2012

Antecedents and Evolution of the Green Supply Chain

David M. Nelson

Erika Marsillac
Old Dominion University, emarsill@odu.edu

S. Subba Rao

Original Publication Citation
Nelson, D., Marsillac, E., & Rao, S. (2012). Antecedents and evolution of the green supply chain. *Journal of Operations and Supply Chain Management* (Special Issue), 29-43.

Antecedents and Evolution of the Green Supply Chain

David M. Nelson
University of Toledo
david.nelson4@utoledo.edu

Erika Marsillac
Old Dominion University
emarsill@odu.edu

S. Subba Rao
University of Toledo
srao5@yahoo.com

ABSTRACT: Supply chains have been developing over time since the inception of commercial trade and barter. The purpose of this paper is to describe the emergence of the Green Supply Chain, the newest entry in supply chain evolution. As a foundation for this, historical perspectives of manufacturing chronology, along with supply chain modifications resulting from changing market conditions are discussed. Managerial implications are offered reflecting pathways towards sustainability.

As production power shifted from manual operation to steam, technology became the main driver for supply chain development leading to a variety of types seen in industry today. Today's supply chain types emerged due to increasing market complexity and competitive pressure. More recently, an additional driver occurred catalyzing the Green Supply Chain – the Environmental Movement. This chain is positioned as the next step in today's supply chain evolution, balancing environmental, economic, and societal needs with customer growth.

Keywords: *Green Supply Chain, Sustainability, Triple Bottom Line, Corporate Social Responsibility, Product Life Cycle*

1. INTRODUCTION

Knowledge is an intangible strategic resource able to create value and achieve superior performance (Grant, 1996; Hult, Ketchen, Cavusgil and Calantone, 2006; Mohrman, Finegold and Mohrman, 2003). In general, researchers recognize that product development is a knowledge-based activity (Clark and Fujimoto, 1991) that denotes knowledge management processes as the only way to ensure survival and success (Mallick and Schroeder, 2005). Product developments is thus a major focus of emphasis for organizations (Handfield and Nichols, 2002; Fliess and Becker, 2006). Developing highly successful products demands firms to employ their existing knowledge while at the same time avoiding their dysfunctional rigidity effects by renewing and replacing this knowledge with new knowledge (Atuahene-Gima, 2005; Atuahene and Murray, 2007; Knott, 2002; Sheremata, 2000). Therefore product development involves both exploring knowledge and exploiting knowledge, yet tensions emanate from their different knowledge management processes (March, 1991; Tushman and O'Reilly, 1996). The management of these tensions concerns the capability to be *ambidextrous*, which implies simultaneous, yet contradictory, knowledge management processes, exploiting current competences while exploring new ones with equal dexterity (Andriopoulus and Lewis, 2009; Jansen, Van den Bosch and Volverda, 2005). Successful firms are those able to balance both exploration and exploitation by being ambidextrous and in so doing enhance their long-term competitiveness (Auh and Menguc, 2005; Gibson and Birkinshaw, 2004; He and Wong, 2004; Tushman and O'Reilly, 1996).

Latest research focuses on how firms can achieve ambidexterity. This increasing attention has contributed to the refinement and extension of the ambidexterity concept (Raisch, Birkinshaw, Probst and Tusman, 2009) and to suggest multiple paths to ambidexterity. Originally, Duncan (1976), and later Tushman and O´Reilly (1996), analyze architectural ambidexterity by recognizing the role of dual structures within organizations, differentiating efforts to focus on either exploration or exploitation. In contrast, Gibson and Birkinshaw (2004) introduce the alternative view of contextual ambidexterity to analyze the social and behavioral means to integrate exploration and exploitation. The structural and contextual antecedents have been extended to investigations of the roles played by networks (Kauppila, 2007), and leadership-based antecedents of ambidexterity (Lubatkin, Simsek, Ling and Veiga, 2006; Smith and Tushman, 2005). This body of work has been categorized and discussed in recent review papers (Raisch and Birkinshaw, 2008; Raisch et al., 2009) that indicate that although both exploration and exploitation are necessary, their contradictions motivate important research issues that remain unexplored, ambiguous, or conceptually vague. For that reason, attempts to achieve ambidexterity continue to be a challenge and the need to address how firms can be ambidextrous still remains.

