

A BOUNDARIES AND FLOWS
PERSPECTIVE OF GREEN
SUPPLY CHAIN MANAGEMENT

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A Boundaries and Flows Perspective of Green Supply Chain Management

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Abstract: Recent years have seen a growth in research related to the environmental and social concerns associated with industrial supply chains. In this paper we provide a boundaries and flows framework to further understand the direction and relationship of research in this emergent and interdisciplinary field. Greening supply chains has become a necessity as environmental concerns have remained at the forefront of the debate of global and local social interests. We describe the relationship between the green supply chain function and other industrial environmental philosophies and practices. Using a generic systems perspective, we identify nine non-exclusive, interrelated boundaries and five flows of resources related to green supply chains. Relatively current published research literature focusing on various aspects of these boundaries and flows is used to describe accompanying issues. Some general arenas for investigation are also introduced.

Keywords: environmental supply chain management, business and environment, life cycle analysis, environment, supply chain

Introduction

Environmental issues within corporate organizational boundaries have been a concern for decades. These issues have ranged from reactive concerns to legislation and regulatory pressures to more proactive concerns that include building organizational competitive advantage and developing a strong corporate environmental image. Greater importance of inter-organizational relationships has caused organizations to consider building competitive advantage by management of their supplier and customer partnerships and networks. This evolution in management and business focus resulted in development of the supply chain and supply management fields. Even though management of resources and distribution channels has been under scientific management study since the early days of commerce and business research and investigation, supply chain topics which include integration and management of the material, information, human, and capital resources across organizational boundaries is a relatively recent area of investigation. Much of the early research in general supply chain management was deconstructive in the sense that specific management and business functions and fields investigated portions of the supply chain. Supply chain management sought to integrate marketing customer relationship and distribution management, logistics and materials management, purchasing and procurement, as well as standard production and operations management areas. As this field grew, so did the scope of the topic.

The integration of environmental concerns within supply chain management has itself evolved into a separate and growing field. There have been hundreds of papers that have helped this sub-field progress over the past couple of decades. Within the operations and supply chain management fields, there have been a number of journals introducing special issues related to green supply chain management topics, which also have been called sustainable supply chains [1-4]. As the field has matured, reviews of the literature (of which this paper is an example) have also started to appear, e.g. [5, 6]. Theory and more complete understanding for this inchoate discipline are currently evolving.

The terminology for the green supply chain management concept (and its many elements) has had many variations over the years and a comprehensive list includes some of the following terms:

- sustainable supply network management [7, 8];
- supply and demand sustainability or corporate social responsibility networks [8, 9]
- supply chain environmental management [10, 11];
- green purchasing [12] and procurement [13];
- environmental purchasing [14, 15]
- green logistics [16] and environmental logistics [17]
- sustainable supply chains [4]

To help further the field of green supply chain management we provide a framework to help appreciate the relationships of the various research streams and topics in this field. The recent literature on this topic is not presented in a typology, typical of literature reviews, but is incorporated into a comprehensive systems-based framework. This framework utilizes the boundaries and flows of a system to help understand the issues facing green supply chains and how the literature has addressed these issues.

Systems typically have five elements including inputs, outputs, transformations, controls and feedback. Another characteristic of systems is that they can be disaggregated into subsystems or aggregated into suprasystems. Thus, we have many levels of systems which can be defined by their boundaries and also various flows and management of these flows through systems as defined by the various elements.

We first provide a brief overview of green supply chain management and its various elements from an organization's perspective. The discussion of the recent green supply chain management literature will touch upon three organizing frameworks. We first relate some of the literature and concepts of green supply chain management with other corporate and industrial environmental practices and philosophies. We then present some major boundary categories that can be used to evaluate and manage green supply chains and how the literature has discussed these boundary issues. Our review then shifts focus to various related flows that need to be managed by and within green supply chains and how the academic literature has introduced these flows into investigation and discussion of green supply chain management. Building on the issues identified in previous sections we provide a emergent and outstanding issues in this field that still may be fertile areas for further development and investigation.

Green Supply Chain Elements

The supply chain can be described from at least four flows and relationships perspectives, upstream, downstream and internal organizational activities. Figure 1 provides an overview of the various stages, relationships and flows in a supply chain with an organizational unit at its center.

Figure 1 about here

Upstream activities, flows and relationships would include purchasing and procurement topics. Included amongst these topics might be outsourcing, vendor auditing, management and selection, supplier collaboration and supplier development. The many activities that focus on upstream supply chain management would be encompassed with the traditional purchasing discipline. Each of these activities can be expanded to have greening components. For upstream dimensions of the supply chain, as with activities throughout the other supply chain dimensions, include activities related transportation and materials movement. Designing the supplier network with its in-bound logistics may include strategic considerations. Managing more than one tier in the supply chain would be part of network design and optimization issues.

Internal organizational supply chain activities are generally related to the traditional production and operations management topics of an organization. Managing the flows, relationships and resources inside the boundaries of a stand-alone unit or organization, the enterprise, is the scope of this dimension. Such activities may include research and design, quality, inventory, materials, and technology management within an organization could each influence environmental characteristics of internal organizational processes. These processes could be defined from either a services and manufacturing perspective that would need to be managed. This portion of the supply chain, under the purview of a specifically defined organization or unit, utilizes and transforms the various upstream flows. As we shall see in our later discussion on boundaries, the definition of an internal organization may not always be clear.

