

The Rise of Green Supply Chain Management: Between Complexity and Necessity

William Loivet, Atour Taghipour, and Dae Seok Kang

Abstract—From approximately 20 years ago, we have seen the emergence of a new concept called green supply chain. This phenomenon has spread to the whole world, including developed and developing countries and to all industries. The purpose of this paper is to trace the origins of this concept that has deeply changed the organizational structure of many companies. In addition, we will discuss different theories that have been used to analyze the implementation of green supply chain management. We will detail the characteristics of these theories by looking at the management of the supply chain. Finally, we will focus on the internal and external factors that can affect the implementation of green supply chain management and discuss the importance of performance.

Index Terms—Supply chain, green supply chain, complexity, management.

I. INTRODUCTION

The interest for green supply chain management has been growing for a few years. Both academia and industry are interested in this concept, which echoes the new environmental concerns that have emerged with, for example, global warming or the premature aging of our planet [1]. This concept is still relatively new and quite unknown. Therefore, there is still a void of literature dealing with the subject. However, some serious articles have been written and allow us to better understand the growing development of this phenomenon.

First of all, we have to go back to the history of green supply chain management. Its origin dates from the industrial revolution in the 19th century. Indeed, since this period and the development of the industry on a global scale, the management of industrial pollution has been a critical issue for society. Simultaneously, we also have seen the need to develop specific supplier and distribution channels in order to be competitive and to be able to stand out from the competition. Therefore, we have seen the birth of the supply chain management and new practices such as lean manufacturing or just in time emerged on the market. At that time, the priority was to improve efficiency and minimize waste, motivated more by economic than environmental reasons.

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At the beginning of the 20th century, debates for taxing companies that were polluting too much started to appear. Philosophical debates to know whether or not the natural environment deserved consideration began to emerge, but no real action was taken.

The importance of environmental issues became evident to the public thanks to a book written by Rachel Carson called *Silent Spring* (Houghton Mifflin Harcourt, 2002) criticizing the influence of the chemical industry on birds and humans. This book enabled to raise awareness of the potential danger of the industry on the environment. From this period, manufacturing and production operations have been seen as the main enemy to environmental protection. The processes of manufacturing were viewed responsible in harming the environment [2]. After the release of Carson's book, new regulations have been implemented and the U.S. Environmental Protection Agency has been created.

The 1980s marked as a turning point in collective awareness. It was during this period that new concepts such as the life cycle assessment have been used for the first time. In addition, the societies began to discuss the possible economic benefits to adopt practices that respect the environment. Gradually, environmental notions such as reverse logistics were integrated in all the stages of the supply chain. A fundamental shift has been brought in the way production systems operate and a move toward sustainability has been triggered.

Generally, we can define the concept of green supply chain management as integrating environmental concerns into the inter-organizational practices of supply chain management, including green purchasing, green manufacturing, green distribution / marketing and reverse logistics [3].

II. PRACTICES IN GREEN SUPPLY CHAIN MANAGEMENT

One common practice in green supply chain management is for firms to assess the environmental performance of their suppliers [4]. Indeed, companies have to check whether their suppliers undertake measures that ensure environmental quality of their products. They can also evaluate the cost of waste in their operating systems.

To be effective, these practices have to be extended to the entire supply chain, from suppliers to consumers [2]. Consequently, for instance, companies can inform their customers about ways to reduce their impact to the natural environment. So, they act as a guide for them selecting the best practices to increase the environmental performance.

The relationship between companies and their suppliers is very important. Firms can encourage suppliers to adopt and create innovative ideas that exploit new technologies [4]. In

doing so, they will be able to reduce costs during the design and development of their products which will benefit their customers. So the management of this relationship is essential for any company wishing to reduce their environmental impact during the product design.

We also note that firms are focusing more tightly on their core competencies and rely on their suppliers for the non-core activities in order to improve their efficiency and profits.

Several techniques exist to help managers assessing the environmental impact along supply chains. The life cycle assessment is used to define and evaluate the total environmental load associated with providing a service. Another example is product stewardship, which is a strategy seeks to ensure that actors of the supply chain take responsibility for reducing the negative impact to the economy and the environment.

