The Supply Chain Response to Environmental Pressures

Discussion Paper

Julie Paquette
Engineering Systems Division
Massachusetts Institute of Technology
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This paper is written as part of Supply Chain 2020, a research initiative investigating the critical factors shaping supply chains of today and tomorrow.

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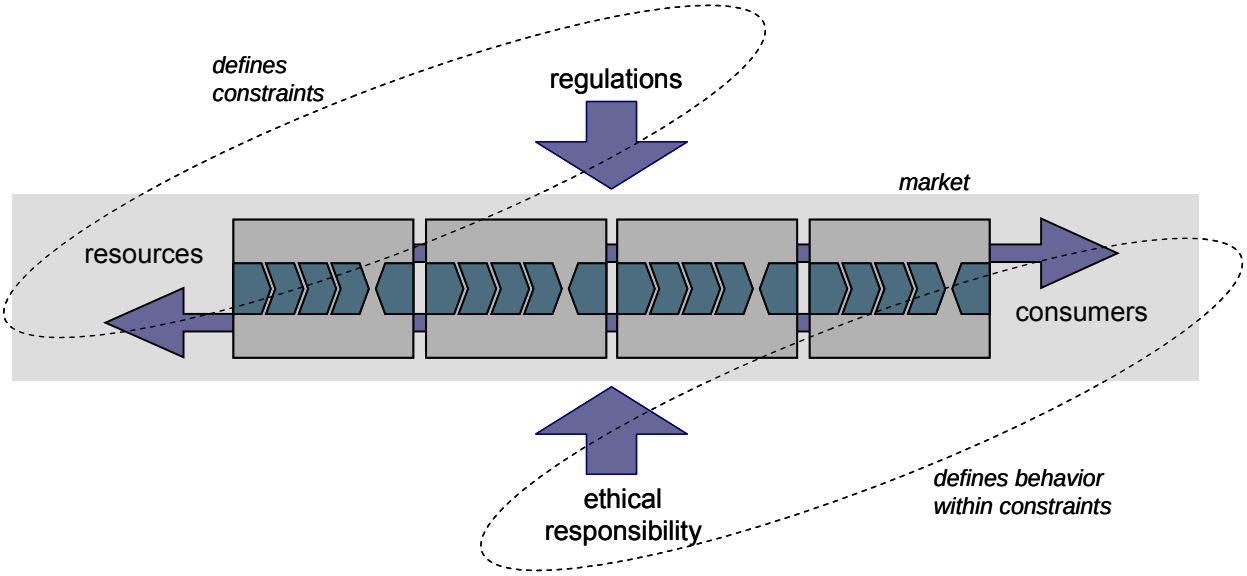
I. Introduction

Supply chains represent the integration of hundreds of decisions, each with discrete economic and environmental implications. While delivering the “right product at the right time” and unprecedented corporate profitability, supply chains have operationalized a linear production path that extracts resources, uses energy, releases emissions, and produce wastes at volumes and rates that place increasing burdens on the natural environment. However, as supply chains mature into sophisticated networks of material and information flow, so does the ability to carefully trace the environmental impacts of individual products along the supply chain and address these impacts proactively. Today, supply chains must respond to an array of environmental pressures, including regulations, consumer demands, and limited resource availability. This response involves the development of distinct operating models, objectives, and new supply chain processes that are expanding the scope of supply chain management within organizations. This discussion paper draws from supply chain and environmental management literature as well as industry case studies to characterize the current state of supply chain environmental activity and form a basis for future research.

II. Supply chains must respond to four sources of environmental pressures.

As supply chains grow to accommodate ever-increasing market demands, so do the environmental implications of linear production and public concerns for protecting the natural environment and human health. Concerns are most visibly translated into environmental regulations that shape the behavior and economics of industry. However, regulations represent just one source of environmentally-motivated pressure, which affects supply chain decision-making. Though significant, this narrow frame of reference may be expanded to include three additional sources: resource availability, ethical responsibility of corporations, and consumer demands for environmentally-advanced products and services. It is critical to understand the context and influence of pressures on the supply chain in order to respond effectively with technical and organizational innovation.

Figure 1. Sources of environmental pressures affecting the supply chain



A. Regulations

Governments use a variety of regulatory instruments to address the environmental and health externalities associated with industrial production. These instruments include environmental directives, taxes and fees, and liability. All three affect the pricing and availability of products and services, and warrant consideration at the supply chain level. This section will describe the changing nature of environmental regulatory instruments as they may be applied to supply chain management.

Directives

The most commonly recognized examples of environmental regulation come in the form of directives, such as pollution limits, material bans, and fuel-economy standards. Regulatory directives set requirements for industry practices and performance. In the United States, more than a dozen statutes form the primary legal basis for federal environmental regulations, including[12]:

- Clean Air Act (1967, 1970, 1977, 1990, 1999) requiring development of National Ambient Air Quality Standards, Hazardous Air Pollution Standards, Motor Vehicle Emissions Standards, Fuel and Fuel Additive Standards, Aircraft Emission Standards, and authorizing provisions for ozone protection
- Clean Water Act (1972, 1988, 1981, 1987) authorizing regulation of wastewater facilities and non-point discharges and provisions for federal funding of municipal sewage treatment systems.
- Resource Conservation and Recovery Act (1976, 1984, 1986) authorizing regulation and banning of the generation, storage, transport, treatment, and disposal of hazardous waste, as well as management of non-hazardous wastes.
- Toxics Substance and Control Act (1976) authorizing regulation and banning of industrial chemicals that pose "unreasonable risk" to human health or the environment.
- Comprehensive Environmental Response, Compensation and Liability Act (1980) allowing federal funding to remediate sites contaminated from prior unregulated disposal.
- Superfund Amendments and Reauthorization Act (1986) authorizing the development of clean-up standards and provisions for increased public participation.
- Emergency Planning & Community Right-To-Know Act (1986) authorizing the EPA to publicly report the release and storage of specified chemicals, and requiring emergency planning at the state level.
- Pollution Prevention Act (1990) allowing provisions for agencies to support "cost effective" changes in production, operation, and raw material use through technical assistance and voluntary partnerships.

