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# Developing green supply chain management strategies: A taxonomic approach

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***Abstract:***

***Purpose:*** The purpose of this research is to explore the empirical green supply chain activities found in the literature, and to develop a taxonomic framework that can be used for formulating appropriate strategies for green supply chains based on characteristic dimensions for the green supply chain.

***Design/methodology/approach:*** The taxonomic framework is developed through (i) analysis of green supply chain activities found in existing empirical work or case studies recorded in the literature, (ii) identification of key dimensions that influence green supply chain management strategies, and (iii) development of a taxonomic scheme for selecting or developing green strategies.

***Findings:*** The paper finds that this study yielded a set of three characteristic dimensions that influence strategic green supply chain management, and a guided structured approach for selecting appropriate green strategies, providing useful managerial insights.

***Research limitations/implications:*** This paper shows that future work includes development of specific performance management indices according to the taxonomy of green strategies developed in this study.

***Practical implications:*** This research provided a practical guided approach that enhances appropriate formulation of green strategies for green supply chain management, while providing sound managerial insights for the decision maker. The choice of supply chain strategy directly impacts the overall environmental, economic and operations performance of the supply chain.

***Originality/value:*** This study presents to supply chain decision makers a new taxonomic framework that simplifies and enhances the formulation of green strategies, and to researchers a comparative understanding of various strategies applicable to green supply chains.

***Keywords:*** green supply chain management, green strategies, environmental performance, reverse logistics

## 1. Introduction

Environmental management has become a topic of mutual concern for businesses, governments and consumers due to increasing high levels of industrialization (New, Green & Morton, 2002; Azzone & Manzini, 1994; Azzone & Bertelè, 1994; Azzone & Noci, 1996; Plambeck, 2007; Roberts, 2009). The growing concern in the global market for "green" issues and the scarcity of natural resources have forced executives to view supply chain strategies from an environmental perspective. High environmental risk industries, including chemical, plastic, automotive, and heavy engineering, have always considered improvements in environmental performance as one of the basic competitive priorities, alongside lower costs, manufacturing lead-time, and quality (Azzone & Noci, 1998). For instance, the European Union passed the Restriction of Hazardous Substance and the Waste Electrical and Electronic Equipment regulations demanding compliance with the relevant regulatory laws of product recycling and prohibiting the use of hazardous substances in products for sale in the market. In this development, the supply chain manager plays an important role of selecting and developing appropriate green strategies with the objective of improving environmental, economic, and social performance as well as gaining a competitive advantage.

### 1.1. Green supply chain management: A brief background

The term "green" is now widely used interchangeably on the more established "sustainability" concept, which points to a more holistic view of environmental, social and economic impact (Dobers & Wolff, 2000; Rahimifard & Clegg, 2007; Saha & Darnton, 2005). Green supply chain management (GSCM) is an emerging field motivated by the need for environmental consciousness (Srivastava, 2007). Stranding out of the conventional supply chain view, GSCM was sparked by the "quality revolution" in the 1980s and the supply chain revolution in the

1990s. Over the years, GSCM has attracted the attention of academics and practitioners, focusing on reducing waste and preserving the quality of product-life and natural resources. Eco-efficiency, which seeks to minimize ecological damage while maximizing production efficiency, and remanufacturing, have become key assets to achieve best practices (Ashley, 1993; Srivastava, 2007). Customer demands and governmental pressures continue to push businesses to be more and more sustainable (Guide & Srivastava, 1998). Consequently, governmental legislations and public mandates for environmental accountability have brought up these issues on the drawing board of many strategic planners, bringing several green concepts into place.

Some of the key green concepts that have emerged in the literature over the years include green design, green operations, reverse logistics, waste management and green manufacturing (Guide & Srivastava, 1998; Srivastava, 2007). Navin-Chandra (1991) considered the need for green design to reduce the impact of product waste. A remarkable design framework arising from the green design concept is the life cycle analysis (LCA) (Beamon, 1999; Arena, Mastellone & Perugini, 2003). The focus of LCA is on life cycle environmental effects of products and processes. Further, the concept of green operations, defined in terms of reverse logistics and related aspects, emerged from the literature (Pohlen & Farris, 1992; Tibben-Lembke, 2002). Waste management is another green practice that emerged in the early 90s (Roy & Whelan, 1992), borrowing concepts from the recycling and remanufactruring concepts (Sarkis & Cordeiro, 2001). Green manufacturing was conceptualised by Crainic, Gendreau and Dejax (1993), and later developed further by various researchers, providing green supply chain models and more green manufacturing concepts (Laan & Salomon, 1997).