III. DESIGNING THE GREEN SUPPLY CHAIN

The challenge here is to coexist the environmental protection with the industrial development. In the case of a green supply chain management, we will not discuss traditional supply chain, but rather about an extended supply chain. Consequently, the first step within this transition will be to redefine the basic structure of the entire supply chain. With an extended supply chain, the goal is to allow consideration of the total immediate and eventual environmental effects of all products and processes. Organizations have to integrate environmental objectives within their operational strategy to benefit from cost avoidance of purchasing hazardous materials as inputs; cost avoidance of storing, managing, and disposing process waste; cost avoidance of market resistance to environmentally harmful products; reduced environmental and health risks and from safer and cleaner factories [2]. So, it will be important to define the overall costs of the system. According to [5], in 2000 the U.S. Environmental Protection Agency provided four basic steps to implement a green supply chain which are:

- 1) *Identify costs*
- 2) *Determine opportunities*
- 3) *Calculate benefits*
- 4) *Decide, implement and monitor*

A fully integrated and extended supply chain includes product and packaging recycling, as well as the processes of re-use and remanufacturing operations [2]. Recycling can be defined as the process of waste minimization strategy in which reusable materials are recovered from a waste stream, and put to the original or different use. Re-use is the process of collecting used products and selling them as used. This is a very trendy model currently. While the process of remanufacturing aims at collecting a used product from the field and replacing worn, broken or obsolete parts with new or refurbished parts. Unlike recycling or re-use, remanufacturing does not degrade the overall value of the materials used and can even increase this value if the design of the replaced parts are improved.

Including all these processes adds complexity to supply chain design. In addition, new potential operational and strategic considerations need to be taken into account such as the uncertainty with the replacement process and the reverse distribution process itself.

The extension of the supply chain requires the establishment and implementation of new performance measurement systems. It exists a set of measures to determine the efficiency of the supply chain. This is often related to customer satisfaction or costs, but due to the complexity and particularities of an extended supply chain, some traditional measures are inadequate for the performance assessment. So firms can use for instance the existing norms such as ISO 14000 to identify the requirements for these measures. The principles established by ISO 14000 need to be followed for achieving the green supply chain. For instance, firms must develop procedures that focus on operational analysis, continuous improvement, measurement and objectives.

We can also evoke the ISO 14031 which provides management with key metrics for assessment of the performance [3]. These metrics relate to environmental conditions, operational performance and management performance. The central idea of this norm is the Plan-Do-Check-Act model for implementing a green supply chain management (Fig. 1).

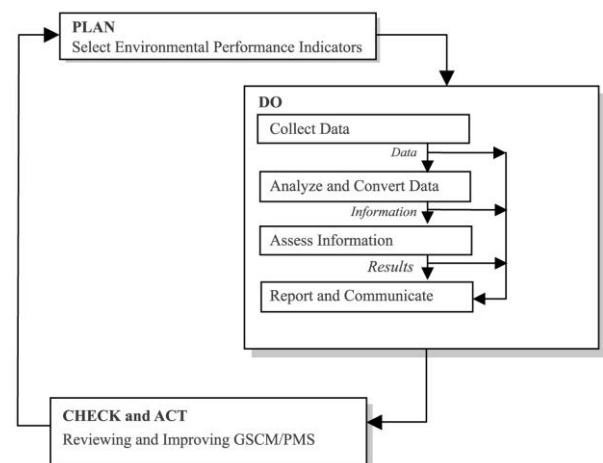


Fig. 1. Continuous improvement process in ISO 14031 guideline.

Now we are going to describe nine theories called organizational theories that have been utilized to investigate various issues related to green supply chain management.

IV. ORGANIZATIONAL THEORIES

An organizational theory is defined by different fields and disciplines such as psychology, sociology, or economics. It can be defined as a tool for management that can help explain or better understand organizational behaviors, designs and structures [1]. We have to keep in mind the fact that the implementation of these theories with a direct link to environmental management is still at an early stage.