Though this list comprises only a few of the more influential statutes from the supply chain perspective, it represents a discernible shift in the federal government's regulatory approach. Stringent "command and control" regulation of industrial point-source releases has given way to agency support for continuous environmental improvement and community risk management. While this shift has moved targets from "end-of-pipe" pollution control to process pollution prevention, current environmental regulations within the United States focus primarily on the *facility*. Facility personnel are responsible for implementing environmental health and safety activities, efficiency measures, and emergency planning. No formal

mandate requires that environmental management processes and improvements extend beyond this domain. Further, while facility-focused regulations impact the cost of operations which very well may change the decisions of supply chain managers, they do not require that any factor beyond cost be explicitly considered.

Environmental regulations are increasingly focused on *consumer products*. Products embody the cumulative environmental impacts from production, use, and disposal. Therefore, regulatory directives aimed at improving the environmental attributes of individual products effectively impact industry as a whole. In fact, product-focused regulation is ostensibly *supply chain* regulation, because changes to products drive changes to the design and operation of supply chains. Whereas regulations targeting manufacturing and transport activities at the facility level largely encourage either compliance or relocation of facilities (both of which are reflected in operation costs), regulations at the product level require new business processes both within the facilities that make up the supply chain and between them.

Today, there are at least three categories of regulatory directives that are focused on consumer products:

- Performance requirements. Standards that address the environmental impact of products during their "use" phase are relatively established regulatory instruments, including product fuel economy, energy efficiency, and emissions standards. In the United States, sequential acts for National Energy Policy (1975, 1978, 1992) authorize the Department of Energy to regulate energy (and to a lesser extent) water efficiency in end-use equipment, appliances, and building systems, notably including Corporate Average Fuel Economy (CAFÉ) standards for passenger cars and light trucks. Use of such standards is increasing across the globe. The European Union recently passed the Directive on the "eco-design" of Energy Using Products[3] which will harmonize and advance the already strict energy and water efficiency standards across the EU. It is likely that performance targets, as well as labeling and reporting requirements, will grow more stringent with time. These requirements place significant demands on product designers and also affect architectural, material, and process choices. Although it may appear that a change in product attributes has limited impact on the design and operation of the supply chain, a large body of research suggests that end-product design alterations affect the entire production system.[4] Therefore, product innovation to meet mounting performance standards will affect fundamental supply chain functions – planning, sourcing, manufacturing, and marketing.

- Material mandates. Research increasingly correlates damage to the environment and human health to the use of toxic and hazardous materials. Accordingly, mandates in the United States have moved beyond manufacturing emissions controls to regulate the use of select materials in consumer products. In concept, material mandates are nothing new. The Food and Drug Administration has

been regulating the materials of food, drugs, cosmetics, medical devices, and radiation-emitting electronics for over a century, representing a large portion of products that consumers purchase[5]. The Consumer Product Safety Commission sets guidelines for material use in consumer goods such as appliances, toys, clothing, and paint. Past mandates have focused on materials that may directly harm human health due to direct exposure, and include a variety of state and federal-level restrictions on products containing asbestos, lead, and mercury.[6] Today, material mandates are being applied to a broader range of materials, products, and industries with arguably less direct health impacts. For instance, the European Union's Restriction on Hazardous Substances (RoHS) Directive is one of the more aggressive bans of materials in history.[7] The directive specifically targets the electronics industry and requires the phase out of lead, mercury, cadmium, hexavalent chromium and two groups of flame retardants in all products by 2008. This type of material mandate not only challenges the technical capabilities of product designers, but also the organizational capabilities across the electronics industry. Although materials for electronics are often selected far up the supply chain for commodity components, RoHS places responsibility for a complete bill of materials and certification on the final producers, requiring a level of information exchange and data management unprecedented in the electronics industry. Supply chain managers will be called upon to manage data, monitor supplier activity, and provide quality control while coordinating material transitions in existing product lines.