The next juncture of a supply chain focuses upon the outbound and downstream relationships and flows. Activities and functions here may include outbound logistics and transportation, marketing, distribution, packaging, and warehousing. The flows are utilized by downstream customers who may be commercial or individual consumers. Some of the greatest pressure for improving environmental performance does flow down the supply chain. Thus, organizations need to be available to complete similar supply chain management programs that they would require of their suppliers.

With the ‘closing of the supply chain loop’ supply chain activities have been extended to include reverse supply chains as well. The idea of closing the loop is that end-of-life materials will eventually be consumed back into the system with recycling, remanufacturing, reclamation, and reverse logistics all part of this concept. Even though the environmental implications of closing the loop are obvious, much of the research in this area has been parlaying the economic and business benefits associated with the concept of closing the loop [18]. The closed-loop relationships here may be direct between the organization, its suppliers and its customers, or internal loops between suppliers, customers and within the organization.

Relationships to Other Corporate Environmental Practices and Philosophies

Green supply chain management did not evolve alone. There are many corporate and industrial environmental philosophies and practices that are closely linked to and support green supply chain management that have also been a focus of significant research, practice, and application. As summarized in Figure 2, environmental management systems (EMS), life cycle analysis (LCA), industrial ecology and symbiosis, product stewardship and extended producer responsibility, and design for the environment (DFE) or ecodesign, are all areas of study that may be closely linked to green supply chain management [19]. We shall identify some of these relationships in this section with literature that has investigated some of these linkages.

Figure 2 about here

EMS is closely aligned as a complement to green supply chain management. EMS adopters are engaging their supply chains by instituting procedures to assess their

suppliers' environmental influences, requiring suppliers to minimize their environmental impacts, tracking waste in their operating systems, adopting their own EMS, and informing buyers of ways to minimize their environmental impact [20, 21].

LCA alignment to green supply chain management is improvement, relationships, and informationally related to the management of products and materials and their sources and impacts throughout a product's life cycle [22]. Knowing the source and impact information of materials and processes for an LCA requires knowledge of the supply chain's materials, products and processes and vice versa. LCA is valuable for optimizing closed-loop supply chains, improving eco-design and product stewardship initiatives which are also linked to green supply chain management [23].

The industrial ecology concept is also pertinent topic relating to green supply chain management. Within industrial ecology the concept of industrial symbiosis, or eco-industrial parks, is a prime example. Within industrial symbiosis the output waste and material flows of one organization used as valuable and productive input of another organization [24, 25]. In a typical organization finding suppliers and customers of these materials is under the purview of supply chain management professionals. To make an effective industrial symbiosis relationship, green supply chain management is a prerequisite [26, 27]. Within industrial symbiosis the goal is to make waste flows into value adding flows of material, energy and other productive resources.

Product stewardship is the management of a product throughout its life cycle including its distribution, usage and disposal typically associated with extended producer responsibility [28]. Even though product stewardship has been variously defined ranging from environmental to general liability issues management, the role of the supply chain is also clear. Product stewardship requires that an organization manage its products and involve members of its supply chain [29].

Eco-design and DFE are related also to involvement of suppliers. It requires an understanding of the sources, destinations, capabilities, and characteristics of the product or service. Collaboration and involvement of suppliers in the eco-design process is an important dimension of a complete DFE program within organizations [30-33].

Green Supply Chains: a Boundaries Perspective

Supply chains consist of and span many boundaries. To effectively manage the environmental aspects of supply chains, policy makers, organizations, and managers need to understand various reaches of supply chains and their environmental implications over these boundaries. Clear boundary definition is a necessary initial step for organizations who wish to manage their supply chains and may help identify their spheres of influence, concern, constraints and control [34]. Numerous boundaries exist and could be determined. Systemically, every boundary can be presented at many levels (layers) of analysis. Figure 3 shows multiple levels of boundaries ranging from individual (sub-micro) to global cross-industry supply chain (supra-macro) boundaries. Boundary determination is important for identifying scope of study for researchers and management

control for practitioners. We present the implications and examples of relationships of these boundaries to green supply chain management research and publication. In this paper we introduce nine forms of interrelated boundaries: organizational, proximal, political, informational, temporal, legal, cultural, economic and technological.

Organizational boundaries

Departments, business units, functional areas, corporate entities, supply chain memberships are all aspects of organizational boundaries. Not only are these organizational boundary units, but also of the organization level that is in charge of management control is also an important issue. Executive, strategic, versus lower level management, operational levels of control is one aspect of level. Another aspect is whether there is centralized or decentralized control of the supply chain. This boundary also relates to level of management and scope of control of management. In supply chain management the organizational boundary internally may be limiting the possibilities of greening the supply chain due to lack of cross-functional relationships [35-37]. From a level of management control perspective there are also implications for greening supply chains. For example, if it is a one-to-one individual (operational level) commodity relationship, the possibilities of greening a supply chain may be severely limiting. These non-strategic lower level relationships would only have minimal requirements in an environmental supply chain program, such as a basic requirement of ISO 14000 certification to 'prove' greenness [38].

Proximal Boundaries

These boundaries include determination of physical and geographical location considerations and dimensions that need to be considered in green supply chain management research and management. Physical distance represents one of the dimensions on whether the evaluation should be local, regional, or global. The geographical and physical boundaries may also be determined by the feasibility to actually monitor, control, and overall manage the supply chain over these distances. Facility location and partnership development will be influenced by the geographical constraints associated with managing transportation environmental influences [39]. To be able to control suppliers it is usually much easier to manage those that are in close proximity. Decisions such as locating suppliers within the organizational facilities through programs such as vendor managed inventory will have environmental implications [40]. With vendor managed inventory suppliers are physically located at the organizational facility. There are implications ranging from easier supplier involvement in eco-design efforts to liability concerns with suppliers possibly managing hazardous materials on-site. The influence of just-in-time (JIT) delivery and management philosophies are also on the environment can be associated to physical distance and geographical factors. The influence of JIT practices has shown variations in environmental implications, sometimes with improved, sometimes with worse influence [41]. These impacts can be partially explained through physical location distances between buyer-and supplier.