This paper focuses on ambidexterity in product development -which has been proved to be well suited to studying innovation tensions-, analyzing both the path and consequences for product development performance. Considering that March expressly suggests that his theory about exploration and exploitation might be applicable to the study of IT (March. 1991; March 1995), this study offer an alternative path to ambidexterity by analyzing the link between information technology (IT) – which is an established knowledge management enabler– and the exploration-exploitation paradox in product development. IT plays a critical role in product development since its potential range from the storing, organizing, processing and access of knowledge to the facilitation of people networks, coordinated flowing and integration of knowledge (Van den Brink, 2003). Previous literature notes that IT can thus influence both exploration and exploitation (Alavi and Leidner, 2001; Gray, 2001; Pentland, 1995; Sambamurthy and Subramani, 2005) and thus can affect the desired balance between them. Whereas existing research has provided contributions on the combined use of several IT mechanisms to support knowledge base capabilities (Sambamurthy and Subramani, 2005; Kane and Alavi, 2007), the mixed messages reflect the complexity of the problem and underscore the need for in-deep research. On the basis of these limitations, this study analyze the exploration-exploitation paradox in product development by considering the integration of two kinds of IT dimensions: (1) the divergent dimension, which is focused on gathering and synthesizing information and knowledge, making it available for creative action; and (2) the convergent dimension, which is focused on knowledge discovering and analysis, and the support of discourse and virtual networking for enhancing collective action.

Specifically, this study proposes both the divergent and the convergent dimensions of IT as paths to ambidexterity and, additionally, analyzes how ambidexterity mediates the relationship between IT and product development performance. In doing so, this manuscript differs from previous research in a number of important ways. First, the contribution to ambidexterity literature comes by considering the use of IT as complementary pathway to achieve the desired balance between exploration and exploitation. Second, following Melville, Kraemer and Gurbaxani's (2004) suggestion on the importance of disaggregating IT construct into meaningful subcomponents, IT is not applied generically to ambidexterity, rather this study support the combined use of several IT mechanisms. Third, while the majority of past studies focus on the benefits of IT use for organizations, this study focuses on benefits for product development. Fourth, previous research highlights the need to examine financial performance, market share or a narrow range of operational performance measures as a primary performance outcome, but this study offers a model where the impact of IT on product development performance is mediated by ambidexterity.

The body of the paper first describes the nature of ambidexterity in product development and establishes the role of IT as an antecedent of ambidexterity. Next, it hypothesizes the relation of ambidexterity to product development performance, along with the mediation role of ambidexterity between IT and performance. The paper next includes the empirical analysis that test and support hypotheses, to conclude with a discussion of the empirical findings.

2. MANUFACTURING CHRONOLOGY

Agrarian Period

The advent of supply chain support for manufacturing occurred long before the term was coined in the 1980s. Artisans represented some of the first innovators of products required by customers. Their production shops consisted of relatively small, family-oriented (organic) firms with flat hierarchies. Limited product inventory necessitated long lead-times, relatively low production volume, and a high level of product quality, requiring a moderately-high degree of skill from craftsmen (Skinner, 1985). Workers typically experienced good job satisfaction, interfaced routinely with customers, and actively participated in both product design, and completion. In this setting, demand depended on repeat customers and referrals based on product quality. Reuse of materials took place with very little waste generated. Suppliers consisted of select firms with close working artisan relationships. Consumers tended to reside within close proximity, accepted lengthy lead-times for orders, and possessed high levels of product satisfaction.

Industrial Revolution

The Industrial Revolution (Table 1) arrived when technology facilitated a change from a craft-based society to an industrial one (Skinner, 1985). During this era the establishment of high-volume production with capital-intensive use of machinery and assembly lines utilizing command and control logic took place (Nahm & Vonderembse, 2002). Geographic regions shifted from agrarian to industrial. A corresponding growth in the domestic market enabled firms to mass-produce standardized products at a lower cost, thriving in a homogeneous national market where all competitors had access to similar resources and supplies. As the supply of manufactured goods expanded, there was a corresponding increase in demand from consumers. However, product selection was reduced in scope (Nahm & Vonderembse, 2002), with a greater emphasis on price and product availability.

Market segments were large and stable. Leading manufacturing firms focused on economies of scale, efficiency, and the reduction of operating costs, while specializing in one product at a time, which resulted in the use of standard supply chains. These firms usually had vertical hierarchies, with established inorganic (mechanistic) structures (Skinner, 1985). Manufacturers typically produced standardized products in mass volume with somewhat narrow product lines, long production runs, and greater lengths of time required for equipment changeover for new products.