Following the green or ecological pressures from customers, stakeholders, and governments, a number of operational guidelines, standards and legislative frameworks have been put in place to minimize environmental impact. Motivated by the need for companies to move towards ecologically sustainable business practices, the ISO14000 series standard was designed with the following objectives (Alexander, 1996; Pratt, 1997):

- encouraging an internationally common approach to environmental management;
- strengthening companies' abilities to measure and improve environmental performance, through continual system audits, and;
- improving international trade and removing trade barriers.

Similar to ISO14000 standards, is the Occupation Health and Safety Assessment Series standards (OHSAS18000) whose focus is on international occupational health and safety management. Other global initiatives in the context of greening the environment include the Restriction of Hazardous Substance (RoHS) and the Waste Electrical and Electronic Equipment

(WEEE) which enforce compliance with the relevant laws relating to product recycling and prohibit the use of hazardous substances in products for sale in the market. Other minor regulatory bodies exist in the literature (Beamon, 1999).

In light of the above issues, it can be seen that GSCM is driven by the increased environmental deterioration such as depletion of raw materials, overflowing waste landfills, and pollution in general. Thus, GSCM primarily seeks to minimise the wastes within the industrial system, to prevent the dissipation of harmful materials into the environment, and to conserve energy resources. The objective, however, is not only about environmental friendliness, but also a good sense of business and higher profits (Wilkerson, 2005). Business organisations have realised the need to upgrade their supply chain management from a purely functional role to a strategic role to comply with current environmental legislations and maintain an enduring competitive advantage, through technological innovation and improved eco-efficiency (Baines, Brown, Benedettini & Ball, 2012; Elkington, 1997: page 22). Operations managers in earlier environmental management systems were involved only at arm's length where individual organizational units managed environmental performance in product and process design, logistics, marketing, compliance regulations, and waste management. Though it has long been realised that green strategies should meet the required order winning criteria in the market place, the idea needs to be extended to the entire supply chain. Best practices call for collaborative integration of environmental and operational performance. There is a growing need for integrating environmentally sound choices into supply chain management practice and research.

### 1.2. Research focus and objectives

In view of the above issues, research in supply chain management has recently shifted its roles to refocus the supply chain in the following areas;

- the natural environment (Beamon, 2008; Azzone & Manzini, 1994);
- environmental performance (Beamon, 1999); and,
- enhancing supply chain collaboration (Baines et al., 2012).

This paradigm shift has been influenced by local and international legislative changes, market pressure, and the increased use of environmental requirements from customers in the supply chain (Alexander, 1996). This has generally encouraged fast acceptance of green principles world-wide (Beamon, 1999). Currently, there is a substantial need for improvement on the best way to select the most appropriate green strategy in a particular industry context. Very few researchers have considered the issue of identifying taxonomies for conventional supply chain management (Christopher, Peck & Towill, 2006; Corbett & Klassen, 2006). Research on taxonomy can provide the basis for developing theories and testing hypotheses. In addition,

taxonomy also provides parsimonious categorical types without losing the main information or characteristics that exist within the type, and has been applied in strategic management and logistics studies (Shang & Sun, 2004). In this regard, the aim of this research is to develop a taxonomic framework for guiding decision makers when developing green strategies for specific industrial situations. In particular, the objectives of this study are to:

- investigate crucial GSCM dimensions based on a survey of extant case studies in the literature
- develop a taxonomic framework to guide the selection of green strategies in supply chain management
- provide some managerial insights on the implications of the green strategies in different contexts.

The next section presents the research methodology used in this work. Section 3 provides a literature search survey on various applications of green strategies in supply chains. Section 4 identifies the dimensions of GSCM that influence the choice of green strategies. Section 5 presents the proposed taxonomic framework proposed for selecting green supply chain strategies. Section 6 discusses the impacts of various types of green strategies on operations policies. Finally, Section 7 presents concluding remarks and further research directions.

## 2. Research methodology

In this research, we made a wide search in academic studies, databases, and bibliographical list to compile the relevant information on green supply chain practices. The first and most important task was to carry out a literature search survey of real-world case studies on GSCM practices and their implementation. Due to huge volumes of publications and publication sources that have tried to address green issues, our literature research was centred on the Business Source Complete Database, which offers access to relevant scholarly publications of interest. This involved searching for empirical case studies from published work in reputable journals concerned with GSCM practices, including Journal of Cleaner Production, Long Range Planning, Business Strategy and the Environment, the Journal of Environmental Management, Ecological Economics, Greener Management International, and International Journal of Sustainable Engineering. In addition, the search included business publications, such as those from Harvard Business Review, the International Journal of Production Economics, the International Journal of Operations and Production Management, and the International Journal of Production Research. The search criteria used included keywords such as “green practices”, “green strategies”, “green supply chain”, “environmental issues”, “ecological”, “eco-efficient”, and “sustainability”. The second task was to highlight the main green strategic focus of each case study. The aim was to determine the major driving elements behind the choice and the final implementation of specific green strategies. This would assist in answering managerial