Political Boundaries

Institutional rules and regulations differ across various political boundaries. Sometimes the supply chain and its environmental sustainability may be influenced and limited by political boundaries which could be at national, regional, local or varying governmental levels. Country level analyses characteristics that utilize political boundaries have shown that the relationships between country level supply chain strength and environmental performance are highly related [42]. Although, the cross-country evaluation of environmental supply chain practices is still relatively rare with some exceptions [42, 43]. Many times these comparisons are focused on the legislative and regulatory differences that exist. The various policy and regulatory regimes across countries may serve as either barriers or enablers to greening the supply chain with such policies as requiring green purchasing by government and public agencies [44]. Supply chains may also be used to effectively incorporate environmental practices regions with varying policies (diffusion of innovation) or in an opposite direction reduce environmental concern due to these policies (pollution havens). Studies have shown that even over great political distances organizations can control their supply chains such that a 'leveling affect' may occur instead of a 'race to the bottom' result from the pollution haven hypothesis [45, 46].

Informational Boundaries

Sometimes there are limits to the availability of information and also on the proprietary aspects (security, competitive advantage, etc.) aspects of information. Virtual boundaries may exist into the sharing of information, but also there are issues of the actual availability of information, where no easily available information may exist after a certain point in the supply chain. This boundary of information availability has been even been more difficult within the supply chains as the dynamics of new information increases [47]. Informational dynamics arises from new product and materials development, new process introduction, and regulatory changes, to name a few. Organizations need to not only be aware of environmental implications of their processes and operations but also their supplier processes and operations. Continuous new information is required. Much of this environmental information is based on LCA tools and similar data development and monitoring. Even though dynamic temporal considerations, which are discussed as the next boundary, are usually not included in LCA information [48]. Sometimes information boundaries are artificially and purposively developed. Supplier firms may find it advantageous not to fully provide information to their buyers for competitive reasons. Sometimes suppliers find that information asymmetry may provide them advantages and thus may not be willing to share environmental information [49]. Sometimes other distances and boundaries, such as physical and cultural barriers and boundaries increase environmental information asymmetry[50].

Knowledge and learning management activities are also critical in determining, defining, and expanding informational boundaries. Collaborative supply chains are noted for knowledge-sharing activities, such as workshops and seminars which can help in supplier training efforts in environmental issues [51]. Lack of knowledge, and

information, sharing between upstream and downstream partners has been acknowledged as major impediments to adoption of practices and technology [52].

Temporal boundaries

Organizational environmental responsibility for a product, material, by-product or waste that flows through and from a system may be defined by time boundaries. Whether the dimension of time is short (minutes, days) or longer (years, decades, centuries) it will influence environmental supply chain management. The issue with time boundaries is that they may go in more than one dimension and level. Environmental risks and impacts may not only be associated with future actions, but also with past actions (for example, potential superfund liabilities) and organizations and supply chains need to be cognizant of this spectrum. In terms of levels of boundaries these actions and impacts may be short term (fleeting) or long term this timing impact characteristic is valuable for managing product the supply chain [53]. Within management the temporal dimension also relates to the level of organizational analysis (and boundaries) that may be required. Short-term time impacts and planning of environmental supply chain are typically associated with operational organizational management, while long-term impacts and planning are typically associated with strategic organizational management [54, 55]. Another important aspect of short-term versus long-term management issues within environmental supply chain management include length of collaboration, relationships and contracting between partners [56-58]. Supply chain relationships that focus on the short term would typically have lower levels of management scrutiny. Longer, strategic partnerships will require significantly greater management and concern for supply chain managers as upper level managers become more involved in the decision making process.

Legal Boundaries

Legal boundaries set the stage for a ‘deep pockets’ situation. A basic question asked of the supply chain is at what point are we no longer liable for the product or material in the supply chain and its consequences? Also related to this boundary may be a ‘moral’ or ‘ethical’ boundary. At what point in the supply chain is an organization no longer responsible from a legal, ethical, moral values perspective? As a legal example, Superfund regulations require that potentially responsible parties be determined and this determination will also focus on the supply chain. In fact, this law even allows for partner firms in the supply chain to form indemnification agreements shifting responsibility [59]. From a moral and ethical boundary perspective, the depth of the supply chain influences should also be defined. Some would argue that companies such as WalMart are morally responsible for ocean biodiversity because they purchase seafood from distributors who purchase from fish farms that practice unsustainable fisheries. Yet, a smaller company, whose resources are limited and markets extensive may not be considered morally responsible in this supply chain. To help address such issues, the use of information and supply chain practices may help further define the moral and legal boundaries of supply chain decisions. The practice of sending out environmental supplier evaluation forms, and then storing this data within the organization, may develop into a ritualized practice that guards against ‘moral liabilities’ emanating from the supply chain [60]. Even though

significant environmental liability and reputational risks affecting legal and moral boundaries that occur in the supply chain, these boundary dimensions have been sparsely investigated. Alternatively, the legal boundary is purposively limited by some organizations who may not wish to expand any boundaries that extend the legal boundaries associated with the environment. That is, some companies worry about assuming legal liability for their suppliers' environmental problems, and would rather not be aware of suppliers' environmental situations to limit their liability [40].

