audits within a company are “engines” that may drive GSCM practices. Within supply chains, an individual company can produce the largest environmental burden. For example, petrochemical companies and their processes may be the supply chain’s largest environmental culprits. When energy consumption and pollution emissions are the supply chain’s environmental focus, managing their internal environmental management practices is where GSCM practices focus should lie.

Eco-design, commonly referred to as design for the environment, is another dimension of GSCM. Eco-design seeks to eliminate product and process environmental burdens at product’s design stage (Lewis and Gretsakis, 2001). Eco-design is a GSCM practice because it is a supply chain wide cooperative design effort that includes both suppliers and customers for effective execution (Johansson, 2002). Herman Miller has integrated their eco-design efforts to avoid hazardous materials, reduce environmental impacts of their products, and improve revenue performance through eco-design efforts.

Customer cooperation on environmental concerns is one of the GSCM practices useful for integrating environmental aspects into the supply chain. Cargill, a major food products supplier to McDonald’s has built a strong customer collaborative relationship with the latter. Together they have worked to reduce deforestation of Amazon rainforests due to unsustainable farming practices. Green marketing and consumer segmentation are additional examples of customer cooperation practices (Ginsberg and Bloom, 2004). In choosing a right green marketing strategy, it is desirable to know how much effort is needed and what differences they can make for product use and after sales management (Donald and Oates, 2006).

Supply chain members may utilize the product life cycle to manage environmental impacts by developing environmental principles for recovery of EOL products (Webb, 1994). Xerox Corporation worked with suppliers to make “smarter” parts and products for their office equipment, especially to facilitate remanufacture of the Xerox copiers and other equipment at the end of useful product life. Regulatory policies, such as WEEE, have put extended producer responsibility requirements on the radar map of many organizations. Companies have to increasingly shoulder the environmental responsibility of their products as these products reach their EOL. This trend accentuates the growing importance of reverse logistics, and EOL product management activity for greening supply chains. Reverse logistics activities include the return as well as upstream movement of a goods or materials resulting from reuse, recycling or disposal.

Cellular phone companies such as Apple have worked on asset and investment recovery to remanufacture phones at the end of their lives. These efforts have also bolstered their financial coffers significantly.

4. Opportunities and challenges related to GSCM

4.1 *Opportunities related to GSCM*

While GSCM may not be mandated by regulatory policy, GSCM business opportunities can be significant motivators. Improved environmental performance is fertile ground for green marketing campaigns potentially enabling organizations to expand market share (Cronin *et al.*, 2011). A robust GSCM strategy has helped Walmart to improve its overall image and reputation.

Additional business opportunities can and do arise. One automobile carpet supplier was required to avoid hazardous substances by General Motors. Prior to this request, the supplier was unaware of the environmental damages caused by its carpet product. After careful examination, the supplier identified that chemical glue was the major and most obvious source of hazardous substances. Based on a simple re-design, the supplier replaced the chemical glue with natural glue, which also resulted in reducing adhesive materials costs by 50 percent. Subsequently, the supplier has positioned their carpet simultaneously as both an environmentally-friendly and lower priced product. Without these supply chain forces playing a role, the supplier would have been oblivious to various cost savings opportunities.

Business continuity is another reason for GSCM practice adoption. A Chinese apparel factory exporting clothes to Japan is an interesting business continuity and supply chain resilience case. The Japanese customer of this apparel producer required the use of dye from a designated supplier located in the Taihu Lake region of China. A Taihu Lake blue algae scare required that dye suppliers cease operations as mandated by the Taihu local government. The resultant supply disruption caused this apparel factory to suffer sales loss due to erratic provisioning, which in turn hurt its customer's supply. GSCM practices are able to address a number of these concerns and if appropriately implemented can contribute to substantial business opportunities.

GSCM practices may also help to generate revenue. We saw evidence of this benefit after visiting a medium-sized Chinese company that manufactures traditional machine tool products. Recognizing the government's preference for clean energy, the company invested in research and development for manufacture of key windmill components, and adjusted their supply chain for this demand. Remarkable revenue generation and financial gains occurred over a five year period. The company has continued to prosper from these earlier innovations by introducing many newly negotiated contracts, guaranteeing market share and business growth. Significant benefits exist for organizations when they identify and become suppliers for green products.