A. Complexity Theory

Complexity theory argues that as complexity increases, companies find it more difficult to predict and plan their actions such as the implementation of a green supply chain

management for instance [1]. Consequently, the success key will be to maximize the interaction between the involved parties in order to enhance the transfer of information and reduce uncertainties. It is also essential for firms being sensitive and responsive to their environment. Managing a supply chain by nature is difficult due to the numerous actors involved. And this complexity can increase as the organization increases in size. And other elements such as environmental, economic or political factor can exacerbate these complexities for implementing a “green strategy”. It is, therefore, essential for all companies to understand these complexities in order to be able to better manage their supply chain.

B. Ecological Modernization

An ecological modernization strategy aims at achieving industrial development through innovation and technological development. This theory is often used to explain environmental actions taken by government and the restructuring of production by major manufacturers. Companies can overcome barriers to innovation by using technological innovation, which will lead to operational opportunities for performance improvement [1]. This is one of the key benefits for using ecological modernization. The action of government is, therefore, very important to motivate companies to implement green supply chain management practices.

C. Information Theory

Information theory aims at reducing information asymmetry by increasing communication and interaction between the involved parties [1]. The sharing of information is a critical factor for coordinating a supply chain and implementing a green strategy. Everyone has to know the actions of each other, and the regulations in terms of environment to be able to work effectively and not make mistakes. If each actor communicate effectively, the likelihood for high information asymmetry will be lessened. Another theory called signaling theory has been developed to mitigate information asymmetry through different mechanisms to favor the transfer of information.

D. Institutional Theory

An institutional theory looks at how external pressures can influence a firm to adopt an organizational practice [1]. Pressures can come from those in power. For example, the government can influence companies to adopt green initiatives through fines, taxes and trade barriers. However, sometimes firms decide to engage in a “green shifting” to imitate the actions of successful competitors in the industry.

The market and consumers can also be a source of pressure since now, studies have shown an increasing awareness of the importance of the environmental impact on the purchasing process. Indeed, they have developed an ethical thinking and consider ethical values as very important. They are ready to pay more if the product respects the environment (“eco-conscious consumers”).

E. Resource Based View Theory

This theory argues that a competitive advantage may be sustained for a firm by exploiting in priority resources that

are valuable, rare, imperfectly imitable and non-substitutable [1]. A resource can be defined as an economic or productive factor required to accomplish an activity, or as a means to undertake an enterprise and achieve desired outcomes. Resources enable a firm to implement specific strategies. For example, having the knowledge and capabilities to engage in the process of greening a supply chain is considered a precious resource. This knowledge is essential for the success of an implementation of an environmentally oriented reverse logistics. Moreover, inter-organizational relationships and learning can enhance the resources of an organization.

F. Resource Dependence Theory

According to this theory, members of a supply chain should be dependent and work together in order to seek higher performance gains in the long run. The long-term perspective is the main element of this model. Firms need to have links to outside parties in order to get access to resources because they cannot be fully self-sufficient [1]. And they have to manage this dependency to remain competitive on a long-term perspective. The quality of this interdependency will determine the success of the implementation of a green supply chain management.

G. Social Network Theory

This theory emphasizes the importance and influence of social network and information on the decision making process for companies [1]. We distinguish two major elements: density and centrality. Density refers to the number of ties in the network that link parties together. Centrality refers to the position of an individual organization in the social network and its ability to control the flow of information. A direct relationship can be made between these two elements. Indeed, when density increases, the ability to resist external pressure from members decreases and as network centrality increases, the ability to resist external pressure increases. So, a social network is multidimensional network, because companies that cooperate with customers also have links with their suppliers.

H. Stakeholder Theory

A stakeholder is defined as a person, group or organization that has an interest or concern in an organization [1]. This theory describes the fact that companies produce externalities that affect stakeholders (internally and externally). Due to these externalities, stakeholders increase pressures on companies to reduce the negative impacts and increases positive ones. Therefore, stakeholders can force companies to adopt measures that will improve the environment for instance.

I. Transaction Cost Economics Theory

This theory explains how much effort and cost is required for the buyer and seller to complete an activity [1]. Consequently, this theory refers to transaction costs and can be easily implemented to the green supply chain management.

All these theories are useful to learn about issues related to green supply chain management. But we have to keep in mind the fact that some questions related to these theories are remaining and we still need to be better informed to assess

the efficiency of these theories.