questions as to why certain strategies are suitable for specific industrial contexts. As such, the third task was to highlight those elements or dimensions that led to the selection and implementation of the chosen (suitable) green strategies. The analysis of the contexts in which specific strategies were chosen provides foundational building blocks or dimensions for the development of a taxonomic framework to guide decision makers in selecting appropriate green strategies, given specific industrial situations. The fourth and final task was to develop a taxonomic framework, based on the identified dimensions, for the purpose of selecting or developing appropriate GSCM strategies. Figure 1 summarises the research approach used in this study.

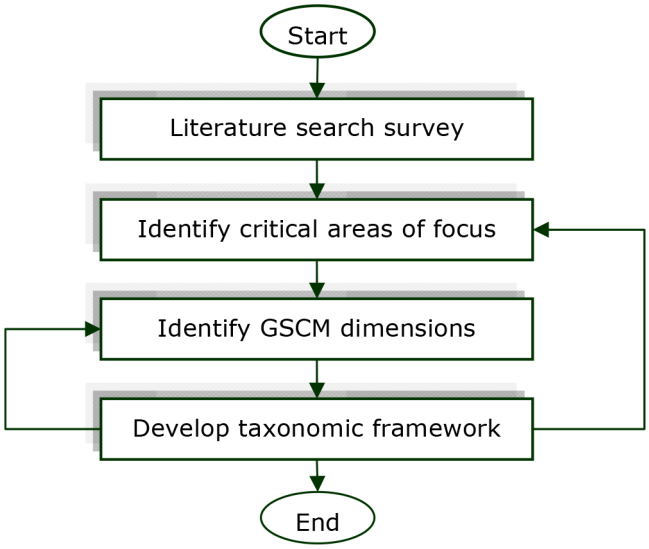


Figure 1. Research approach

The next section presents the results of the literature search survey of real-world case studies on the implementation of green supply chain management strategies.

### 2.1. Results of literature search survey

Major contributors found in the literature relevant to this study were Hart (1995, 1997), Porter and Van der Linde (1995), Azzone, Bertelè and Noci (1997). Other researchers in the area include Azzone and Noci (1996, 1998), Srivastava (2007) and Azzone et al. (1997). Following our literature search process, perusal of selected publications indicated that a number of organisations have embarked on introducing green practices such as green procurement, green production or manufacturing processes, green distribution, recycling and remanufacturing. Wal-Mart adopted green procurement of biodegradable and/or recyclable packaging. Automotive companies such as Toyota and Ford require ISO 14000 certification for their suppliers. A number of firms have invested in recycling and reuse practices, for instance, Dell, Hewlett Packard, Toshiba and other electronics industries (Hu & Hsu, 2006). In Western Europe, there is an obligation for 100% collection on "white goods" (Vlachos, Gaorgiadis & Iakovou, 2007). The general acceptance of green activities has led to increasing empirical

studies on the external and internal factors leading to the uptake of green practices and their impact on organisational performance (Simpson & Samson, 2008).

### 2.2. Critical areas of GSCM focus

Some patterns can be observed from the perusal of the empirical case investigations in the literature. In order to identify the appropriate dimensions of GSCM strategies, critical areas of focus and the main driving forces behind the green strategy chosen were analyzed. A closer look at the selected studies indicated that these studies can be categorised into four main areas of focus as shown in Table 1.

| No. | Description of area of focus of case study | Seclected References |
|---|---|---|
| 1. | Use of performance standards, prescribing basic environmental requirements across the supply chain | Plambeck (2007); King, Lenox & Terlaak (2005); Melnyk, Sroufe & Calantone (2003). |
| 2. | Integrating operational efficiency and waste reduction alongside supply chain objectives | Yan & Xia (2011); Corbett & Klassen (2006); Plambeck (2007). |
| 3. | Use of environmental friendly technologies and innovations and their transfer across the supply chain | Klassen & Vachon (2003); Ninlawan, Seksan, Tossapol & Pilada (2010); Lamming (1989); Heying & Sanzero (2009); Roberts (2009). |
| 4. | Supply chain collaboration, development of remanufacturing and recycling systems | Hu & Hsu (2006); Pohlen & Farris (1992); Stock (1998); Tibben-Lembke (2002); Guide, Jayaraman & Linton (2003); Barros, Dekker & Scholten (1998); Kumar & Yamaoka (2007); Pagell, Wu & Murthy (2007). Ruiz-Benitez & Cambra-Fierr (2011) |

Table 1. An analysis of case studies in GSCM and their main areas of focus

**Finding 1:** Four main areas of focus are environmental performance standards, eco-efficiency, green technology innovations, and collaborative supply chain with remanufacturing and recycling practices.