4.2 *Challenges related to GSCM and potential responses*

It is not uncommon for companies to encounter various operational challenges and risks from lack of supplier monitoring and control. For example, KFC China was targeted by protestors because Sudan Red One, an industrial dye, was found in its chicken wings and chicken hams (China Anti-Counterfeiting Report, 2017). Through careful product monitoring for the product's life cycle and its supply chain, Sudan Red One was found to originate from one of KFC's third-tier suppliers. KFC suffered a reputation loss and faced a liability risk from this food safety event. It also took a significant amount of time before gaining back customer confidence and loyalty. Another example of supply chain risk occurred to Sanlu Group, a notorious milk powder producer in China. The Sanlu melamine milk event shocked the

international community. Sanlu brand milk powder contained excessive levels of melamine, an ingredient introduced by dairy farmers. This tainted milk caused infant urinary calculi, causing health problems in over 6,000 infants (Zhang *et al.*, 2010). Eventually, this event led to Sanlu Group's bankruptcy. Although KFC and the Sanlu Group were not the major sources of these problems, they seriously suffered from the resulting damage.

Environmentally-oriented problems can arise anywhere in a product's supply chain. An appropriate response to these problems may ease environmental pressure or even convert these problems into opportunities. One such circumstance arose when Unilever was blamed for causing rainforest destruction. In response, the company implemented a GSCM strategy to address deforestation problems from its cultivation of palm oil (Bordewijk, 2006; Pretty *et al.*, 2008). Unilever initially committed to the Roundtable on Sustainable Palm Oil framework, and publicized their effort to purchase all palm oil from certified sustainable sources. In this effort, Unilever formed a networked coalition of more than 50 cross-industry organizations, including major food companies such as Nestle, Kraft, Pepsico; household and personal care companies such as P&G, Colgate, Kao, Lion; major retailers such as Tesco, Ahold, Sainsbury, Marks & Spencer; banks such as Rabobank; and NGOs such as Greenpeace, WWF, Oxfam, Conservation International. In reducing greenhouse gas emissions, GSCM proved a critical dimension of Unilever's environmental solution (Canals *et al.*, 2011).

Another example of taking a problem and reforming it as an opportunity is the Asia Pulp & Paper Co., Ltd (APP). Established in 1994 in Singapore, APP is one of the largest pulp mills in the world. APP products were boycotted by restaurants in Hangzhou due to its alleged destruction of sensitive forests in Yunan Province. APP managed to demonstrate its environmental efforts through a tree planting program with its forestry suppliers (Cheng, 2007). APP expanded its GSCM practices beyond tree planting to cleaner production, recycling and supplier evaluation on their environmental performance improvement. APP has evolved to be one of the leading environmentally-friendly companies in China's Zhejiang Province.

In summary, even though GSCM practices may result in business opportunities and improve competitiveness, monitoring, evaluation, buy-in and control of suppliers' environmental performance are important risk management activities. Environmental impacts are caused not only by a company itself but also by other companies in their supply chains. For Walmart, 92 percent of environmental damages are indirectly generated from its suppliers (Makower, 2015). For WalMart, improving environmental performance through its supplier network is critical to sustain its supply chain operations. KFC, who has exemplary internal environmental and health management practices, is required to pay close attention to its suppliers where much of the environmental risk to its reputation may occur.

5. How should organizations implement GSCM practices?

Not integrating environmental management and oversight into supply chains has caused companies significant strategic and operational challenges and risks. By examining the product life cycle, a company can identify existing or potential challenges related to environmental issues. With in-depth understanding of these issues in the upstream or downstream supply chain, the company can create value by cooperating with supply chain partners and/or other stakeholders. As we have seen, GSCM practices are comprised of a broad range of activities and actions. It is not feasible for a company to implement each and every kind of GSCM practice. Where should companies begin and what should be done first? What priority should a company pursue for successful GSCM practices implementation? To answer these questions, we put forward the following three steps.

5.1 Step 1: understanding your product life cycle

To select the right GSCM practices, companies should understand where opportunities and risks exist in their supply chains. A simplified product life cycle analysis (LCA) can be

useful for companies to first identify where opportunities and risk occur in the supply chain (Nakano and Hirao, 2011). A simplified product life cycle can be roughly divided into four stages, they are: materials acquisition, production, use and EOL recovery/treatment/disposal. The largest environmental burden can occur in any one of the four stages. Using this life cycle perspective, products can be classified into four broad types (see Figure 2). Various environmental burden examples can provide some perspectives on the issues facing each product type.