- Extended producer responsibility legislation. In an effort to reduce material waste, conserve resources, and prevent hazardous disposal, several countries have enacted the principle of extended producer responsibility (EPR) within statutory frameworks. EPR directives place financial responsibility for the collection and disposal of products at the end of their useful life on manufacturers, thereby aiming to create incentive to redesign products for reuse and recycling. EPR legislation, also referred to as "take-back," is attractive to policy-makers not only because it is a market-oriented instrument for environmental improvement, but also because it reduces the burden of waste disposal from individual municipalities.[8] While deposit schemes for the recovery of aluminum cans and car batteries represent variations of "take-back" directives, EPR as discussed here has approximately a fifteen-year history beginning with packaging initiatives in Europe. The early efforts of several European countries were formalized in 1994 by the EU's Packaging and Packaging Waste Directive that stipulates national collection systems and recycling quotas.[9] A variety of public and private systems have developed in response, including Germany's Dual System which collects waste and coordinates recycling at a profit for producers who pay an upfront fee to display the "green dot" logo on their packaging.[10] EPR directives have since targeted more complex products, including automobiles, appliances, and electronics. The more aggressive legislative efforts are coming out of East Asia and Europe, and include Japan's End-of-Life Vehicle Recycling Initiative (1996) and Home Appliance Recycling Law (2001), and the EU's Directive on End-of-Life Vehicles (2000) and Directive

on Waste Electrical and Electronic Equipment (2002). Although, regulations have been adopted or proposed in Korea, China, India, Brazil, Venezuela, Chile, and some states within the United States as well. In order to comply with EPR requirements, companies must design, implement, and possibly operate comprehensive reverse supply chains.[11] Representing no small endeavor, reverse supply chains may involve collection facilities, reverse logistics, partnerships with disassembly and recycling providers, integrated remanufacturing and reuse plans, and marketing initiatives to encourage consumer participation. Altogether, "take back" requires considerable organizational, technical, and financial commitment from industry.

This discussion of product-focused directives is in no way exhaustive, rather providing a broad overview of present and future regulatory directions. Altogether, several broad conclusions may be drawn:

First, the global nature of today's markets and supply chains complicates regulatory compliance efforts. The broad and sometimes conflicting requirements of various regulatory bodies must be managed effectively, presenting an additional element of complexity to supply chain management. As such, there is considerable incentive to standardize environmental processes across the supply chain when possible. In the past decade, the United States has taken a much different approach to regulating industry than other nations – favoring environmental improvement through voluntary partnerships with corporations over more adversarial and legislative measures. While this shift may be preferable for supporting a market-oriented environmental response, it is likely that the more stringent regulations coming out of Europe and East Asia will set the standard for performance in all countries for better or worse.

Second, product-focused regulatory directives raise the stakes for industry because they assign chief responsibility for environmental improvement to the most visible players in the production chain – the final manufacturers. A requirement that the product embody certain environmental attributes ensures that some level of improved environmental coordination occurred along the supply chain, regardless of whether or not the product was imported from a country with little to no environmental regulations. While regulations that required facility improvements affect operation costs along the supply chain, product-focused directives change the entire decision framework of the supply chain, influencing cost and adding environmental criteria to fundamental processes in sourcing, manufacturing, operations, distribution, and data management.

Third, the optimal supply chain response to product-focused directives will be difficult to determine in the near future. Not only are global production systems increasingly complex, but such regulatory frameworks are relatively new, still evolving, and seemingly unclear about ultimate environmental goals. For instance, it is unclear whether EPR legislation is intended primarily to minimize waste, reduce the toxic constituents of waste, encourage alternative waste disposal methods, or achieve a combination of these things.

Evidence from past governmental initiatives suggests that it is difficult to achieve multiple goals with one policy instrument (Walls, 2003). For this reason, it may be presumed that future regulations will require multiple activities as an integrated response to multiple policy goals.

Taxes and fees

Environmental taxes either "impose a tax cost on a product or activity that is environmentally damaging or they give a tax benefit to some product or activity that is environmentally beneficial."[12] For example, in the United States, the federal government imposes an excise tax on ozone-depleting chemicals and offers a tax credit to people who buy electric vehicles. In this sense, environmental taxes do not replace regulatory directives, but rather help regulate the use of resources by visibly changing the purchase price. Environmental taxes, if applied aggressively and globally, may transform the way supply chains are designed and operated. For instance, suppose the United States levied a substantially higher gasoline tax. Logistics systems might change dramatically in light of escalating transportation costs. This response could either foster regional supply chains and economic development or irreparably damage international markets. Environmental fees create the same affect, increasing the cost of select activities to environmentally-preferable ends. Fees may be applied to landfill, hazardous waste, or raw material extraction, with ramifications that ripple along the supply chain.

While a large body of literature discusses the use of taxation to shape consumer behavior and raise government revenue[13], the direct impact of various taxation schemes on the management of global supply chains is not addressed. Environmental taxes and fees may be effective instruments for environmental progress, though arguably less effective for *supply chain* progress. In changing the visible price of a product or activity, supply chain decision outcomes may be different, but the decision framework and business processes in place may stay the same.

Liability

Liability for environmental damage serves as pressure for performance improvements. Under United States tort law and environmental statutes such as the Resource Conservation and Recovery Act, "strict liability places the full burden of environmental costs on the pollution generator, independent of the safety or precaution taken by the defendant."[14] This liability extends along the supply chain, creating situations where organizations may be held liable for environmental damage even when that damage is not a direct consequence of their actions. In the case that larger companies are conducting business with supply chain partners who have limited assets, it is in the best interest of those large companies to put into place technical support systems that assure compliance in the use of their products.[15] In fact, companies that

have “relative advantages in certain risk reduction factors should implement these to reduce the liability of the entire supply chain.”[16] Risk reduction activities may include training initiatives, product redesign, management of end-of-life products, and service offerings. For example, Greentech Assets, Inc. in Rhode Island offers recycling services specifically targeted at corporations aiming to limit the environmental and privacy risks associated with retired electronics.[17] Ashland Chemical reduced their own liability and that of their customers by offering chemical services rather than sales.[18] Ashland sells product on a “turn-key basis, taking on all the responsibilities of providing and disposing chemicals.”[19] In this sense, liability becomes an extremely effective regulatory instrument for several reasons. One, assigning liability to the most influential player creates incentive for the adoption and diffusion of environmental practices. Two, liability also invites pressure for environmental practices from insurance providers who underwrite industrial activities. Third and perhaps most importantly to supply chain processes, liability creates business opportunities to those companies who have invested in environmental literacy and services because they are able to reduce the risks associated with the activities of their customers’ and the supply chain as a whole.[20]