Minimization of waste was based on economics with little/no attempt to reduce environmental pollution resulting from manufacturing (Sarkis et al, 2011). Suppliers were viewed as non-integral and multiple supplier sources were sought to keep competition strong and margins low. Confronted with rapidly changing market conditions from both customer and supplier

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perspectives, firms faced a paradigm change from industrial systems (focusing on mass production and reduced cost) to post-industrial systems (focusing on quick response for a variety of high-quality products, with varying customer demands).

Post-Industrial Revolution

As the economy shifted from industrial to post-industrial due to improvements in technology (Table 1), the scope of products expanded and the man As the Post-Industrial Revolution progressed, enhanced consumer knowledge facilitated corresponding increases in both turbulence and complexity in the market (Huber, 1984). Societies became more affluent and modernized and consumers became more discriminating and demanding (Doll & Vonderembse, 1991), seeking lower cost, better quality, enhanced availability, and greater product variety. Consequently, horizontal and vertical integration, along with flexible manufacturing technology (FMT), and lean/time-based manufacturing practices evolved (Tu et al, 2001). Efficiency no longer dominated the efforts of competing firms and consumer expectations extended beyond cost, quality, and responsiveness (Duclos et al, 2003; Moore & Babu, 2008; Pagell & Wu, 2009). Supply chain complexity increased where competition no longer occurred between large individual firms, but amongst supply chains themselves (Li et al, 2005). Adjustments enabled firms to modify their processes to accommodate changes, including short life cycles, and differentiated products (Moore & Babu, 2008; Nemetz & Fry, 1988; Vonderembse et al. 1997). These expansive changes established the foundation for transition of manufacturing towards green supply chains. ufacturing base extended from national/near shore to global. Firms competed in heterogeneous global markets while competitors had access to a variety of resources and strategies (Vonderembse et al. 1997).

Market segments were both narrow and constantly changing due to increased uncertainty. New products were introduced with greater speed in addition to comparatively shorter product life cycles. In order to enhance stability, leading companies focused on broadening their portfolios by seeking more expansive ranges of products, along with short production runs and relatively quick change-over time required for product switches (Nahm &Vonderembse, 2002).

During this period Lean, Agile, and Hybrid supply chains emerged (Moore & Babu, 2008; Sarkis et al 2011). In order to accommodate increased complexity, lean/time-based manufacturing practices (TBMP) occurred enabling firms to eliminate waste, increase speed and enhance flexibility establishing the foundation for customization of responsiveness, cost-effectiveness, and demand volume adjustment (Tu et al, 2001). Economies of scale took a secondary position, while those of scope became one of the main drivers for manufacturing a wide variety of products, quickly and economically to meet customer demands. Firms had more flattened hierarchies with organic structures. The view of suppliers changed from one of a cost burden necessity to an extension of the manufacturing process and integral sustainability component.

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Table 1 Manufacturing Chronology

Time Frame	Era	Supply Chain Type	Firm Characteristics	Mfg. Focus	Env. Focus	Technology	References
Before 1780	Agrarian	Standard	Small, organic, horizontal hierarchy, depended on quality of product to sell.	Economy of Scope	Tendency to reuse all materials	Agrarian, Craftsman, manual	Skinner, 1985
1780 - 1840	Industrial Revolution	Standard shifting towards Lean	Greater production achieved, but constrained by limitations of small-scale transportation, limited power, and flexibility.	Economy of Scale	Minimal reflection on adverse environ. effects of waste. Main focus on reduction of waste from an economic standpoint	Harnessing of water and steam energy enabled mechanization	Skinner,1985; Nelson, 1975
1840 - 1850			Advances in metalworking and production enhanced flexibility			Interchangeable parts developed to enable quick repair during production.	
1850 - 1890			Mass production where efficiency dominates. Substantial advances in technology			Massive, rapid changes in technology. High-volume production with interchangeable parts.	Skinner, 1985; Chandler, 1977; Nelson, 1975
1890 - 1920			Industrial expansion in size, variety, complexity, diversity.			Systematic controls focusing on complex mkts.	Skinner, 1985
1920 - 1960			Increasing consumer requirements in latter period	Economy of Scale and Scope.	Growing need recognized	Automation took place in late 1950s.	Skinner, 1985
1960 - 1980	Post Industrial Revolution	Lean, Agile, Hybrid	Consumer demand increases for variety, timeliness and cost, driving greater market complexity	Economy of Scale and Scope with focus on latter	US EPA established followed by strong focus on pollution prevention and mitigation strategy in each state	New systems - Just-in-Time (JIT)/Kanban greatly improve product quality and delivery	Skinner, 1985
1980 - Present		Agile, Hybrid, then a shift towards Green	System design shifted towards consumer needs and paradigm changes from linear/sequential to parallel, integrative, and systematic. Move to integration across production chains, with flat organizations. Automation used only for added value.			Info. exchange becomes critical as single mfg. syst. produces large variety of different products. Integration more important than automation.	Skinner, 1985; Petrie, 1992; Susman, 1992; Vonderembse1997; Rao, & Holt, 2005 ; Sarkis et al, 2011