Other theories exist and help us to better understand the green supply chain management. We can quote the innovation theory which argues that the adoption of innovations is, most likely, for firms facing pressures for greening their supply chain. The path dependency theory says that the implementation of green supply chain management can improve the results of a company if adopters are more and more numerous. Structuration theory focuses on the links and driving forces to implement a greening strategy and agency theory focuses on the costs from conflicts of interests between managers and stakeholders.

After having looked different theories to understand the implementation of green supply chain management practices, we will now detail this concept and give some details applied to the industry.

V. A GREEN SUPPLY CHAIN: CHARACTERISTICS, BENEFITS AND CRITICS

A. The Ecological Footprint

The ecological footprint is an important factor to assess the environmental damage of any businesses [6]. This concept is defined as the amount of land required to meet a typical consumer's needs. Companies can assess their ecological footprint as well as countries. Several indicators can be used to measure the ecological footprint. For instance, packaging cannot only be evaluated based on packaging material used, but also by the amount of air or useless space in the package. The volume selected for recycling the re-use supply chain is also an important factor.

And greening supply chain can be considered as something to improve the ecological footprint. Problems related to the environment are gaining increasing importance within companies as well as environmental management. Once again, literature about the topic is limited. But, despite that, we can affirm that using reversed logistics alone is not enough for the transformation into a green supply chain. Reversed logistics is the process of dealing with goods that have been returned to the company by customers. This is also a new phenomenon that is fully in line with this ecological transformation.

B. The Benefits of Investing in Greening Supply Chain

Some researchers such as [7] argue that investing in greening can be beneficial for companies. Indeed, through these investments, greening can result in resource saving, waste eliminating and productivity improving. Consequently, by implementing a green supply chain, businesses can lower their environmental impact but also raise efficiency and can create a real competitive advantage in innovation and operations. Therefore, this can be a useful tool to stand out from the competition. Indeed, greening can be used as a unique selling point with environmentally conscious customers for example.

Thus, we see an increasing number of firms implementing this green shifting. Environmental activities become part of their strategy and they operate strategically with the aim to

reduce the impact on the environment. This is a day-to-day process with a long-term perspective. Also, firms adopt a resource-productivity framework to maximize benefits attained from environmental programs. Greening a supply chain requires much effort and investments, but is worth to be done according to experts. All the actors of the supply chain (from supplier to retailer) must be engaged in this program and play an important role.

C. The Concept of Environmental Management Systems

An environmental management system is a system which gathers a collection of policies, assessments, plans and implementation actions which affect the entire organization and its relationships with the natural environment. Clearly explained, it is a system of management processes that enable organizations to continually reduce their impact to the natural environment [4]. Consequently, this is directly linked with the establishment of environmental policies. One purpose of an EMSs is to help companies integrate environmental practices within their operational frameworks to become part of their overall business strategy. This mechanism is useful to improve environmental and business performance.

Once a company implements an EMSs strategy, it has the possibility to ask for the ISO 14001 certification standard. This is a very famous certification, active on a worldwide scale that reflects the engagement in a green process for a company. The objectives are numerous such as encouraging an internationally common approach to environmental management, strengthening abilities for companies to improve and measure environmental performance etc. This demanding standard implies many actions. For instance, a company must identify a polluting process that is continually improved over time. An analysis of the environmental impact of all new activities, products and processes has to be done every time, special procedures need to be followed in the event of non-compliance with established environmental policies and many other rules have to be followed. Having an ISO 14001 certification enables firms to improve their corporate image and can increase profits. But, despite these advantages, EMSs are sometimes criticized.

D. Critics of EMSs

The implementation of an EMSs asks a question of legitimacy [4]. Indeed, some experts argue that some organizations affirm having an EMSs strategy just for their own reputation while in reality, this is not the case. And it is very difficult for stakeholders to measure the improvements in terms of environmental performance. Also, they say that improvements are likely to occur within the organization's operational boundaries rather than being extended throughout the entire supply chain. But, if a green strategy wants to be successful, it is essential that it be extended to the entire supply chain including all actors. In addition, we know very little whether the adopters of this strategy promote green supply chain management practices.