B. Consumers and Ethical Responsibility

Markets create powerful venues for change since a savvy consumer base continually demands more value from products, services, and the organizations that offer them. In this sense, end consumers drive fundamental characteristics of the supply chain, including environmental performance. This type of pressure for environmental attributes and responsibility creates distinct market opportunities for supply chains that can deliver the “right product at the right time.” This section will describe how consumer product demands and the ethical responsibilities of corporations are realized through supply chain level environmental performance.

Quality

Consumers demand quality products. As environmental awareness and expectations increase, so do demands for products with improved environmental qualities, including energy-efficient appliances, organic food and fabrics, recycled paper goods, and non-toxic cleaners. Past studies have shown that pinning down the exact status of environmental consumerism is challenging and subject to debate. Even as “79% of Americans consider themselves environmentalists and 67% state they would be willing to pay 5-10% more for environmentally compatible goods,”[21] actual buying practices have *not* supported opinion polls. Consumers rarely accept environmentally-preferred products with inferior performance, and very few are willing to pay a price premium for environmental attributes.[22] While environmental expectations may be high all around, many companies still view the green consumer as a niche market.

Regardless, the niche market has demonstrated consistent growth in recent years and currently comprises more products with improved environmental attributes than ever before. Sales in select product categories demonstrate this phenomenon:

- Organic: While the conventional food industry is generating a steady 2-3% per year growth, the organic industry has grown at rates between 17-20% annually for the past several years.[23]
- Energy-efficient: Energy Star, a labeling program administered by the United States EPA since 1992 to reward the most energy-efficient products, has expanded to include 11,000 different models within 40 product categories, ranging from washing machines to light bulbs.[24]
- Non-toxic: Natural household cleaners, including laundry and dishwashing detergents, have risen in sales from $140 million in 2000 to $290 million in 2004.[25]

Industrial sales mirror these trends. Purchasing Magazine reported in 2002 that "the most significant factor affecting supply, demand, pricing, and availability of solvents is the environmental issue." While demand for conventional solvents will be essentially flat at 0.2% per year growth, green solvents will post robust gains averaging 5.7% per year through 2005.[26]

The issue of branding adds another element to managing consumer pressures for environmental performance. Research suggests that environmental expectations are higher when products are marketed with a strong brand. Since branding efforts essentially encourage consumers to develop an emotional attachment to a company's image and reputation, consumers in turn expect a relatively higher level of social and environmental performance. In fact, one of the most comprehensive surveys conducted in this area, covering 25,000 individuals in 26 countries, found that "more consumers base their impression of a company on its corporate social responsibility than do on (product) reputation or financial factors."[27]

A positive "reputation is a valuable corporate asset, hard to build, yet easy to diminish."[28] The higher the profile of the brand, the more responsibility that that company must take for environmental activities along its supply chain. Environmental activities, however, represent just one aspect of the broader corporate social responsibility (CSR) agenda which has gained wide appeal in the past fifteen years. Also referred to as corporate citizenship, CSR involves the ethical treatment of employees, resources, the natural environment, communities and nations in which companies operate. Non-profit advocacy organizations have evoked the concept of CSR to raise awareness and build pressure for more ethical corporate behavior. For example, Global Exchange launched an infamous campaign against Nike, Inc. for sub-contracting to "sweatshops" throughout South East Asia that employed children, required long hours, and maintained no environmental health and safety policies.[29] The Silicon Valley Toxics Coalition condemns brand name electronics manufacturers for toxic components and hazardous waste as a result of

irresponsible disposal. Their seminal publication, “Exporting Harm: The High Tech Trashing of Asia,” drew public attention to the practice of exporting electronic waste to be processed in parts of Asia.[30]

On the other hand, some companies such as Stoneyfield Farm and Aveda have built a name for themselves on a basis of CSR. The efforts of these companies may drive both consumer demand for environmentally advanced products and competitive pressure for more responsible behavior in general. In a time when marketing, media, and public relations define success for many high profile companies, pressure to project an image of corporate ethical responsibility is very high. While it may be relatively easy to pay tribute to CSR in annual reports, it appears considerably more challenging to implement and enforce practices along the supply chain that yield measurable environmental benefits.

Altogether, consumer demands create serious challenges for supply chain management because while environmental expectations are high and extend beyond final manufacturers to include multi-tiered suppliers, consumers are unwilling to sacrifice product performance or price. Improved environmental performance, whether necessitated by regulatory directives or consumer demand, require product design changes which ultimately affect supply chain functions in planning, sourcing, manufacturing, and marketing. In the case of directives, often regulatory agencies provide technical assistance and facilitate compliance activities to a degree. However, the onus of meeting consumer pressures for environmental improvement in a time of greater corporate ethical responsibility is on those who sell the products.