Type 1 products use large amounts of energy or produce pollution during the first stage of materials acquisition portion of the life cycle. A typical Type 1 product is single life cycle packaging. A tin container for canned food is one such product. Using less packaging but more environmentally-friendly materials is crucial for reducing the environmental damage caused by these products.

Type 2 products tend to have environmental burdens mainly in Stage 2 activities of manufacturing or production. For example, paper products, electronic appliances and laptop computers may belong to this product category. Controlling energy consumption and pollution emissions during manufacturing or production is given priority for mitigating the environmental impacts of products throughout their life cycles.

Type 3 products consume significant amounts of energy or have their highest pollution emissions during usage. Automobiles represent this product type. Lessened fuel consumption or utilizing alternative energy sources are two trends for developing new generations of automobiles.

Type 4 products require significant resources or cause greatest environmental harm at their treatment stages. Mixed materials products are one product type example for Type 4. For example, mixed materials of stainless steel and aluminum have been used for kitchenware. Outer stainless steel guarantees non-health issues while internal lighter aluminum can reduce costs for both materials and transportation. However, such products with mixed materials are hard in treatment for recycling. Batteries are other products which

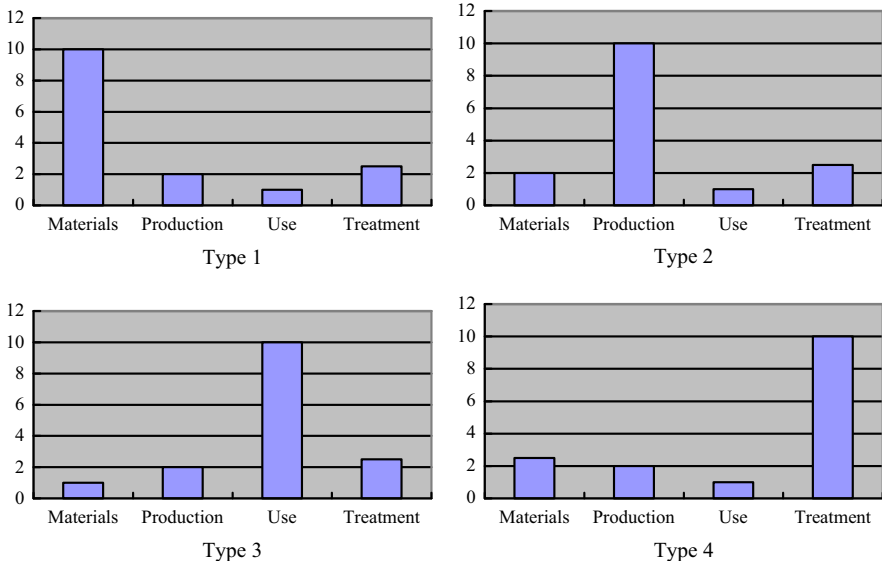


Figure 2.
Four types
of products

may be less harmful in earlier stages, but due to their hazardous materials characteristics, they cause their greatest environmental burden and costs during treatment stages.

5.2 Step 2: understanding where your organization is located relative to largest supply chain environmental burden

Understanding product types is the first step for companies to green their operations. Implementing management practices from a life cycle perspective is the next step to follow (Palmer *et al.*, 2011). The right GSCM practice requires that organizations understand their supply chain positioning with respect to where the largest environmental burden occurs. Figure 3 represents three organizational positions in a multi-tier supply chain. The position identified by a starburst indicates the supply chain company contributing the greatest environmental burden.

Companies that appear at Position 1 would be concerned with upstream supply chain environmental burdens. For such a company, green purchasing activities are prioritized. For example, WalMart is not a polluter itself while its suppliers bring many environmental burdens. Thus, WalMart has implemented GSCM practices with a focus on green purchasing since 2008. Similarly, for China Mobile, the majority of environmental impact comes from energy consumption of its equipment. Thus, China Mobile initiated its “Green Action Plan” formally by signing memorandums with key suppliers in December, 2007.

The Position 2 company is identified as the one having the largest supply chain environmental burden. In this situation, there is a need to implement internal environmental management practices, such as cleaner production activities. For example, Sinopec brings the most environmental burden through its product life cycle due to its industrial characteristics. In this case, the most effective GSCM practice for Sinopec is to focus on international environmental management such as cleaner production with more advanced technologies and innovative management measures.