Cultural Boundaries

Cultural boundaries that determine the type of management capabilities and control existing may also be based on social and cultural dimensions. A simple example of this type of boundary may be related to communication, and more specifically language, barriers with suppliers. There may be issues of trust, acceptance, and numerous other cultural differences that may cause these boundaries to exist within a supply chain. These cultural differences may be at the international level [43], or at individual, group, and organizational levels [61]. The boundaries of the supply chain analysis and management control may expand or contract depending on whether cultural barriers exist. For example, organizational cultures that are non-egalitarian and focused on economic bottom-line issues, may not be included into the environmental analysis of the supply chain due to a non-receptive corporate culture. Cross-cultural research may provide some insight into the way supply chains function in multicultural situations [62].

A significant element of the cultural boundaries dimension is values, norms, and mores sharing. These cultural boundaries also occur at varying scopes. For example, individual belief systems, whether they are upper management or shop-floor employee, play a significant role in greening organizations and their supply chains [63, 64]. Understanding internal organizational individual beliefs is important for managing the green supply chain, but with green consumerism and marketing playing a large role the behaviors and beliefs of individual consumers also plays an important role as an external stakeholder driver [65].

One aspect of management of the cultural beliefs and ethics in global supply chains are standardization efforts on environmental and ethical beliefs and practices [66]. The existence of international standards such as ISO 14000 and ISO 26000, for example, may require subsidiaries and partners to follow expected social and environmental practices [67]. It is expected that these practices will extend cultural boundaries where conflicts can be mitigated through these standards. Care should be taken, since ethical issues related to imposing value (environmental or social) standards on other cultures do arise, whether it is through standards or coercive supply chain pressures [66].

Economic Boundaries

Economic boundaries are exemplified through fiduciary and financial responsibilities of the entity. A basic question with this boundary is at what point it no longer becomes economically feasible for an organization to manage the supply chain in

an environmentally responsible way. This issue relates to financial flows within the supply chain as well. Regulatory boundaries may also play a role in the economic boundaries for organizations. For example extended producer responsibility regulations typically make the original equipment manufacturer economically responsible for the whole life of a product [68, 69]. We have already mentioned the issue of potentially responsible parties that focus on the legal boundaries, which may also define the economic boundaries of fines and penalties associated with poor environmental supply chain practices related to these practices for which an organization may only be peripherally responsible.

Even though there are economic costs that may be encountered, there are also economic benefits and savings that may occur across the supply chain from effective environmental practices [70]. The boundary of recipients of these benefits and how they are accrued may be an important dimension for acquiring buy-in for environmental activities from supply chain partners. That is, if benefits and costs are shared across the supply chain, then it is more likely that the adoption of environmental practices will occur. A difficulty arises in determining who deserves what share of the costs and benefits and how the cost accounting is to be completed not only internal to the organization, but across organizations [71]. Thus, the need to complete a total cost analysis integrating the many tangible and intangible costs and benefits associated with environmental practices needs to be extended from management of internal operations to the supply chain [72]. Some initial effort to help model and apply this approach has utilized the value stream map as a technique. This approach adapts model material flow of both parts and packages and an integrated material flow analysis for cost analysis along with other life cycle analysis tools [73]. But even this tool is based on the level of organizational control (boundary) as determined by operations managers. This shows the situation where the financial boundaries (as other boundaries) may be limited by organizational and other boundaries.

Another promising tool linking product and process to the management of costs and benefits in an environmental setting are activity based management and costing approaches [74]. The expansion of this approach to environmental issues along the supply chain has occurred from a reverse logistics perspective for managing and justifying projects, products and partners [75, 76]. Even though they do not include multiple supply chain members explicitly, the separation of activities and analysis can cross organizational boundaries. Yet, the practical application of such tools would be difficult if the systems for cost information acquisition and determination (e.g. inter-organizational cost management systems) are not in place.

Technological Boundaries

Sometimes the technological infrastructure, which may include information, process, product, or organizational support technology [30], does not make it feasible for an organization to manage a green supply chain. Thus, technological boundaries based on the range of particular technologies or incompatible technologies for managing green supply chains. Pollution-prevention or end-of-pipe technology categorizations of

technology [77] also provide implications for boundary identification. Within the supply chain, prevention technology is more likely to be prevalent due to the requirement of extending the technological boundary throughout the supply chain. It should be recognized that even end-of-pipe technology for one organization may be prevention for another organization downstream in the supply chain. Thus, these types of technologies and where they occur within the supply chain may help to identify technological boundaries.

One determinate of the scope of a technological boundary may be partnership intimacy within the supply chain. Greater intimacy may require a larger boundary where technologies are compatible and available. Industrial customers may require suppliers to implement specific technologies, e.g. organizational and design environmental technologies such as EMS and DFE, to help expand the technological capability boundaries and minimize various transactions hazards [78]. Much of the technological environmental innovation has tended to occur in upstream portions of the supply chain due to many of these pressures from industrial customers in the supply chain [79].

Expanding the clean technology boundaries through the supply chain has also occurred through governmental practices and policies. The British government's Energy-Efficiency Best Practice campaign, the United States Environmental Protection Agency's (US EPA) Environmental Technology Best Practice program, and the Korean government's Supply Chain Environmental Management (SCEM) initiative are all examples of diffusing 'best practice' technology to smaller manufacturers and supply chains [80]. These adoption framework and supply chain partnership determinants for environmental technology (and practice) adoption can be categorized along a monitoring (coercive requirements) to collaborative (closer intimacy) spectrum [51].