Cost

Consumers also demand competitively-priced products. In order to offer the “right price” and maintain profitability, production system costs must be carefully balanced with performance along the supply chain. Ample anecdotal and empirical evidence suggests that environmental waste equals financial waste in production systems.[31] High utilities, fuel costs, and waste disposal fees provide incentive for the adoption of environmental management systems that streamline production and yield greater efficiencies along the supply chain. An oft-cited paper by Michael Porter and Claas van der Linde published in 1995 presents basic reasoning for environmental improvements as investments that yield both product and process benefits and possibly create major competitive advantages in innovation and operations.[32] These mechanisms for efficiency include:

Process

- substitution, reuse, or recycling of production inputs;
- less downtime through more careful monitoring and maintenance;
- better utilization of by-products by conversion of waste into valuable forms;
- lower energy consumption during the production process;

- reduced material storage and handling costs;
- savings from safer workplace conditions; and
- elimination or reduction of the cost of activities involved in discharges or waste disposal

Product

- higher quality, more consistent, safer products;
- lower product costs;
- lower packaging costs;
- lower net costs of product disposal to customers; and
- higher product resale and scrap value

This concept of keeping operation costs low through environmental improvements has been plugged by business environmentalists for years as the illustrious "win-win" situation. As such, there are abundant anecdotal case studies that endorse the use of environmental management systems and processes both within individual facilities and as collaborative efforts between supply chain partners.[33] In a document published in 2000, the EPA reported that[34]:

- GM reduced disposal costs by $12 million between 1987 and 1997 by establishing a reusable container program with its suppliers. Additionally, reusable containers can reduce solid waste, product damage during shipping, and worker safety problems that come with slicing open boxes.
- Andersen Corporation developed a composite material from wood wastes generated during its manufacturing process. This innovation yielded internal rates of return exceeding 50% and enabled Andersen to decrease solid lumber purchases by 750,000 board-feet.
- Public Service Electric and Gas Company saved more than $2 million in 1997 in storage and product disposal fees by requiring maintenance and operating material suppliers to adhere to stringent return policies. These costs had previously been hidden in overhead accounts.

Examples like these may be found in many publications, old and new, along with a wide range of process tools for organizations to identify and implement tailored environmental strategies. Notably, a tool called GreenSCOR[35] has been developed to merge environmental management with supply chain management in order to integrate environmental considerations into the entire supply chain process. An offshoot of the Supply Chain Council's original Supply Chain Operation Reference model (SCOR), benefits to GreenSCOR include the ability to reduce environmental impacts and related costs system-wide while supporting traditional supply chain objectives. The approach also raises the visibility of the financial and operational benefits of environmental supply chain practices.

While the desire to keep operating costs low is good reason to pursue environmental performance

improvements along the supply chain, this desire does not represent a unique *environmental pressure* within this framework. It is perhaps more accurate to group the "win-win" situations described here as either 1) operational improvements motivated by economic pressures that happen to demonstrate environmental benefits, or 2) environmental improvements motivated by regulatory, consumer, or ethical responsibility pressures that happen to yield cost-savings. In the future, environmental pressures will require significant and pervasive changes in supply chain design and operations, changes that will not likely be motivated by incremental cost-savings.

C. Resources

Escalating global population and affluence create demand for more and more products. The corresponding rates of production inevitably place strains on the natural environment's ability to supply resources and absorb wastes. Traditional supply chains "are based on a linear production paradigm which relies on constant input of virgin natural resources and unlimited environmental capacity for assimilation of wastes and emissions."[36] Despite considerable progress in resource conservation and process efficiency measures, this paradigm is still pervasive. The secure supply of critical feed-stocks will remain a supply chain challenge into the future.

An examination of the global supply and demand for fish illustrates this point well. The World Resource Institute reports that consumption of fish and fishing products has doubled in the past thirty years and has increased five-fold since 1950.[37] "Fish supply has become one of the major natural resource concerns, as seventy-five percent of commercially important marine and most inland water fish stocks are either currently being over-fished, or are being fished at their biological limit."[38] This situation bodes poorly for those in the fish business, including global corporations such as Unilever that sells fish and uses fish products as raw materials. Unilever is one of the world's leading suppliers of food, home care, and personal care consumer goods. In the mid-1990s, Unilever launched a comprehensive effort to secure a sustainable supply of fish. First, they provided seed money to the World Wildlife Foundation to research the situation and establish the Marine Stewardship Council as an independent organization to certify sustainable fish supplies. Then, they initiated discussion with competitors and national regulatory bodies in support of the Council's standards. Finally, Unilever publicly endorsed the work of the Stewardship Council and committed to purchasing only certified fish.[39]

The availability of energy and water resources for manufacturing also presents a challenge to supply chain management. Water shortages are increasing world-wide as demand for drinking and irrigation grows. The United Nations Environmental Program reports that one third of the world's population lives in countries where consumption exceeds 10% of total supply and more than 2.7 billion people will face severe water shortages by the year 2025.[40] Supply chain managers must consider resource constraints

when locating facilities and planning operations, since energy and water shortages may dramatically affect business. For example, both Pepsi and Coca-Cola lost their license to use local groundwater at bottling plants in Kerala, India following a local drought.[41]

While it may be easy to take for granted the availability of natural resources to support industrial activities, resource constraints represent a systemic environmental pressure. The most successful companies will recognize natural limitations, in time to plan for conservation, substitution, or production of their own feed-stocks. Such a response will require a broader perspective on the role of companies in providing goods, services, as well as stewardship of the resources that enable economic success.