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3. SUPPLY CHAIN EMERGENCE

Different types of supply chains emerged progressively according to consumer influences, market demands and changes in technology – Standard, Lean, Agile, Hybrid, and Green. There were no distinct boundaries amongst them due to varying degrees of overlap. As supply chains evolved they were distinguished according to the type of products manufactured: Standard, Innovative, Hybrid, and Green (Fisher, 1997; Vonderembse et al 2006). Table 2 illustrates a framework categorization of supply the various chain types by product type and stage of the product life cycle (Vonderembse et al, 2006). Product life cycle in this paper is defined as the complete lifespan of a product, from cradle to grave, including all costs (burdens) and benefits based on the product.

Table 2 Supply Chain Classification based on Product Type and Life Cycle Phase
(Adapted from Vonderembse et al., 2006)

<table>
<tr><th>Authors</th><th>Definition</th><th>Conflicting demands</th><th>Definition</th><th>Definition</th></tr>
<tr><td>Product Life Cycle Phase</td><td>Standard</td><td>Innovative</td><td>Hybrid</td><td>Green</td></tr>
<tr><td>Cradle
(Design, Inception)</td><td rowspan="5">Lean Supply Chain</td><td rowspan="3">Agile Supply Chain</td><td rowspan="5">Hybrid Supply Chain</td><td rowspan="6">Hybrid Supply Chain with Green Focus</td></tr>
<tr><td>Introduction</td></tr>
<tr><td>Growth</td></tr>
<tr><td>Maturity</td><td rowspan="2">Lean Supply Chain</td></tr>
<tr><td>Decline</td></tr>
<tr><td>Grave
(Recycle, Reuse, Reverse Logistics)</td><td>Optional</td><td>Optional</td><td>Optional</td></tr>
</table>

The product life cycle is subdivided into six phases (Rebitzer, & Hunkeler, 2003; Rebitzer, et al, 2004). The initial phase (Cradle) encompasses inception, design, acquisition of raw materials and general factory setup for manufacturing. This is followed by Introduction, accommodating either a new requirement (innovative product) or existing need (revision of standard product). The next phase entails growth of product, reflecting high demand, and increased consumer acceptance leading to improved market share. At that point, competitors try to imitate the Innovator's product. This phase evolves into one where product maturity occurs, and competition imitates the Innovator's products with facsimiles at a lower cost. In the Decline Phase, consumer demand is reduced, resulting in lowered sales and decreased margins. By this time, more innovative (incremental) replacement products have entered the market and product sales taper off. The final phase (Grave) reflects several overlapping issues, such as product and component reuse/recycle, waste streams, legal liabilities, as well as potential penalties for disposal.

Table 2 also categorizes several types of products with differing design and demand schemes depending on their relative phase in the Product Life Cycle. Standard products reflect stable demand exhibiting slow changes in both design characteristics and production requirements over time, where purchases tend to be periodic, rather than continuous (Fisher, 1997; Vonderembse et al. 2006). During this timeframe, products range from commodities to small electrical appliances, where appliances tend to be in the latter part of the growth segment of their product life cycle. Innovative products are relegated to unstable designs, changing customer needs, reflecting new/derivative products, requiring continuous customer contact often found at any stage of the product life cycle. Hybrid products tend to be more complex, ranging in the number of components required. Green products can be considered the most complex since they not only require a hybrid base to achieve economy of scale and scope, but also must be certified as environmentally compliant. In addition to a brief introduction of the standard supply chain, three supply chains are reflected on - lean, agile and hybrid, with regard to their product types (Vonderembse et al., 2006). This is followed by a discussion of green supply chains.

Standard Supply Chain

Supply chains developed as businesses found that they couldn't provide all the requirements for manufacturing and transporting their products. With this reality, the necessity for suppliers occurred. The first supply chains, for lack of a better term, were referred to as standard where the focus was to produce what the customer wanted, with little regard to flexibility, or conservation of resources (Beamon, 1999; Lummus & Vokurka, 1999).