Position 3 is when downstream companies or consumers cause the greatest environmental burdens. Companies in this latter supply chain position need to focus more attention on customer cooperation activities. For example, gasoline consumption brings much air pollution and resource scarcity. As a result, electrical cars have been produced. For companies producing automobile power battery, they need cooperate with automobile manufacturers for effective and efficient use of battery and even right treatment of used battery.

5.3 Step 3: choosing your GSCM practices focus

After a company clearly identifies its product type and its position with respect to where the greatest environmental burden occurs in the supply chain, it can then determine what GSCM practices are required. Table I summarizes the GSCM practices priorities for companies, providing examples of companies that appear in various supply chain members and industry characteristics. These three types of supply chain companies include: materials extractors,

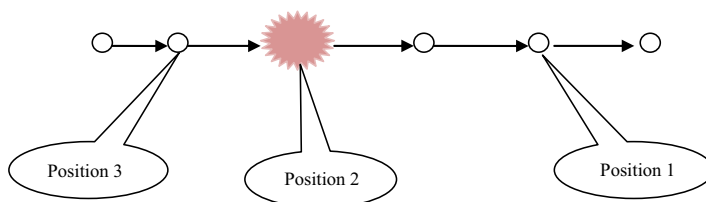


Figure 3. Supply chain member positioning and relationship to largest environmental burden

Table I.
A matrix of GSCM priorities based on product types and supply chain positions

Product types	Extractors	Producers	Retailers
Type 1	Internal environmental management Recovery for materials recycling	Green purchasing Recovery for materials recycling	Green purchasing End-of-life product recovery
Type 2	Customer cooperation on cleaner production Recovery for product recovery	Internal environmental management Eco-design for cleaner production	Green purchasing End-of-life product recovery
Type 3	Customer cooperation for green marketing Eco-design for green marketing	Eco-design for green consumption Customer cooperation for green marketing	Customer cooperation for green marketing Green purchasing
Type 4	Eco-design for end-of-life product treatment Customer cooperation for end-of-life product treatment	Eco-design for end-of-life product treatment Green purchasing	Green purchasing of recoverable products End-of-life product recovery

producers and retailers. For example, assume there is a supply chain with a Type 1 product. A materials extractor in this case would likely be the location with the greatest environmental burden, in that case international environmental management and recovery of materials for recycling are the GSCM practices accorded with highest priority. In this supply chain, producers and retailers would both focus on green purchasing practices. A slight difference is that producers may focus on recovery of materials for recycling while retailers should focus on EOL product recovery in greening of the supply chain.

Some practical cases can further exemplify this evaluation.

Clothes and textiles can be considered Type 1 products. Textiles and dyes are procured materials typically with significant environmental burden. Thus, apparel manufacturing companies (producers) need to focus on green purchasing.

The Chinese apparel company that suffered losses due to its dye supplier's bankruptcy is one example. This company did not realize the importance of GSCM practices to ensure environmental compliance of its supplier to help maintain a consistent and acceptable supply of dyes. In this situation, green purchasing activities are helpful and the company may explicitly stipulate in contracts or select dye manufacturers to meet certain environmental requirements.

Many paper goods are Type 2 products. We return to the case of APP (one of the largest paper manufacturers in the world), who was accused of practicing unsustainable forestry. In this situation, APP extended its environmental concerns and policies to both its upstream and downstream supply chain partners. In their upstream supply chain activities, APP planted trees and used waste paper as a production input materials. In the downstream portion of its supply chain, APP publicized their efforts on environmental practices as part of customer awareness raising. Realizing the environmental burdens of their manufacturing processes, they put significantly more resources and effort on internal environmental management such as eco-design for cleaner production practices.

Petrochemical manufactured products may also be categorized as Type 2 products since their production requires significant energy resources. In our discussion with a petrochemical company director of environmental management, the company had keen interests in the GSCM concept (especially external GSCM activities such as green purchasing and customer cooperation). We guided this director toward internal environmental management activities. Given that this company's manufacturing activities were a key source of environmental burden in their products' supply chains, focusing externally would not address the major greening supply chain concerns.