One important observation from these empirical research activities is their remarkable focus on operations that influence environmental performance, as opposed to conventional supply chains which focus on customer satisfaction, service quality, responsiveness, and the supply chain cost. The central goals of the green supply chain are primarily centred on those process operations that influence environmental performance (Beamon, 2008). Thus, the end goals of GSCM are categorised as follows:

- Waste (of all types): minimization of waste;
- Energy usage: minimize energy consumption; and
- Resource usage or material consumption: optimize resource usage.

**Finding 2:** The main goals of GSCM practices are minimal waste, minimal energy usage, and optimized resource usage.

Fisher (1997) presented examples from a diverse range of consumer products such as food, fashion apparel and automobiles, demonstrating why different supply chain strategies were appropriate depending on whether products were *functional* or *innovative*. Functional products tend to have stable demand with long lifecycles (Christopher and Towill, 2002). Since the characteristics of products have a direct influence on the choice of production process, their production systems tend to be functional as well. On the other hand, innovative products generally have unpredictable demand with short lifecycles. Consequently, their production processes are often innovative in nature. Therefore, product/process characteristics have a great influence on the choice of supply chain strategies (Hart, 1997). As in conventional supply chain management, the choice of GSCM green strategies is directly affected by product characteristics (Fisher, 1997). The success of GSCM goals, that is, waste reduction, minimal energy usage and optimal resource consumption, are strongly dependent on the green operations or processes chosen. On the one hand, processes can be eco-efficient by focusing on operations-based efficient targets which provide secondary environmental benefits. On the other hand, processes can be more *environmentally specific*, with more product-life cycle considerations (Hart, 1995). Such processes tend to be more focused on *green efficiency*. It is important to note that the green process operations are directly related to the inherent product characteristics.

**Finding 3:** GSCM goals are influenced by the green product (process) chosen; a green product (or process) can either be innovative or functional, while a process operation can be centered on eco-efficiency or green efficiency.

One other important observation in this study is that the above empirical research activities show that green supply chains tend to improve their performance by developing specific green capabilities and by building collaborative supply chain relationships (Kumar & Yamaoka, 2007). According to Modi and Mabert (2007) supply chain improvement towards the green practices is enhanced through competitive pressure from the market or customers, regulatory certification schemes, incentives, and direct involvement. Supply chain relationships are often developed based on two different climates, namely, (a) *coercive climate*, where contractual clauses are enforced between suppliers and customers (Zhu & Sarkis, 2007), and (b) *collaborative climate*, which calls for increased mutual involvement for customers and suppliers (Liker & Choi, 2004; Paulraj et al., 2008). These climates act as determinants of the success of green strategies chosen. Because the coercive approach demands a prescribed minimal level of compliance to standards, it lacks capacity to encourage advanced performance management. On the other hand, collaboration encourages new knowledge, technologies and innovation. However, a higher level of inter-organisation involvement and collaboration is required, if green supply chain goals are to be achieved (Christopher, 2000). In this regard, we draw on the influence of

supply chain collaboration on the success of GSCM strategies to define a framework for selecting appropriate green strategies. But how does the nature of process or product influence the success of the green supply chain?

**Finding 4:** GSCM goals are enhanced by two types of green supply chain relationships, that is, coercive or collaborative relationships.

From our literature search survey, a question arises as to what might be the most appropriate green supply chain strategy given a specific context, with a particular product, a specific process, and/or a particular supply chain relationship. What are the underlying GSCM dimensions upon which the right choice of green strategies can be made? In this study, we draw on the critical issues of supply chain relationship, product and process types to establish a taxonomic methodology for the selection of appropriate green supply chain strategies. The next section identifies the relevant dimensions of GSCM strategies together with their specific gradations.

**Finding 5:** The selection of GSCM strategies is influenced by three main dimensions; supply chain relationship, product, and process technology.