So consequently, we are still questioning about the real effectiveness of EMSs on the environmental level. However, in practice, EMSs encourage firms to increase their environmental consideration and is a tool that may facilitate the implementation of green supply chain management.

E. EMS Adoption and GSCM practices: 2 Entities Working Well Together

EMS and GSCM are two complementary systems. When they are implemented together, they offer the possibility to better understand the means of defining and establishing sustainability among networks of business organizations. And we remark that when an EMS is implemented without a GSCM, environmental benefits are lower. The association of both practices is a key for sustainability [4]. But, the implementation of these systems requires numerous capabilities. For instance, an EMS strategy requires for an organization to encourage its employees to work together and sharing their knowledge between each other. With an EMS, companies have to rely on lean production practices, etc. And skills required to adopt GSCM are complementary because both systems encourage enterprises to reduce input use and decrease waste during their production process.

As a result, firms that decide to adopt EMS have a greater capability to implement GSCM practices because they know how to manage the environmental impact of their supply chain. Indeed, employees are trained to improve organization's environmental management and they systematically evaluate and share knowledge about the organization's environmental impact.

Collaboration between parties is once again vital to maintain sustainable GSCM practices. One effective way of increasing collaboration between the parties is to create product design teams with people from different internal departments working together and discussing environmental issues facing product design.

So both systems can be considered indivisible if firms want to implement an effective green strategy. A study has shown that EMS adopters are more likely to impose indirect control mechanisms on suppliers and are more likely to improve the environmental sustainability of their organization.

In order to develop the use of green practices, governments could for instance, offer incentives to organizations that have already adopted EMSs and vice versa. Benefits are important for companies and the future of our planet is at stake.

F. External Pressures

Institutional pressures can encourage the adoption of both EMS and GSCM practices [2]. One of the key arguments used by these institutions is to say that it will increase the legitimization of the business. We can also talk about regulatory pressures that can use penalties, fines and even extortion to force firms adopting green practices [3]. Market pressures also need to be considered. As explained before, we observe an increasing awareness of the importance of environmental concerns to the customers. In 1999 in the USA, 75 % of consumers claimed that their purchasing decisions were influenced by a company's environmental reputation and 80 % were willing to pay more for environmental friendly goods. And these figures did not stop to increase. Environmental concerns are now a real preoccupation for consumers. Prices are no longer the major determinant of purchase. Consequently, this phenomenon influences firms to adopt EMSs and rely on GSCM practices. This adoption enables firms to develop an environmentally conscious

reputation and can be considered a competitive advantage over the competition. Finally, the pressures from the community need to be taken into account due to their increasing influence [4]. We can quote, for instance environmental groups, the media, labor unions, etc.

VI. THE STUDY OF DRIVERS AFFECTING THE IMPLEMENTATION OF GREEN SUPPLY CHAIN MANAGEMENT

We can identify critical factors for implementing GSCM practices. For instance, in 2001, Trowbridge distinguished between internal and external factors [5]. Internal drivers refer to the willingness to improve risk management due to potential interruptions in the supply chain and focus on the collaboration with suppliers to find alternative materials and equipment that minimize environmental impacts. While external drivers include customers, investors and non-governmental organizations that can influence the organization's decisions. Walker et al. ([8]) identified in 2008 internal barriers such as cost and lack of legitimacy as well as external barriers such as regulation, poor supplier commitment and industry specific barriers.

Wee and Quazi ([9]) determined critical factors for the success of environmental management like top management commitment, training of all actors of the supply chain, supplier management, measurement, information management, etc. All these recommendations need to be respected for an effective green strategy.

Other researchers such as Reinhardt ([10]) defended the idea that the environmental quality could only be ensured through governmental regulation given the fact that environment is a public good. So law often directs the need for green practices.

In addition, we have to keep in mind that the implementation of GSCM practices in different industries is not uniform. Each industry has its own particularities that need to be taken into account before adopting a green strategy.

Therefore, the implementation of GSCM is not an easy task and is made even more difficult by external and internal pressures. Drivers affect the implementation of GSCM practices and adopters must be aware of these drivers and the techniques for implementing them (example of the requirements from ISO 14000). Also, government through legislation and reverse logistics are important drivers to achieve the collaboration between product designers and suppliers to improve the environmental impact during the production process.