It has been argued that as environmental initiatives in organizations mature, similar to maturation of quality initiatives, the horizons and boundaries for management concern will continue to expand [81]. Also there are many interrelationships amongst these boundaries. Thus, for example, a product's environmental concern for an organization may be focused initially on the engineering and design function within an organization (limited organizational boundary), for only one week (limited time boundary) and only effecting users in specific local market (limited promixal boundary). As a company gathers information (expanding the informational boundary) and starts trying to market in other states or countries (expanding legal, cultural, and political boundaries) the extensions in boundaries may be likely to occur. Thus, one major observation is that if one management boundary expands, its sphere of control and influence with respect to other boundaries will tend to increase. Similar to energy entropy as corporate environmental management and supply chain management mature, boundaries will expand.

In figure 4, we show the variety of boundaries discussed in this section. Note that each boundary may be of differing scope and also of certainty/importance (the outline of a boundary). We have also shown in this figure the various flows within the supply chain

that run through these boundaries. We now consider these flows and their relationships to green supply chains.

Figure 4 about here

Supply Chain Flows

Similar to boundaries issues related to various flows within the green supply chains also influence how they are managed and perceived. As shown in Figure xx, we identify five flows, materials, services, financial, information and knowledge, and waste flows. These flows may also have different scale levels, and thus, are directly related to the boundaries that envelop them or through which they flow. The types of flows, their purpose, and how they are managed may also differ depending on the boundary context. For example, materials flows from an organizational boundaries perspective would require that materials be cooperatively agreed upon by managers and designers, and from a proximal perspective the decisions on where they are designated to be located and stored. Another example would be information flows where legal requirements have them managing the information so they can be reported to customers, while information related to environmental costs may only be of concern to an operations manager or environmental department. We now provide an overview of the different flows and some relationships and studies on green supply chain.

Materials Flows

Materials flows are typical physical flows associated with supply chains and may include parts, components, raw materials or finished goods. Much of the research in supply chain management has focused on the management of tangible durable goods. One of the basic tools is material flow analysis which has been recommended for evaluating an integrated environmental supply chain [82]. The environmental aspects of these flows are well documented in and between organizations and have implications on all forms of environmental media implications ranging from solid waste management, resource productivity, dematerialisation and climate change issues [83]. Some recent research has proposed that material flow analysis be a core aspect of managing supplier environmental relationships [84].

Service Flows

These flows represent more intangible flows of services amongst organizations. Example service flows would be utilities and transportation services offered to organizations. Some of the service flows from these two industries are major contributors to the major environmental concerns facing the world, climate change, and are critical elements of the supply chain [85]. Since we incorporate utilities into this flow, we could include energy service and critical water flows, albeit water may also be a physical material flow. Energy services in the supply chain are essentially pertinent since they are grouped at levels of importance similar to material flows and are also critical flows for service industries [86]. In fact, the energy service providers have greatly increased in

importance amongst supply chains as deregulation (especially in the US) has seen increased growth since the early 1990's [87]. Services may include many supporting activities that may not be completely carried out by the organization or require specific materials. Information and financial services may also fall within this scope for industrial and retail level consumption. This more generic service industry has seen little research in the green supply chain management literature, except for some hospitality and tourism service industry perspectives [57].

Within the supply chain, the shift to dematerialization could be enhanced with servicizing materials flows [88]. Servicizing, also defined as product-service systems [89], is essentially the process of selling services rather products or materials to organizations. One example of this is in Xerox's strategy to offer a service, document management, for its copiers by leasing them rather than selling them. It provided a leasing service of a product which was taken back and reclaimed after lease expiration. In a servicizing relationship, both the buyer and the supplier wish to decrease material usage, where cost savings can be shared.

Another aspect of service flows are those services provided by nature and include the following ecosystem service categories [90, 91]: provisioning such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as nutrient cycles and crop pollination; cultural, such as spiritual and recreational benefits; and preserving, which includes guarding against uncertainty through the maintenance of diversity. Managing these service flows may or may not be under the control of a man-made supply chain, but certainly have some relationships to all supply chains.

Financial Flows

Financial flows are primarily the flow of capital (money) across the supply chain. These flows are critical to the management of supply chain practices. The environmental implications of these flows are mostly associated with the funding of practices and service/material flows which may cause environmental damage and consumption [92]. The management of these flows can have profound environmental implications (for example financial institutions may not lend due to environmental risks associated with certain organizational projects). Tools integrating the financial flows into supply chain management have relied on standard accounting tools such as activity based costing [93]. Financial flow evaluation and analysis integrated into environmental supply chain management has been very limited. As the recent world financial crisis shows, financial systems will greatly regulate the amount of material flows and requirements for all supply chains.

One of the missing links in evaluating financial (capital) flows is the integration of nature's capital into the evaluation of supply chain economics [94]. Integration of nature's services into supply chains' financial flows analyses can provide significantly more accurate perspectives on the influence of environmental supply chain management practices of organizations. The difficulty arises from the various assumptions that have to

be made for such a flow. Valuation of environmental resources is certainly a mystifying exercise with significant variances in estimations.

Information Flows

Information and knowledge flows are also one of the critical management aspects of green supply chain management [95]. Much of the environmental information within the supply chain can be related to product life cycles and LCA type analyses [96]. Operations across the supply chain can also benefit the environment just with regular information. Some of these benefits can be tied to the principle of information substitution, having accurate information about material and goods that replace the need to hold durable material and goods. Information substitution can greatly reduce the amount of energy, transportation, and material inventory in the supply chain [97]. With the advent of e-commerce and inter-organizational information systems within the supply chain, information substitution along the supply chain will have significant environmentally beneficial influence [98, 99].