## 3. Dimensions of green supply chains

There are a few taxonomic schemes proposed in the literature, specifically for guiding the selection of conventional supply chain strategies (Christopher et al., 2006; Childerhouse, 2002). Christopher et al. (2006) used a 2 x 2 matrix method, based on supply chain characteristics and demand characteristics, to develop a pipeline selection strategy for conventional supply chains. Findings in this present work suggested that supply chain relationship has a direct impact on the appropriate choice of green supply chain strategies. As such, relationship is a crucial dimension that must be taken into consideration when developing a taxonomic framework for the selection of appropriate green strategies. Findings in this study also identified product and process technology characteristics as key dimensions that influence the choice of green strategies. We suggest a three dimensional taxonomic scheme that is more appropriate for delineating GSCM strategies. The dimensions and their gradations are as follows:

- Relationship (supply chain relationship) - is either coercive or collaborative;
- Process - focuses on either eco-efficiency or green efficiency;
- Product - is either functional or innovative.

A coercive supply chain relationship is characterised by enforced contractual clauses between suppliers and customers (Pagell et al, 2007). This approach demands a minimal level of compliance to standards, with very low information sharing. Suppliers seek to meet predictable

demand at the lowest possible costs. On the contrary, a collaborative supply chain calls for enhanced mutual involvement between customers and suppliers (Liker & Choi, 2004; Paulraj, Lado & Chen, 2008). In addition, supply chains tend to respond quickly to unpredictable demand due to their high agility and flexibility. Product life cycle costs and overall supply chain costs are the main objectives of the collaborative supply chain (Zhu & Sarkis, 2007). This approach is conducive to innovation and dynamic technology evolution. In light of these issues, we provide a summary of our views on the characteristics of coercive and collaborative supply chain relationships as shown in Table 2.

| Characteristic | coercive | collaborative |
|---|---|---|
| Information exchange | Low information sharing | High information sharing |
| Market responsiveness | Supply at lowest possible cost | Respond quickly to dynamic demand |
| Supplier selection approach | Consider cost and quality | Consider overall supply chain costs, flexibility |
| Product strategy | Minimize cost, maximize profit | Consider product life cycle costs |

Table 2. An analysis of coercive versus collaborative supply chain relationships

Although characterising products as functional or innovative may be an oversimplification, it is a practical high-level classification. In our view, functional products tend to satisfy basic needs, which do not change much over time, e.g., staples. Consequently, such products have stable, predictable demand and long life cycles. It follows that their processes do not change much over time, and they focus on eco-efficiency through optimal resource usage and low waste in order to maximize economic performance. On the other hand, innovative products tend to satisfy fast-changing needs. As such, innovative products have unpredictable demand and short life cycles, e.g., hand phones. What makes a product innovative is the drive towards green efficiency through the application of specialised processes with the aim of keeping up-to-date with emerging environmental legislation. Hence, innovative products and green efficiency are highly related. Deriving from Fisher (1997), we summarize our views on the characteristics of functional and innovative products in Table 3.

| Characteristic | Functional | Innovative |
|---|---|---|
| Demand | Predictable demand | Unpredictable demand |
| Product life cycle | Usually long, e.g., more than 2 years | Usually short, 3 months to 1 year |
| Product variety | Low (5 to 20 variants) | Very high (thousands of variants) |
| Process | Low-tech processes, cost efficient | High-tech processes, green efficient |

Table 3. An analysis of functional versus innovative product characteristics

Deriving from our findings in the above analysis, there are eight (2 x 2 x 2) possible theoretical strategy types. However, some of them are highly unlikely or even non-viable in real-world green supply chains. For instance, an innovative product matches with a green efficiency focused process due to its primary focus on environmental efficiency, while a functional product matches with an eco-efficient process due to its focus on minimizing costs while

gaining some environmental benefits (Klassen & Vachon, 2003). This analysis is summarised in Figure 2. Hence, it is worthwhile simplifying our taxonomic scheme into two dimensions: either relationship and product type, or relationship and process.

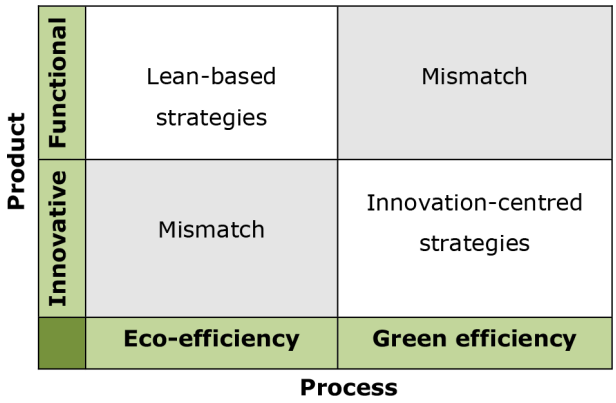


Figure 2. Product-Process characteristics and green strategies

In the following section, we further deliberate on the taxonomic framework for selecting appropriate green supply chain strategies.