To conclude this paper, we are going to discuss about the importance of performance measurement for GSCM.

VII. PERFORMANCE MEASUREMENT FOR GSCM

Performance measurement of a green supply chain is definitely challenging given the fact that it is difficult to attribute performance results to one particular entity within the chain. We notice a lack of systems to measure performance due to multidimensional reasons, including non-standardized data, cultural differences, etc. But, the

measure of performance is vital to assess the effectiveness of a strategy [3].

The purposes of performance measurement are external reporting (economic rent), internal control to manage the business better and internal analysis to implement continuous improvement strategies.

It will be important to examine the performance of supply chain. In fact, all actors of the supply chain have to be assessed and especially suppliers. But, each company is different and can be members of multiple supply chains simultaneously. Consequently, the performance measurement system will have to be unique for each individual organization. At the same time, the system of performance measurement has to be used for planning, implementing and monitoring proposed systems. It is, therefore, a strategical tool.

A condition of success for performance measurement of a green supply chain is an organization-wide coordination. Each metric measured must take a supply chain perspective and each entity constituting the supply chain must be measured and improved with a common objective. But, performance measurement systems must face internal issues, which are mainly cost and profit driven. There are many internal controls, which include data management systems, total quality management or industry specific standards such as ISO 14000.

The internal resource base and procedures of firms will affect their capacity to respond to internal and external changes. And sometimes, companies do not adopt any environmental innovation due to their limited financial resources or their type of organizational structure. Nevertheless, for firms that have the capacity to implement these innovations, they can benefit from economic and environmental gains. But, having the resource is not enough for effectively implement these strategies. Indeed, they also need to have a knowledge about product, material and process characteristics and available technologies and markets.

Companies must also face external pressures that complicate the implementation of performance measurement. We can quote pressures that can be either from regulatory or from the market. And the ability to respond to these pressures will depend on the size of the business, but also on the type of industry the company is in. At the same time, other external pressures such as environmental compliance or liability exist.

Despite these issues, monitoring supply chain environmental performance may add a competitive advantage over the competition by showing to the final customers and stakeholders their continuous improvement of performance and how well they are performing in their greening process. Metrics such as product modifications, pollution prevention opportunity audits, total fuel use or participatory management can be used to assess the environmental performance of companies. These indicators have implications for all levels of management from strategic to operational planning. But, today the major difficulty is to determine which one to use, when to measure them and how to measure them.

To overcome pressures, top management must provide financial and strategic support for environmental

performance measurement and be aware that the types of support may vary along the implementation life cycle.

In order to effectively implement the system of measurement, human resource personnel must be involved in training and data acquisition. The teamwork is essential for the success of GSCM and performance measurement.

Once completed, the results from the measurement may serve numerous purposes such as external communications, internal improvements and regulatory compliance. It is important for companies to communicate about their result in order to improve their reputation on a local, regional or worldwide scale. It also has to be communicated internally to improve, for example waste elimination, recovery or recycling. The objective here is to go always further in the greening process.

VIII. CONCLUSION

Green supply chain management gains increasing interest over the last few years. This is the result of a collective awareness of the impact of the industry on the environment. Consequently, firms willing to adopt a green process have had to adapt their strategy and have implemented an extended supply chain taking into account the environmental concerns. This supply chain, more complex than the traditional one has to involve all actors being effective and beneficial for the company as well as for the society. Greening is a collective process that has a long-term perspective. An effective greening strategy will be beneficial for companies as it will enable them to save money, to reduce the environmental impact and consequently will improve their reputation vis a vis the customers. Another advantage is that using the greening process will improve the health of population due to the ecological actions respecting the environment implemented by firms. But, green supply chain management is still a recent concept. It is therefore difficult to measure. However, some organizations have developed standards to help companies assessing their strategy.

We all know the importance of acting today to save our planet. As a result, we can affirm that green supply chain management will continue to increase and spread over the business environment in the coming years.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

In this research W. Loivet conducted the research; A. Taghipour and DS Kang supervised the research. All authors had approved the final version.

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