D. Summary

Altogether, supply chains must respond to environmental pressures from four sources. Resource availability and regulatory pressures place physical, legal, and economic constraints on supply chain management, while consumer demands and the ethical responsibilities of corporations define desirable behavior in the market and within those constraints. As supply chains mature and environmental pressures become more diverse and demanding, technical and organizational innovation is needed in supply chain design and operation.

III. The supply chain response involves a distinct operating model, objective, and processes

In order to characterize how industry may best respond to environmental pressures through their supply chains, it is important to understand the role supply chain management plays in supporting business strategy. Given that "ample evidence exists to support the premise that supply chain management processes have a significant impact on the operational and financial performance of companies," it is appropriate to ask what constitutes a supply chain that successfully brings value to a company.[42] In a working paper that forms the basis for the Supply Chain 2020 research initiative at Massachusetts Institute of Technology, a four statement hypothesis defining an "excellent supply chain" is proposed. "An excellent supply chain:

- enhances and is an integral part of a corporation's business strategy;
- leverages a distinctive operating model to gain competitive advantage;
- executes well against a balanced set of operational objectives or metrics; and
- focuses on a small number of best business processes that are aligned with objectives."

This hypothesis may be further examined with respect to environmental excellence.

A. Integral part of strategy

First, if an excellent supply chain is considered an integral part of a corporation's business strategy, then it should also be integral to a corporation's environmental strategy. Supply chains operationalize the existing linear cycles of industrial production, and represent the cumulative environmental impacts of a product from extraction to final delivery. It is reasonable to believe that if a company has an environmental strategy, then that strategy would be implemented through activities at the supply chain level. Many companies have exhibited a commitment to the natural environment through corporate responsibility statements in marketing publications and on the internet. One may evaluate whether or not these companies' supply chains are enhancing or undermining their stated environmental positions.

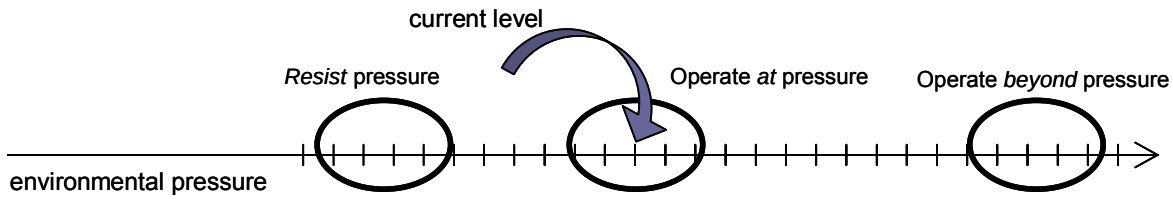
B. Distinct operating model

Second, an excellent supply chain should leverage a distinctive operating model to gain competitive advantage. An operating model defines an organization's overall strategy for business, and may be reduced commonly to simple statements like "to offer the lowest priced products" or "to provide the largest selection of products." Supply chains either support the designated operating model, effectively

coordinating supply channels and production activities, or they do not.

A supply chain may also leverage a distinctive operating model with respect to environmental pressures. Although environmental activities are typically regarded as ancillary to business operations, under ideal circumstances, these activities are aligned with and augment the core operating model. Regardless of whether or not this alignment exists, as environmental pressures increase and require action at the supply chain level, a company must choose 1) to operate beyond environmental pressures, 2) to operate at environmental pressures, or 3) to resist environmental pressures.

Figure 2. A response to environmental pressures requires an environmental operating model.



This categorization of environmental operating models is not a new concept. Several researchers have described various corporate environmental orientations in a similar way. R. Kopicki presents three approaches in environmental management: the reactive, proactive, or value-seeking.[43,44] Steve Walton offers a comparable model in characterizing the purpose of environmental activity as either "comply with the letter of the law," "clean up," or "be proactive."[45] Robert Klassen describes the continuum of behavior from reactive to proactive orientations in several publications.[46] Ad de Ron designates environmental strategy as following, market-oriented, or sustainability-oriented.[47] Finally, Paul Murphy introduced a survey tool that classifies companies across industries as environmental progressives, moderates, or conservatives.[48] It is important to note, however, that these categorizations of corporate environmental orientation focus primarily on behavior *within the facility,* as opposed to articulating a product-focused supply chain response. Also, they do not explicitly identify the different sources of environmental pressure - regulations, consumers, and resources – in recognition of the fact that it may be advantageous to operate *beyond* pressure for one and *at* pressure for others. Despite this more limited view and slight difference in descriptive terms, it is generally agreed that environmental and core business activities are best when mutually supportive. Accordingly, an excellent supply chain should leverage a distinct operating model that is *informed by environmental pressures* to gain competitive advantage.