Lean Supply Chain

The premise of this chain reflects a concern for continuous improvement, elimination of waste and non-value steps along the chain. Generally, internal efficiencies are sought via setup time reduction, and cost-effective production of small quantities. The focus is simplicity, cost reduction, quality and limited flexibility (Vonderembse et al. 2006). This form of supply chain evolved into a variety of niches competing for production with a range of volume and the capability of satisfying multiple market segments. However, lean SCs may be too brittle to withstand unanticipated disruptions, as experienced with the SC disruptions seen following the 2011 Japanese earthquake and tsunami (The Economist, 2011; Moore & Babu, 2008). Standard products would be delivered by this supply chain for all stages of the product life cycle, whereas, innovative products would be designed and produced in the maturity and decline stages (Fisher, 1997). Generally, reuse and recycling of product components in the grave stage would be based on profit options.

Agile Supply Chain

This type of chain emerged to better accommodate market disruptions (Moore & Babu, 2008), reflecting the interface between companies and markets, acting as an external perspective on flexibility (Vonderembse et al. 2006). The primary foci are on responding to unpredictable market shifts while capitalizing on them through fast delivery, in addition to lead-time flexibility utilizing new tools, and technologies to resolve unanticipated issues. Integral to this is reliance on electronic data interchange, and knowledge-based systems. In this scenario virtual organizations are formed based on customer needs. Innovative products are produced in both the introduction and growth stages characteristics of a standard product evolving as maturity occurs. Recycling of product components in the grave stage are based on profit options.

Hybrid Supply Chain

This chain type is indicative of a combination of Agile and Lean Supply Chains. A Hybrid chain acts as an intermediary exhibiting the logic of 'assemble to order' transporting products which have been forecast with relative accuracy (Vonderembse et al. 2006). In this type of manufacturing, production differentiation is postponed until final assembly, thereby reducing cost. Hybrid Products are designed and produced by Hybrid Supply Chains throughout the demand/sales phases due to their complexity. Product component re-introduction into the final (grave) stage is based on economic feasibility. To integrate green products, the Green Supply Chain evolved, following similar logic of the Hybrid Supply Chain, with additional requirements encompassing environmental compliance (Srivastava, 2007) throughout the entire lifespan of the product from inception/design (Cradle) to disposal/reuse (Grave).

Green Supply Chain

Several green supply chain interpretations exist, which all revolve around the concept of improving environmental performance along the chain (Srivastava, 2007; Zhu & Sarkis, 2004). In this paper, the Green Supply Chain is approached as evolving from a Hybrid one, with a goal of continuous compliance of all relevant environmental regulations in addition to mandates for development, manufacturing, use, recycling, reuse, and re-introduction of products. As such, all parties and benefits/burdens are considered, including society, environmental impact, and economic, i.e., Triple Bottom Line (Pullman et al, 2009: Sarkis et al, 2011). For this type of chain, reuse and recycling of product components in the final stage would be mandated by government and/or acted upon voluntarily by the firm.