Knowledge flows arise from having knowledge of environmental policies, technology, practices, and programs that can be shared across the supply chain. Not only are operations effected by knowledge, but supply chain innovation is also influenced. Innovation builds on and requires knowledge, knowledge generation, and knowledge exchange. Innovation from knowledge flows are especially pertinent to smaller organizations within the supply chains who typically lack the knowledge resources related to environmental actions for their operations [100]. Environmentally oriented organizational and inter-organizational learning is also dependent on effective knowledge flows through training and continuous improvement programs and supply chain collaboration [57, 101]

Information is not only critical for internal supply chain management operations, but can be a very effective regulatory tool which may cause organizations to reevaluate their supply chain processes [102]. That is, environmental information flows may be used to provide certain public images of the supply chain and its members. Having this information made public can cause significant pressures from external stakeholders on the overall supply chain to improve environmental and social performance [103]. Recent research has shown that within the supply chain, information will have varying impacts and will be used in different ways by supply chain members. Overall, these differences in application and sharing of information and management of environmental information flows is based on a variety of factors including expected costs or expected revenues/benefits related to environmental improvements, perception of external stakeholder demand, perception of supplier relationship (from the perspective of the supply chain manager) and top-management environmental commitment [104].

Waste Flows

We could consider waste flows as an element of all the previous flows which does not necessarily have social (environmental) or economic benefit, non-value adding, to the

unit under consideration. These waste flows cause greater costs to occur and may require separate programs to minimize them. For example, lean and green typically focus on minimizing waste and inefficiency within supply chains [105]. Thus the management of this flow will also be critical, and may be separated within a supply chain. From a broader informational and industrial symbiosis perspective, waste exchanges between organizations can alter the waste flows into useful material flows and have been applied to disparate materials and flows such as water [106], construction material [107-109], plastics [108], electronic products [78] and energy [110]. These waste exchange networks and flows not only can span inter and intra-organizational boundaries, but also across informational boundaries as the waste exchanges become more available through information and e-commerce systems [39, 111].

The other aspect of waste flows is that of end-of-life management of products and the type of disposal that should be completed. There are issues with landfilling, incineration and returning materials back into the supply chain. Within the landfilling and incineration debate, the type of material may determine which is more economically and environmentally feasible [112]. Rather than disposal of these wastes, recycling and reverse logistics network flows can be designed to manage these streams. Thus, as with any systems decisions, many variables will come into play before a clear-cut solution is available and decisions on managing these waste flows will range from individual consumer level to broad governmental policies [113].

Arenas for Investigation

Investigating green supply chain management interaction with specific industrial environmental practices, the role of specific boundaries, or the role of specific flows are all areas of investigation. We will not delve into discussion of investigation into these specific areas, but consider issues for investigation amongst general and multiple dimensions of green supply chain management, industrial environmental practices, boundaries, and flows.

Interdependency Issues

The interaction and effectiveness of green supply chain management through the joint adoption of other environmental practices such as environmental management systems and ecodesign will be influenced by the type of boundaries that are limiting the scope of these practices. For example, stringent informational boundaries and limitations, may seriously undermine the effectiveness of ecodesign practices, even when all departments and organizations in a supply chain feel that organizationally and culturally they are ready. Thus, determining critical boundaries and flows needed for joint effective implementation of green supply chain is needed. Yet, determination of what is or isn't a critical boundary or flow, is not necessarily trivial. Thus, scales and metrics development for boundary identification and flow determination is needed just to begin this investigation.

Theory Application and Development

Antecedent organizational theories to help explain the relative relationships and potential performance that do or may exist among the various dimensions introduced in this paper may be utilized. For example, Institutional theory would posit that boundaries will be extended and practices integrated due to various external isomorphic environmental pressures [114]. A resource-based view of the firm would state that development of internal capabilities and resources [20] would assist in extending the scope of flows and boundaries. Formality, level of control, and centrality, all part of coordination theory [115], can be used to identify environmentally-oriented boundary limitations and flow requirements between supply chain entities. The transaction cost and resource dependence literature suggests that firms are more likely to vertically integrate in the event of uncertainty and to reduce economic hazards [78, 116, 117], thus boundaries and flows with greater uncertainty may actually cause the boundaries to become more formalized to help reduce these risks. Ecological modernization theory [118, 119] which arises from the policy literature, also can be used to help identify various boundary relationships and the management of flows. Particular to this theory is its linkage to environmental and economic (boundary) performance through technology (technological boundaries) and innovation (knowledge boundaries). Finally, stakeholder theory, where internal and stakeholder influences play a significant role in management decisions, may also provide ample opportunity to understand and manage boundaries and flows within the green supply chain [120-122]. These theories and possible explanatory relationships and events may all lead to various propositions. We do not take that next step in this paper, but research agendas around these initial general observations can be developed.

These exemplary theories that have been used to investigate supply chain and more specifically green supply chain management are only starting to be investigated in these realms. The development and testing of alternate theories from marketing, operations, policy, and environmental fields will also provide insights. Eventually, green supply chain theory may be developed as the field continues to mature.