Automotive vehicles are typical Type 3 products. An engine manufacturing supplier with more efficient fuel consumption can have greater market potential. However, greener engines and vehicles may have limited popularity especially if these environmental characteristics compromise convenience, availability, price, quality and performance of a product (Ginsberg and Bloom, 2004). Thus, eco-design that balances the other performance measures for consumer usage and demand is needed to produce a greener vehicle. Customer (consumer) cooperation through incentives and marketing would also be appropriate to reduce the environmental burden of this product's supply chain.

The lack of resources and inadequate space for landfills, especially for hazardous materials products, are significant environmental burdens that can be managed for EOL electrical and electronic products. Xerox and Huawei implemented eco-design for reuse, recycling and remanufacturing of their EOL products for competitive business reasons, but also anticipated environmental issues. These Type 4 products from some environmental burden dimensions need EOL product recovery by manufacturers and those organizations working with end-users in the supply chain.

6. Conclusions and practical implications

Extended producer responsibility regulations, social consumer pressures and expectations, and strategic differentiation and competitive strategies, have all caused organizations to rethink how to green their products and supply chains. Adopting GSCM practices can help address these issues and mitigate environmental burdens. Unfortunately, many organizations either do not know how to adopt green practices or adopt them inappropriately when trying to reduce the overall environmental burdens of their products.

Recognizing this continuing supply chain management difficulty, this paper provides a three-step approach for companies to determine actions for greening their chains. To begin with, companies need to understand the life cycle characteristics of their products and the required GSCM practices to reduce their environmental burden. Doing so helps them to identify major supply chain environmental burden causation activities. Here, companies need to understand how they are positioned in the supply chain upstream from raw materials suppliers down to end consumers of products. An upstream supplier position requires control at the input side to mitigate environmental upfront causes with practices such as green purchasing and eco-design of products. Servicing in the downstream supply chain, and if this supply chain position causes the greatest environmental burden, requires cooperation with downstream customers and better utilization of resources through materials recovery.

A major implication is that GSCM practices will require differing priorities when seeking implementation. Careful tailoring of these practices to various product types and supply chain positions is needed. Increasing confidence that these GSCM commitments will effectively and efficiently benefit greening of supply chains will reduce implementation futility. Companies should initiate proper GSCM practices and coordinate with GSCM practices of their supply chain partners to help leverage the business opportunities of greening and avoid risks of failure. Understanding the various environmental burdens and positions throughout the supply chain requires integration and coordination of GSCM activities.

Contemporary supply chain management not only serves the interest of direct beneficiaries of products in the supply chain, but other stakeholder groups and their concerns should not be neglected. These groups include both governmental and non-governmental bodies which are not directly related to the supply chain operations, but their environmental concerns, if not properly handled, can cause business loss or even

bankruptcy as illustrated in the KFC and Sanlu cases. Given the interconnected global supply chain, it is important to extend the green efforts beyond the immediate downstream and upstream parties covering the inputs from, and the cooperation with, related parties in the network to succeed.

Thus, companies have moved from whether or not to implement environmental management practices to how to address environmental challenges while maintaining competitiveness (Kleindorfer *et al.*, 2005). A number of issues need to be addressed:

- the greatest burden of products occurs throughout the supply chain and need to be determined;
- companies should complete simple product life cycle assessments to determine where in their supply chains the greatest environmental burdens occur; and
- companies should implement appropriate GSCM practices that are most effective and most easily avoid risks.

This paper develops a general GSCM approach after introducing why and how to green supply chains. However, there are several limitations. First, no objective data are available to demonstrate effectiveness of proper GSCM practices. Second, due to globalization, suppliers and customers can be located in different countries and may be far away. Thus, even a company understand its reasonable and even necessary GSCM practices, it can be a big challenge to control its supplier. Third, without technologies available, internal effective environmental management can be difficult.

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Appendix. About the research

Our article is based on about 18 years of study on GSCM. We did surveys in China in 2001, 2005, 2012 and 2016, respectively. We also did numerous site visits and interviews among

manufacturers as well as key GSCM stakeholders such as governments, NGOs and researchers, mainly in China but also in Japan, Germany and Canada. One of our main objectives was to develop models that can be helpful for companies to identify right GSCM practices and implement GSCM effectively and efficiently. A key three-step, LCA-based GSCM approach, can be useful for companies to initiate suitable GSCM practices to achieve opportunities and avoid risks.

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