4. GREEN SUPPLY CHAIN EVOLUTION

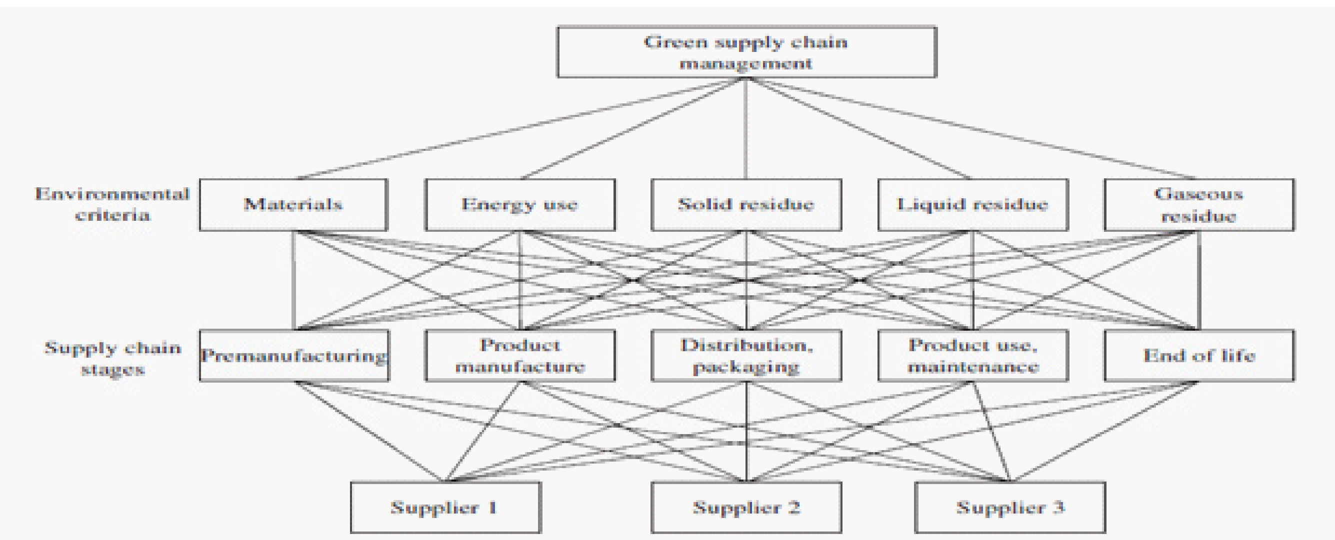
Management

To be successful, all supply chains need to be managed, typically by the focal firm. From an organizational theory standpoint, when environmental consequences impact the focal firm, the welfare of the entire supply chain is also affected (Simpson et al, 2007). Traditional supply chain management focused on cost, efficiency, and product variety with low regard to environmental consequences, such as adverse ecological impacts (Sarkis et al, 2011; Simpson et al, 2007). Over time, government environmental regulations have changed this considerably, resulting in the need for manufacturers to regard not only adverse impacts of processes (taxes, penalties), but also the financial and social benefits of reusing and recycling product components (Curkovic & Sroufe, 2011; Gavronski et al, 2008;). Over the past 15 years, the concept of closed-loop supply chains has emerged, reflecting the profit recovery of value-added components, product reuse, and business opportunities in recycling (Guide & Van Wassenhove, 2009).

The environmental movement in the United States was catalyzed in the late 1960s due to increased consumer concern about degradation, resulting in the formation of the Environmental Protection Agency in the early 1970s, with the directive of enforcing regulations covering industrial manufacturing of all firms along the supply chain (Carson, 1962; Sarkis, 2011). As environmental regulations were promulgated, strictures began to impact manufacturing processes and logic. These resulted in an increasing need for the application of environmentally-sound decisions in Supply Chain Management (SCM), shifting planning from reactive to proactive. Consequently, environmental performance standards have become increasingly incorporated into contracts and guidelines for supply chain partners (Simpson & Samson, 2007). A firm's response to the environmental requirements of external stakeholders is directly influenced by their level of commitment related to both environmental awareness and performance. In such environmentally-based scenarios the supplier-customer relationship is impacted by both existing transaction cost requirements as well as environmental commitment of both entities.

Responding to growing needs for environmental compliance, Green Supply Chain Management (GSCM) evolved, reflecting an integration of environmental thinking. GSCM entails a comprehensive perspective, including product design, material sourcing and selection, manufacturing processes, delivery of final products to the consumers, as well as end-of-life management of the products (Srivastava, 2007). According to Srivastava and Lu et al. (2007), Green Supply Chain Management is growing in importance and driven by increasing environmental degradation, diminishing natural resources, and rising pollution levels. As such, Green Supply Chain Management is based on various environmental criteria interlinking with supply chain stages that both stem from and interact with all suppliers along the chain (Figure 1).

Figure 1 Green Supply Chain Hierarchies
(Lu et al., 2007)