## 4. Taxonomic selection of GSCM strategies

From our findings in this study, we develop a taxonomic framework based on the three GSCM dimensions derived from the literature search. Supply chain managers can select and develop GSCM strategies based on two basic dimensions that influence strategic green supply chain management; supply chain managers can conveniently use a matrix method to determine the best green strategy. Figure 3 shows the resulting 2 x 2 matrix, which characterises the relationship-product characteristics that influence the choice of green strategies. The horizontal axis shows product characteristics defined in terms of the level of innovation. Innovativeness, which can be defined in terms of the number of innovative changes per period, is used to position products on the horizontal axis. On the other hand, the vertical axis reflects the relationship or the level of collaboration in the supply chain of that product.

As outlined in the matrix analysis, there are four feasible generic green supply chain strategies. In cases where a product is functional and the relationship is collaborative, lean strategies, optimal resource usage and low waste can be adopted. In situations where players in the supply chain are collaborative and the level of innovation is high, closed-loop, product take-back, reverse logistics, and remanufacturing strategies are imperative. Where processes are highly innovative with low level of collaboration (coercive), innovation strategies such as green product design are appropriate. Finally, in a coercive supply chain environment with minimal inter-organisational engagement and functional product (process), compliance-centred strategies are adopted where concerned industry merely focuses on satisfying stakeholder regulatory requirements. An exact analysis using relationship-process characteristics is shown in Figure 4.

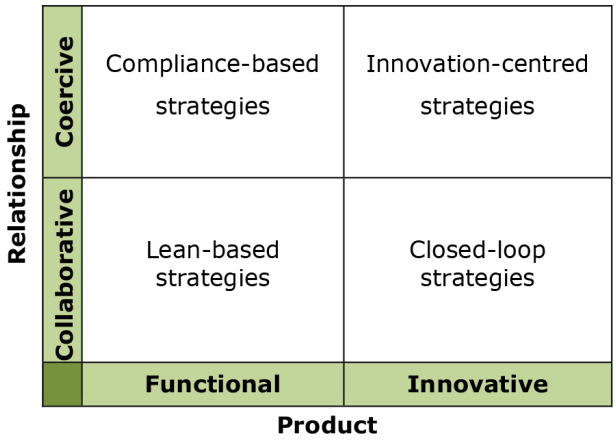


Figure 3. Relationship-Product characteristics and green strategies

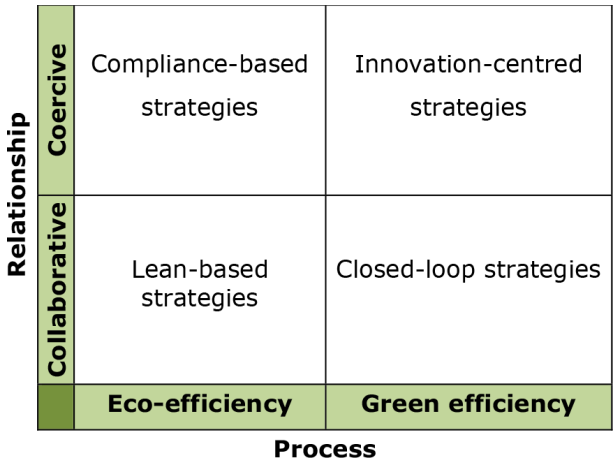


Figure 4. Relationship-Process characteristics and green strategies

Similar to the matrix analysis in Figure 3, Table 4 outlines the four suggested solution strategies emerging from the taxonomic framework. In the next section, we deliberate on the four generic green strategies as suggested by the matrix analysis.

| Relationship-product characteristics | Resulting green strategies |
|---|---|
| Coercive relationship + Functional product | Compliance strategies |
| Coercive relationship + Innovative product | Innovation strategies |
| Collaborative relationship + Functional product | Lean strategies |
| Collaborative relationship + Innovative product | Closed-loop strategies |

Table 4. Relationship-Product characteristics and resulting green strategies

### 4.1. Compliance-centred strategies

When inter-organisation engagement is minimal and the product and its processes are functional (standard), firms adopt compliant-based strategies merely in response to environmental regulations, stakeholder requirements, and customer pressure. In other words, the nature of supply chain relationship is rather coercive than collaborative. Companies considering the introduction of green strategies in their supply chains commonly adopt these strategies.