C. Balanced operational objectives

Third, an excellent supply chain executes well against a balanced set of operational objectives or metrics. Classic supply chain objectives are described by the Supply Chain Council to include reliability,

responsiveness, flexibility, cost, and asset utilization.[49] A "balanced set" may include only one or two of these operational objectives depending on the designated operating model. For instance, a corporation may focus on supply chain efficiency and may employ metrics such as line-items-picked-per-hour or cash-to-cash-cycle-time to indicate performance. With regard to the environment, operational objectives may be developed for each environmental *operating model* in response to each type of environmental *pressure* as follows:

Table 1. Environmental operational objectives

		environmental pressures		
		Resources	*Regulations*	*Markets*
environmental operating models	*Operate beyond pressure*	Substitute Expand	Obviate the need for Exceed	Drive Create
	Operate at pressure	Conserve Secure	Comply	Meet Satisfy
	Resist pressure	-	Breach Relocate	Exit Ignore

Suppose a corporation elects to operate *at* regulatory pressure. This corporation's operating objective, therefore, is to comply with all regulatory directives that affect its activities with the least disruption to other business processes. Metrics such as number-of-non-compliance-incidents, or fines-for-non-compliance may be selected to indicate direct environmental performance. Metrics such as cost-to-compliance and time-to-compliance may be used to indicate efficiency and environmental performance. A large body of research discusses the application of metrics to indicate direct environmental performance, such as energy use or total waste generated.[50] An interesting extension of this research involves the development of metrics to indicate environmental performance of an entire supply chain.[51]

Table 1 presents a useful framework for examining industry environmental activity at large. Proponents of corporate environmental initiatives may argue that a proactive orientation "operating beyond environmental pressures" is the best way to protect the natural environment and sustain long-term value and profitability. However this framework suggests that environmentally-aware supply chain excellence may be achieved within *each* operating model. In this sense, excellence may perhaps rely on three conditions: 1) environmental pressure is effectively signaled to the company, 2) there is sufficient time to respond to the pressure, and 3) the company has adequate management and technological capability to implement a response at the supply chain level. A company that is reactive, flexible, and efficient in execution may operate extremely well *at* environmental pressure, while a company that is proactive,

innovative, and differentiated from competition may best place themselves beyond pressure. The operating model decision may be further determined by market conditions and product attributes.

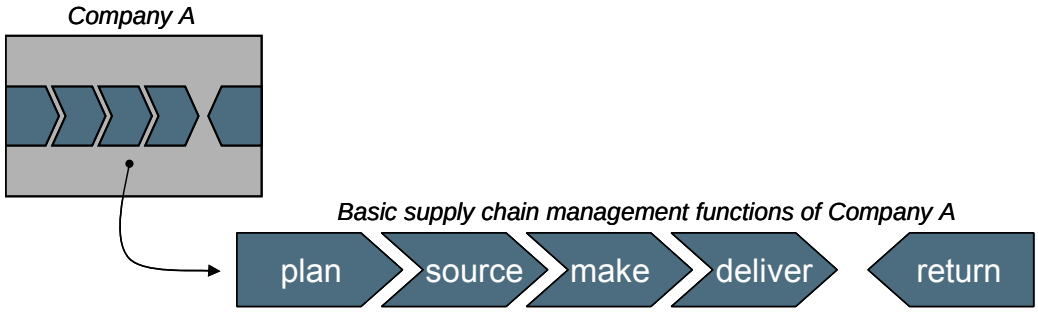
D. Best business processes

Fourth, an excellent supply chain focuses on a small number of best business processes that are aligned with operational objectives. While comprehensive supply chain management may require hundreds of processes to be performed in a structured manner, the greatest operational and financial benefits result from concentrated efforts on a relatively small number of unique business processes. The same may be said about environmental benefits: an excellent supply chain with respect to environmental performance focuses on a small number of processes that are aligned with environmental operating objectives.

During the past decade, best business processes have typically included cross-functional processes, extended or inter-enterprise processes, the use of formal optimized decision-making, the use of stochastic decision-making, and the use of risk management.[52] Interestingly, the vast body of environmental management literature echoes these themes, encouraging many of the same approaches in developing processes to improve environmental performance. Accordingly, concepts proposed by environmental management literature may be understood and effectively applied to the context of supply chain management.

Consider environmental processes arranged by the most basic functions of supply chain management as defined by the SCOR model:

Figure 3. Basic supply chain management functions as defined by the Supply Chain Council



Plan

The chief variables that influence the environmental performance of a product or system are determined

during the planning phase. A number of processes may be used to aid environmental decision-making while planning the supply chain.

- *Environmental cost accounting*[53] is a technique to identify and assign discrete costs to environmentally harmful activities within a broader system. The term "cost" as used implies two meanings. The first is the monetary cost that an individual company might incur from a specific activity, such as the fees associated with hazardous waste disposal. The second is the cost of damage to human health or the natural environment that may be directly attributed to a corporate activity. Companies motivated to reduce operating costs or to demonstrate an environmental commitment use environmentally accounting techniques to capture environmental costs not typically captured through conventional accounting methods. The US EPA commissioned a comprehensive study of the use of environmental accounting in hospital purchasing and waste management in the year 2000, which serves as an excellent reference about accounting techniques.[54]

- *Environmental life cycle analysis* is a method used to identify and evaluate the environmental impacts associated with a product or service throughout its entire life from material extraction to eventual disposal and assimilation into the environment. As opposed to environmental cost accounting, life cycle analysis implies non-monetary environmental assessment and is used as a product or system design tool. A number of life cycle analysis methodology books and software programs are available,[55] although not specifically geared to supply chain managers.