Green Supply to Green Demand

A significant amount of research in production and supply of green products, materials, and services has occurred throughout the world. Yet, the other dimension of this topic, some may call a dichotomy, albeit a false one, is that of sustainable and green consumption. Much of the focus on green supply chain management is focused on business and industry, whose goal is to maximize sales and profits. Changing consumption patterns to be more sustainable and green is a relatively difficult paradigmatic perspective for businesses who may not have the wherewithal or tools to accomplish this task [123, 124]. As an example of the paucity of applying tools and defining consumption boundaries and flows, the application of LCA in sustainable consumption is lacking, if not non-existent [125]. Traditional industrial LCA and green supply chain management are not focusing on the issues facing consumption. We have included, within the supply chain definition, downstream activities such as green

marketing. Support for utilization of green and social marketing by businesses to reduce consumption has been voiced [126, 127]. In this balance between sustainable consumption and products, service flows and regulatory boundaries may see greater emphasis due to the need for shifts in corporate and social behavior [128].

Beyond Greening to Sustainability

In this review of the recent research in this field, we have purposefully shied away from using the term sustainability or environmental sustainability. There are many connotations associated with this term that cause greater confusion and obfuscation [129-131]. Sustainability will incorporate other dimensions of corporate social responsibility that include ‘triple-bottom-line’ factors [6, 116] and inter-generational ethics [42]. Typically, when sustainable supply chain term is used the default perspective has typically been environmental or ecological sustainability [132]. The more complete inclusion of social sustainability is occurring, albeit not at the pace of environmental integration into supply chain research. But, issues related to boundaries and flows will arise by evolving to the more general sustainability and corporate social responsibility supply chains practices. Whether the boundaries and flows identified in this paper play larger or smaller roles becomes an issue. For example, materials flows and technological boundaries may not play as important roles as new ‘values’ flows or legal boundaries. This evolution in the framework and elements described in this paper may be quite substantial if it is to fit in the broader perspective.

Conclusion

This paper provided a review of the literature in the emergent field of green supply chain management. The field has seen growth over the past two decades as it has expanded in scope and definition. We utilized a boundaries and flows framework to help identify research in this field. We have shown how green supply chains relate to other broadly defined industrial environmental management practices and philosophies. Nine major comprehensive, overlapping, boundaries were defined and research and practice pertinent to these boundaries were identified. As part of the systemic perspective, we also introduce five major and interrelated flows that green supply chains need to manage within the boundaries. Finally, we have identified potential areas for investigation that focus on the general relationships between the boundaries, flows and industrial practices to green supply chain management. Due to the complexities and many dimensions of green supply chain management a number of research directions, social, economic, business, scientific, engineering, psychological can all be taken.

In this paper, we relied on more recent literature in this field. Significant reviews of green supply chain and business practices have occurred previous to this article. Additional, older references for the many topics covered here could have been used. Many of these were filtered out to provide some of the latest work in this area.

It is an exciting time in business and supply chain research. There is substantial work ahead for us to more fully understand and promote a greener world for ourselves and future generations.

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Figure 1: A green supply chain diagram with stages and relationships.

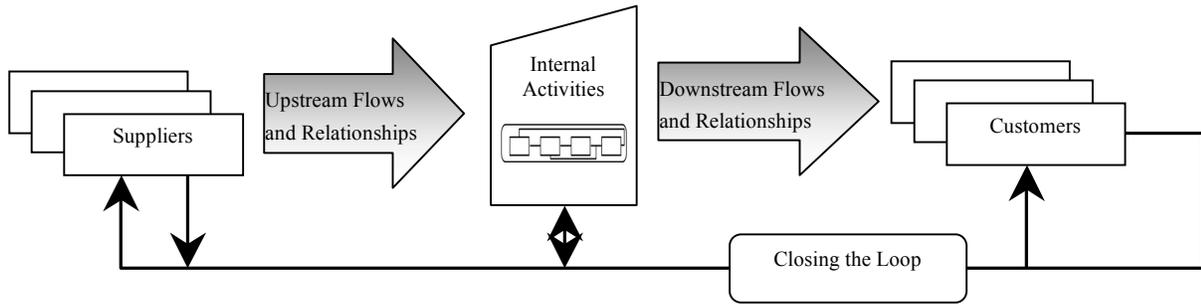


Figure 2: Industrial Environmental Practices Related to Green Supply Chain Management