Compliance-based strategies include establishment of international standard systems such as ISO 14001 (King et al., 2005), use of performance standards, inclusion of purchasing contracts for suppliers to meet certain regulatory requirements. Similar to basic certification systems is the use of broad statements with purchasing principles or guidelines for suppliers. Most organisations such as DuPont, Wal-Mart and Seventh Generation introduced procurement requirements for compliant purchasing (Shang & Marlow, 2005; Plambeck, 2007). The advantages offered by compliance-centred strategies are as follows:

- Environmental performance benefits;
- Use of globally recognised systems, and;
- Third party management of performance.

These aspects in turn, improve recognition and acceptance not only by suppliers, but also by the market and stakeholders. Any ambiguity in regards to the desired performance is reduced significantly. The disadvantage of these strategies is that, because if their reactive approach, they offer limited competitive edge due to their lack of innovativeness, a lack of uniqueness, and ease of application by competing supply chains. Since these systems are managed in a low collaboration climate, they only guarantee compliance with regulatory requirements. As a result, additional benefits from innovation or economic efficiency are very unlikely.

### 4.2. Lean-based strategies

Lean strategies are a more recent group of green strategies whose focus is on eco-efficiency in which suppliers are required to satisfy certain operations-based efficiency targets. In addition, secondary environmental performance benefits may be obtained from some operations practices that provide green performance advantages. These strategies are ideal when the supply chain relationship is more collaborative and the process/product is still functional. A high level of inter-organisational collaboration, arising from the use of integrative inter-firm performance requirements, is necessary for situations with complex problems associated with waste reduction and recycling (Klassen & Vachon, 2003). The lean-based strategies link environmental performance with operational efficiency within the supply chain, allowing for the extension of performance requirements into the supply chain that maximises economic performance while enhancing environmental performance through waste reduction and optimized (minimal) resource usage. Wal-Mart introduced green strategies aimed at creating zero waste and selling of products that sustain Wal-Mart's resources and the environment (Plambeck, 2007).

The advantages of lean-based strategies are: (i) they offer eco-efficiency to the entire supply chain and (ii) they readily lend themselves to existing organisation goals of optimisation and cost reduction. On the other hand, lean-based strategies do not give room for advanced

environmental management initiatives such as green product design, innovation and material substitution. In so doing, the lean strategy is considered as technically weak.

### 4.3. Innovation-centred strategies

Innovation-centred strategies focus on developing specialised technologies, product designs, processes and strict green performance standards in order to keep up-to-date with changes in environmental regulations. The point of departure for the innovation-centred strategies from the lean-based strategies is the focus on more environmentally specific performance strategy. In other words, the main investment focus of the supply chain is in complex performance standards for suppliers, and specialised processes and technologies. Thus, the shift from lean to innovation-based strategies with higher levels of innovation and environmental performance requires specialised environmental resources and specialised personnel in order to keep abreast with changes in environmental legislative agreements (Lenox & King, 2004). At product level, resources are necessary for building environmental innovative designs into product design and development, product characteristics and functionalities. At process level, resources are necessary for building environmentally sound production systems and processes essential for innovative green production and distribution. Case examples in this category include Taiwanese information industries whose focus is mainly in product/process innovation and eco-design in order to comply with emerging environmental directives from regulatory bodies (Hu & Hsu, 2006; Ninlawan et al. 2010).

The advantage of innovation-based strategies is in their ability to offer competitive advantages in a fast-changing environment with ever-changing environmental legislation. However, keeping up-to-date with environmental legislation changes may offer huge challenges due to the need to shift to a collaborative inter-firm relationship. The level of information exchange and relational integration tends to be more complex. As environmental legislation continues to tighten, stakeholders in the supply chain may call for recovery of materials for re-manufacturing or reuse (Kocabasoglu, Prahinski & Klassen, 2007).

### 4.4. Closed-loop strategies

Closed loop strategies call for the highest level of inter-firm collaborative relationship over the whole supply chain, with appreciable levels of innovation. Companies adopting these strategies are able not only to keep abreast with complex requirements of the closed-loop supply chain but also to follow a pro-active approach through active and integrative relationships with suppliers from design phase to product take-back. "Closing the loop" involves the capture and recovery of materials for remanufacture and/or recycling (Vlachos et al. 2007). Recovered materials arise from returned, post-use, or end-of-life goods. Thus, closed loop strategies tend to integrate environmental performance to the entire supply chain. Supply chains that endeavour to implement closed-loop strategies certainly need high ability to control the reverse logistics of used materials. Well-known case examples falling in this category are

Hewlett Packard's return of printer cartridges, Kodak's take-back and remanufacture of its disposable cameras, and various auto industries' end-of-life vehicle requirements as collaboratively agreed among the supply chain players (Guide & Van Wassenhove, 2002).