- *Design for environment* is an approach to reduce the environmental impacts of a product by introducing specific design criteria during the product development phase, such as "design for recyclability" or "design for energy efficiency." Once the environmental impacts of a particular product characteristic or life-cycle phase are identified through a formal or informal analysis, design for environment may be used as an organizing design principle to ameliorate those impacts. Many industries have successfully implemented a design for environment approach in product development. For instance, appliances that have been awarded Energy Star rating by the US EPA are designed to meet specific energy efficiency criteria,[56] and Kodak "Fun Saver" one-use-cameras are designed to be disassembled and remanufactured into new cameras.[57]

Source

Sourcing professionals may consider the environmental attributes of materials, components, and products, as well as the environmental performance of the suppliers' direct activities using the following processes.

- *Environmental auditing* is a procedure to verify the environmental performance of a material, component, product, or facility. Auditing may be conducted by a third-party organization or the buyer in accordance with previously established environmental guidelines. Many multi-national companies, including Limited Brands, Inc., Texas Instruments, and General Motors have designated standards and routinely audit suppliers for environmental performance.[58] Internal auditing is also widely promoted as part of the ISO 14000[59] environmental management standards.

- *Environmental certification* is a guarantee that a product or facility meets environmental standards defined by a third party. Certification typically involves product labeling for consumer marketing in response to regulatory pressures or consumer demands for products with improved environmental attributes. Examples of prevalent certification programs include Green Seal[60], Germany's Blue Angel[61], Certified Organic,[62] and the building industry's Leadership in Energy and Environmental Design certification[63]. Companies may undergo environmental certification for their own products or seek to purchase certified products.

Make

As discussed earlier, the manufacturing response to facility-focused regulatory directives has evolved from end-of-pipe pollution control to the implementation of environmental management systems. It may be expected that this evolution will continue domestically and extend to facilities in regions with weaker regulatory regimes, involving the following processes:

- Pollution prevention is an approach to preemptively identify and alter activities that create waste. Prevention techniques including substitution, product modification, improved maintenance, and recycling have been successfully applied at several facilities following the Pollution Prevention Act of 1990 and several state-level regulatory directives. The Journal for Cleaner Production[64] and the Pollution Prevention Resource Exchange[65] serve as excellent references on this topic.

- Environmental management systems are sets of processes that enable an organization to identify, monitor, and address the environmental impacts of its activities. Systems typically include guidance for employees in environmental health and safety procedures and facilitation tools for continual improvement of environmental performance. While developing an environmental management system does not guarantee better environmental performance, it generally helps companies comply with regulations and manage risk more consistently and effectively. While ISO 14000 serves as the international standard for environmental management, the US EPA also provides several good references to develop a system independently.[66]

Deliver

The environmental implications from transportation are growing, as materials, components, and finished products travel longer distances through production and distribution cycles. The total impact of delivery functions correlates to two variables that logistics professionals manage directly: transportation distance and mode.

"Green" logistics is an approach that considers the environmental impacts of procurement, transport, inventory control, and distribution activities along with other considerations in order to minimize environmental costs. For example, in addition to considering monetary cost, time, and reliability of freight service, one may also consider the volume carbon dioxide emissions. There are several interesting studies that compare the environmental impacts of various product distribution systems, including online retail models.[67]

Return

Return processes are gaining in strategic importance as companies compete further to maintain customers, recover assets, minimize liability, and meet extended producer responsibility regulatory requirements.

- Reverse logistics is a set of activities to collect, transport, and manage products and materials after sale and delivery to the customer. Reverse logistics has been typically used to facilitate unsold product and warrantee returns, and it is being further developed to address "take back" regulatory obligations and to pioneer concepts of closed-loop supply chains. This subject represents an important area of emerging research within supply chain management.[68]

- Remanufacturing is a process to clean, repair, and restore used durable products to good condition for resale. Remanufacturing is typically integrated with reverse logistics processes because valuable products and components must be appropriately transferred from the consumer to the manufacturer. In addition to logistical challenges, remanufacturing involves serious technical, planning, and inventory management challenges, areas which are increasingly explored in practice and research literature.[69]

- Recycling is a procedure to reuse materials, which may otherwise be considered waste, in a form other than primary use. Recycling is facilitated by return processes in part because existence of a secondary market depends on the quality of recycled materials. Whether recycling recovered materials or using purchased recycled content in production, processes require additional planning

due to fluctuations in material timing and availability.

This list is by no means exhaustive or prescriptive. Rather, it provides an overview of the many business processes that could yield significant environmental improvements while being conscious of the impact on corporate strategy. Although some may argue that true environmental excellence is a product of the holistic integration of many processes, concentrated efforts on even one may yield significant environmental benefits that ripple through the supply chain and create economic value. As said previously, an excellent supply chain focuses on a small number of *best* business processes, which prompts the question: when it comes to the supply chain response to environmental pressures, *what is best*?

IV. Conclusion

Environmental pressures add a new element of complexity to supply chain management, requiring a comprehensive response involving environmental operating models, operational objectives, and new supply chain processes. As environmental pressures grow more diverse and demanding, the quality of an individual company's supply chain response may confer significant competitive advantage. This discussion paper presented an overview of the types of environmental pressures that impact supply chains today, as well as a framework for characterizing what may be an excellent response to these pressures. From here, we may explore the different models and processes that companies within one industry are implementing in response to a single pressure. This future research may establish a relationship between the quality of a supply chain response and the extent of competitive advantage, offer a prescriptive, evaluative framework for addressing environmental pressures, and present a path towards the proactive development of supply chains that enable increased profitability and environmental sustainability.

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