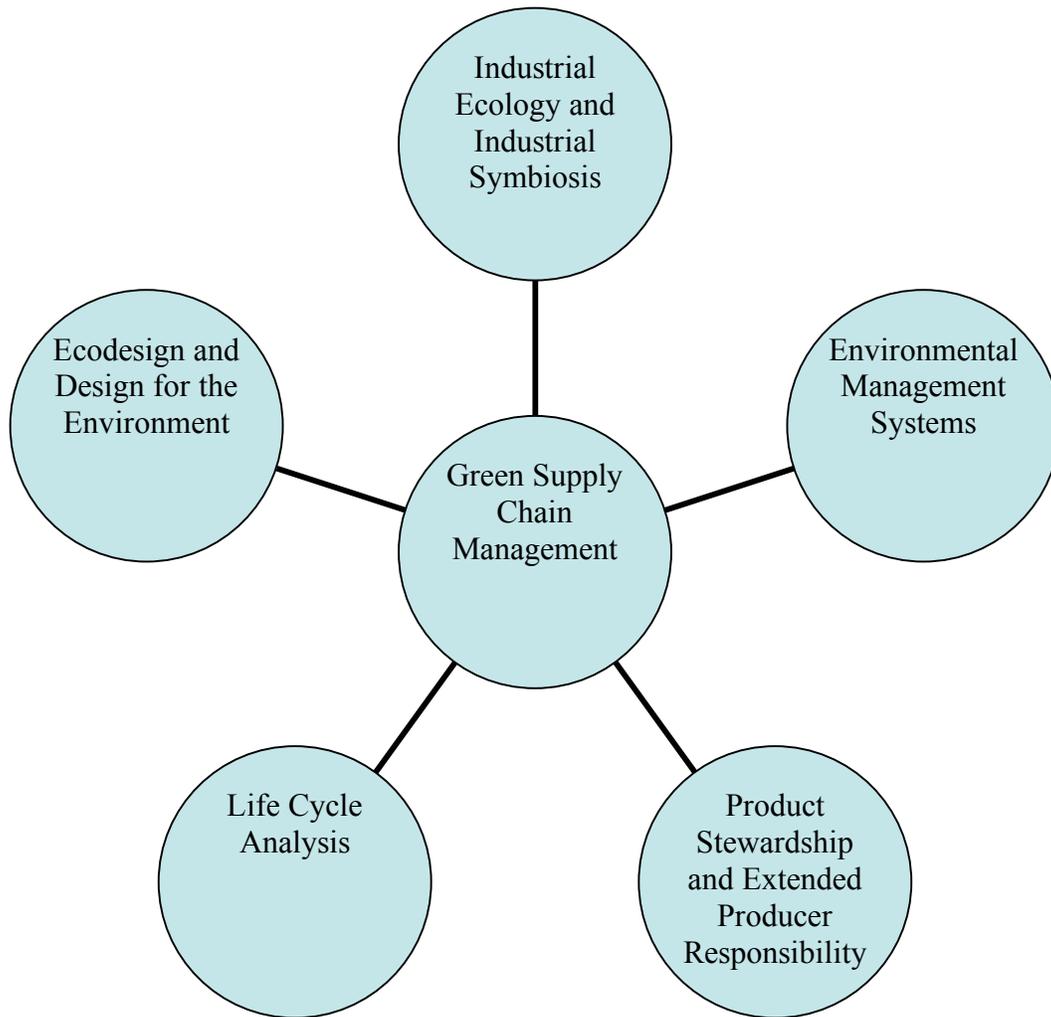


Figure 3: Layers and levels of supply chain boundaries.

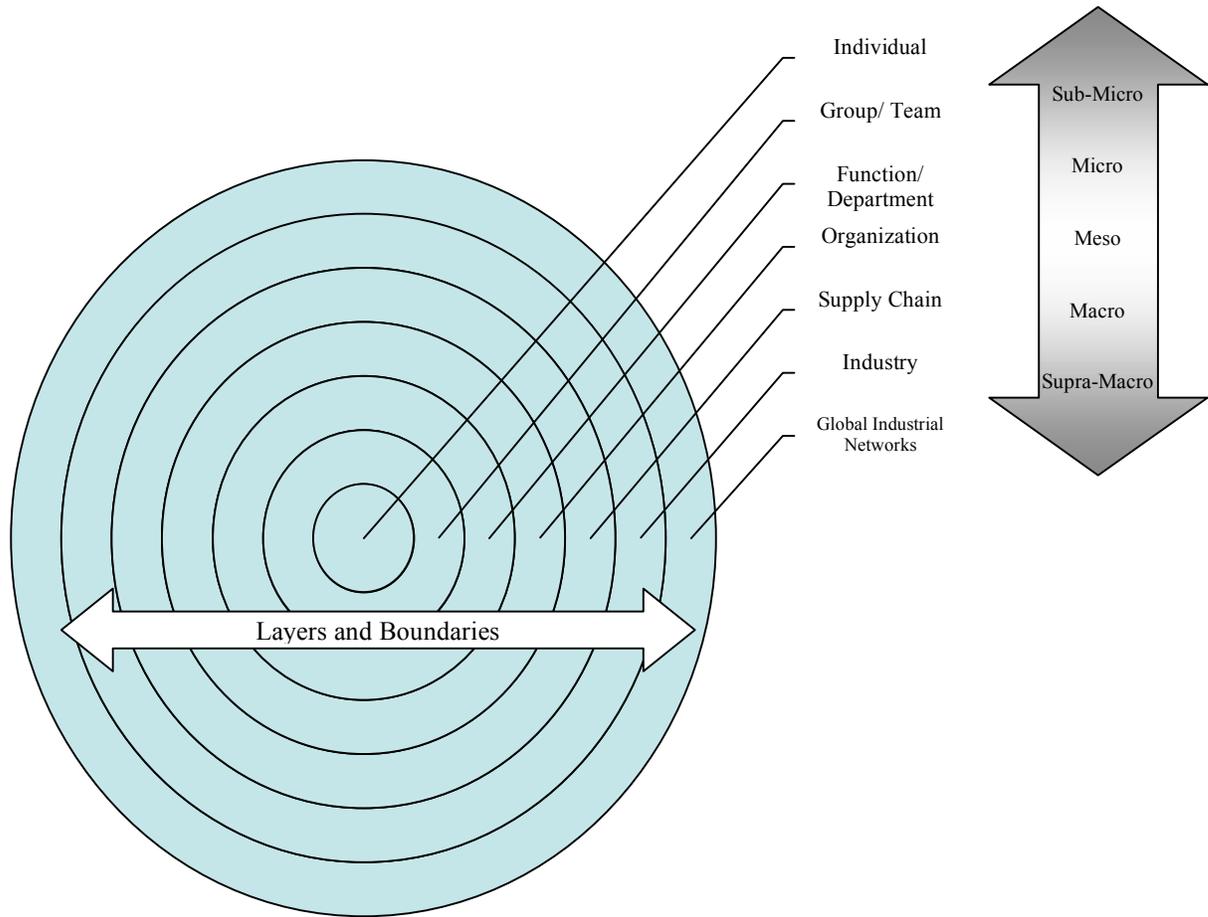


Figure 4: Integration flows and boundaries.