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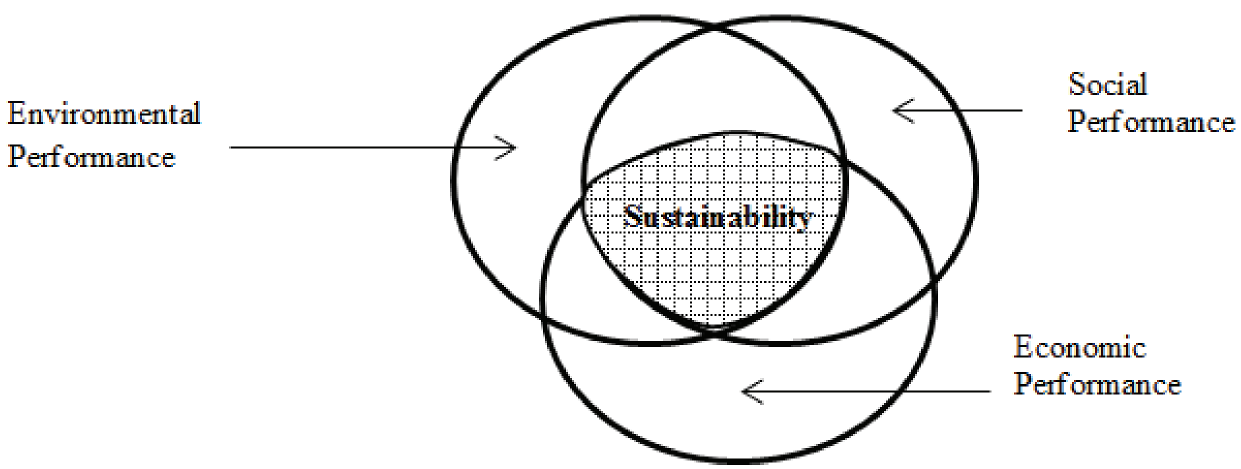
Historically, supply chain focus had been on cost, and efficiency, with little regard to issues concerning waste and environmental consequences. Green supply chain management now incorporates the entire chain housing personnel with a full range of expertise in prevention and mitigation of environmental issues, as well as reducing the liability of the manufacturing firm. This expertise is developed by focusing on the use of ecologically-sound practices and procedures, achieving societal endorsements for the firm's products and services, in addition to maintaining economic viability, while promoting the concept of green products. In effect, this houses the Triple Bottom Line (Sarkis et al, 2011). According to the Institute of Supply Management (ISM) this also encompasses the definition of sustainability (ISM, 2008).

As firms and supply chains increased in size and complexity, they also tended to seek pathways towards sustainability. The primary goal of a sustainable supply chain is to shift from services and products that negatively impact the environment to those embracing environmental principles (Curkovic & Sroufe, 2011). Pagell & Wu (2009) concur, and also add balancing economic and social principles as a valuable goal. The more sustainable suppliers there are in the chain, the greater the potential for full integration of sustainable practices along it.

There are mutual benefits amongst the suppliers and focal firm. Suppliers benefit when environmentally-relevant goals are embedded into contracts. The focal firm's knowledge is often imparted to suppliers, facilitating compliance, and resulting in education about product-specific environmental issues (Simpson et al., 2007). Shared knowledge provides an opportunistic venue for the focal firm, suppliers, and other partners along the supply chain. Such sharing of knowledge is valuable to the firm, enabling the development of a more responsible company (Cruz, & Matsypura, 2009; Sulkowski & White, 2010).

The practice of corporate social responsibility (CSR) has emerged where the firm voluntarily reports their environmental, social, and economic impacts, also known as the Triple Bottom Line (Pullman, 2009; Sarkis et al, 2011). This policy has a positive effect on consumer attitude towards the firm which correspondingly helps enhance financial support of the firm's products/services. As can be seen in the following figure, the Triple Bottom Line reflects the intersection and overlapping of social, economic, and environmental performance (Carter & Rogers, 2007).

Figure 2. Sustainable Supply Chain Management (Carter & Rogers, 2007)



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Lamming et al (1999) previously discussed environmental soundness as part of a firm's corporate strategy with a similar figure. They discussed the three dimensions of Environment, Economics and Social as broad elements of sustainable development. The area of opportunity for environmentally sound development was exhibited in the center. Carter & Rogers (2007) developed this concept further into a discussion of sustainability and supply chain management. In the center is the overlap (sustainability), where all dimensions benefit from optimizing the supply chain's competitive advantage. This perspective corresponds with Pagell & Wu's (2009) sustainability discussion, where they posit that SC performance metrics should not be restricted to profit alone, but should also encompass the impacts to ecological and social systems. When overlapping areas of environmental/social performance exclude economic performance it can be costly to the firm since these dimensions do not always incorporate financial considerations. According to Carter & Rogers (2007), the overlapping areas of economic/social and economic/environmental do tend to benefit the supply chain, but not optimally, since they pose more risk to the supply chain than when all three dimensions overlap and sustainability is achieved.

Optimization of this comprehensive perspective makes sense since the firm's sustainability initiatives and corporate strategy throughout the supply chain must be in alignment. If not, separation of programs and activities can result in reduction of transparency and differing departmental directives, introducing constraints to sustainability. Due to global communication, social networking and the Internet, corporate transparency is increasingly sought after by consumers, when reflecting on the social dimension of the Triple Bottom Line. Carter & Rogers (2007) contend that transparency not only apprises stakeholders of potential environmental, social and economic impacts, but also elicits their feedback. Such interaction and information exchanges better facilitate buy-ins from the consumers, as well as improve supply chain processes.