One main advantage of closed loop strategies is in their endeavour to seamlessly integrate economic, operational and environmental performance. In this regard, closed loop supply chains tend to incorporate all the advantages offered by the three categories of strategies outlined above. The disadvantages of the closed-loop supply chain strategies include: (i) socially complex relationships, which involve complex processes such as product take-back, reverse logistics, reuse, recycling, or remanufacturing, (ii) the lack of readily available infrastructure for "closing the loop", and (iii) the general disbelief that its implementation can be economically viable.

## 5. Impact of green strategies on operations policies

The above study highlighted the fact that specific green strategies affect various aspects of supply chain operations, including the purchase of materials and energy, new process technologies, process control involving disposal operations as well as water and air pollution and the output of green and clean products. In retrospect, each strategy has specific impacts on purchasing, product technology, process technology, and logistics and transportation activities, as well as performance measurement systems. We outline the impact of these green strategies in the following sections.

### 5.1. Impact of compliance-centred strategy

Since the strategy calls for compliance with stakeholders' requirements, organisations tend to react to changes to regulatory requirements. As a result, purchasing policies should be focus on avoiding the use of hazardous materials through development of appropriate material selection criteria. Often, ad hoc solutions are introduced on production processes in a bid to adapt to new environmental requirements, which may be costly in the long term. Not many changes are expected in logistics and transport operations. Basic environmental performance standards such as ISO14000 and OHSAS18000 series standards are adequate for this strategy.

### 5.2. Impact of innovation-centred strategy on operations

In the innovation-centred strategy, managers should give special attention to developing strict performance standards for suppliers of materials and specialised process technologies. Procurement policies should be supported adequately with performance management systems that cater for stringent measures for procurement control. Specialised skills are essential for enhancing innovative product development in order to keep abreast with fast-changing environmental regulations. Investment into production process technologies may pose a great challenge in a dynamic innovative environment as managers seek to maintain their competitive

position in product and process innovation. Thus, the innovation-centred strategy requires huge investments in R&D and product and process technologies.

### 5.3. Impact of lean-based strategy on operations

Since the focus of the strategy is to minimise costs and waste, this may require a managerial paradigm shift from individualistic attitude to a more cooperative approach. The expected outcome is a developed ecological network that minimize waste, for instance, one supply chain player may utilize waste output from another player. Management may need to consider investing in new process technologies that minimize waste and improve on production efficiency.

### 5.4. Impact of closed-loop strategy on operations

Significant changes are highly expected regarding operations policies as the supply chain players seek to gain a competitive advantage. Procurement policies are supposed to be changed through collaborative relationships. Supply chain value partners have to collaborate in establishing research and development (R&D) projects that carry out product life-cycle analysis aimed at introducing new product and process technology innovations to contribute to the overall value creation. As far as production processes are concerned, organisations do not only seek to gain green efficiency from an ecological perspective, but also to take advantage of the green strategy to gain a competitive position. New green products that can be remanufactured or recycled are expected. As a result, management should pay attention to developing relationships between supply chain operations. As far as logistics is concerned, recycling and product take back initiatives are a priority. Therefore, logistics operations should be redesigned to suit such integrative relationships between players.

## 6. Conclusions

The development and application of the most appropriate green strategies and the insight of the implications of the chosen strategy is a challenge to most decision makers in GSCM. Supply chain managers should be able to identify the most appropriate green solution to meet various needs of different product-market characteristics. Moreover, the decision makers should find ways to evaluate the impact of potential supply chain strategies to the natural environment and the environmental performance change, apart from the economic advantages expected from the strategy. In this study, we have proposed a taxonomic approach to the selection of appropriate green supply chain strategies, based on a study of real-world case studies found in literature. The study identifies three key dimensions upon which our taxonomy is based, that is, *product*, *process*, and supply chain *relationship* or *collaboration*. Unlike previous taxonomies that focused on the nature of the product and its life cycle, this study suggests the use of relationship and process/product variability metrics. Our approach categorises green supply

chain strategies into compliance-based, eco-efficient, innovation-centred, and closed-loop strategies, proving case examples in each category.

This research offers a significant contribution to both academics and practitioners in green supply chain management. First, the study goes a long way in providing a practical tool or framework for managers when developing green supply chain strategies, given specific industrial contexts in which the strategies are to be applied. Second, the taxonomic framework offers managerial insight into the implications of the choice of specific strategies on the operations policies of the supply chain. Third, the study goes a long way in advancing the body of knowledge in GSCM.

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