Consumers also seek product/service certifications reflecting adherence to proper working conditions, and labor law compliance from businesses where they elect to purchase products and services (Pagell & Wu, 2009). Socially-responsible firms employ certification pursuit as a standard operating procedure, even though it may reduce their short-term profit margin. Not all firms seeking pathways of supply chain sustainability place profit maximization as an ultimate goal. Corporate culture, core values and a sense of purpose act as the driver above and beyond the economic bottom line encompassing all firms along the chain with an underlying premise of an eco-centric view where the company takes into consideration its relationship with the broader social and natural environments (Carter & Rogers, 2007; Pagell & Wu, 2009).

Components

In accordance with the evolution of the green supply chain there are complementary, yet overlapping, components necessary to ensure environmental neutrality of the manufacturing and delivery system (Srivastava, 2007). Green supply-chain management stems from both Supply Chain Management literature and Environmental Management literature. Srivastava posits that with the addition of a green component, the influences and relationships between Supply Chain Management and the natural environment are intertwined (Figure 3).

Green Design has been presented in the literature to differentiate and distinguish the development of products with specific environmental considerations while encompassing a systematic approach (Srivastava, 2007). This type of process is pro-active versus the traditional method of dealing with environmental issues after the fact, in a reactive, less efficient manner (Curkovic & Sroufe, 2011; Vachon & Klassen, 2008). Prior to the manufacturing and assembly of each component part, green design specifies the process of environmental compliance related to appropriate standards, such as governmental, and voluntary industry standards such as ISO 14001. Adopted in 1996, this international standard has become a major focus for the development, implementation and maintenance of a formal Environmental Management System with a long-term focus (Curkovic & Sroufe, 2011). According to Srivastava, green design includes an array of disciplines in a variety of fields in addition to product design, such as risk management, environmental compliance, product safety, worker safety/health, pollution prevention, resource conservation and waste management. Green design therefore leads to green operations.

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throughout a product's life cycle, it is not a panacea since there are hurdles to overcome. However, many of these are short-term constraints, which will dissipate over time as the 'green' philosophy permeates the firm's culture and business logic. Indeed, one of the benefits of the green supply chain is the comprehensive perspective required for appropriate application and implementation. Using a comprehensive product and supply chain perspective allows manufacturers and stakeholders to address triple bottom line issues over a product's development, use, and post-life, facilitating the pathway towards sustainability of the supply chain.

Additionally, Vachon & Klassen (2006) discuss focal firm and supplier collaborations with respect to requirements for environmental compliance, from both mandatory and voluntary perspectives, such as ISO 14001 (Curkovic and Sroufe, 2011). Vachon & Klassen (2006) suggest that collaborative environmental efforts enhance interactions amongst members of the supply chain in ways that reduce overall environmental impacts. They offer that a smaller supplier base may correspond to increased environmental collaboration, which seems plausible if the smaller base of suppliers is easier to manage with goals consistent with the focal firm. Supplier interactions often include joint planning sessions, knowledge sharing, consumer involvement, and green product design. Some leading firms have already implemented similar supply chain stakeholder collaborative projects addressing environmental issues, such as monitoring greenhouse gas emissions (Wal-Mart), incorporating consumer environmental concerns, particularly the use of toxic chemicals, into purchasing, materials handling, and inventory decisions (Anderson Corporation), and working with suppliers on process developments to reduce waste (Clorox) (USEPA, 1998; USEPA, 2000; Walmart.com, 2007).

This logic of transparency and collaborative interaction contrasts with the historical view of environmental requirements as being a burden on the firm (Vachon & Klassen, 2006). Vachon & Klassen (2006) found that a collaborative customer-supplier relationship can lead to environmental performance improvements and better product/service positioning for both the customer and suppliers. One of the reasons for these improvements is that consumers are now more knowledgeable about the environmental infractions of businesses. When this takes place, they are then able to place increasing pressure for compliance on not only the companies they seek to utilize, but all firms. This pressure affects both suppliers and the focal firm. It then follows that as relationships between suppliers and the focal firms lengthen and mature, increasingly stringent environmental requirements are incorporated into the supply chain, enhancing the focal firm's goals in their pursuit of sustainability pathways.

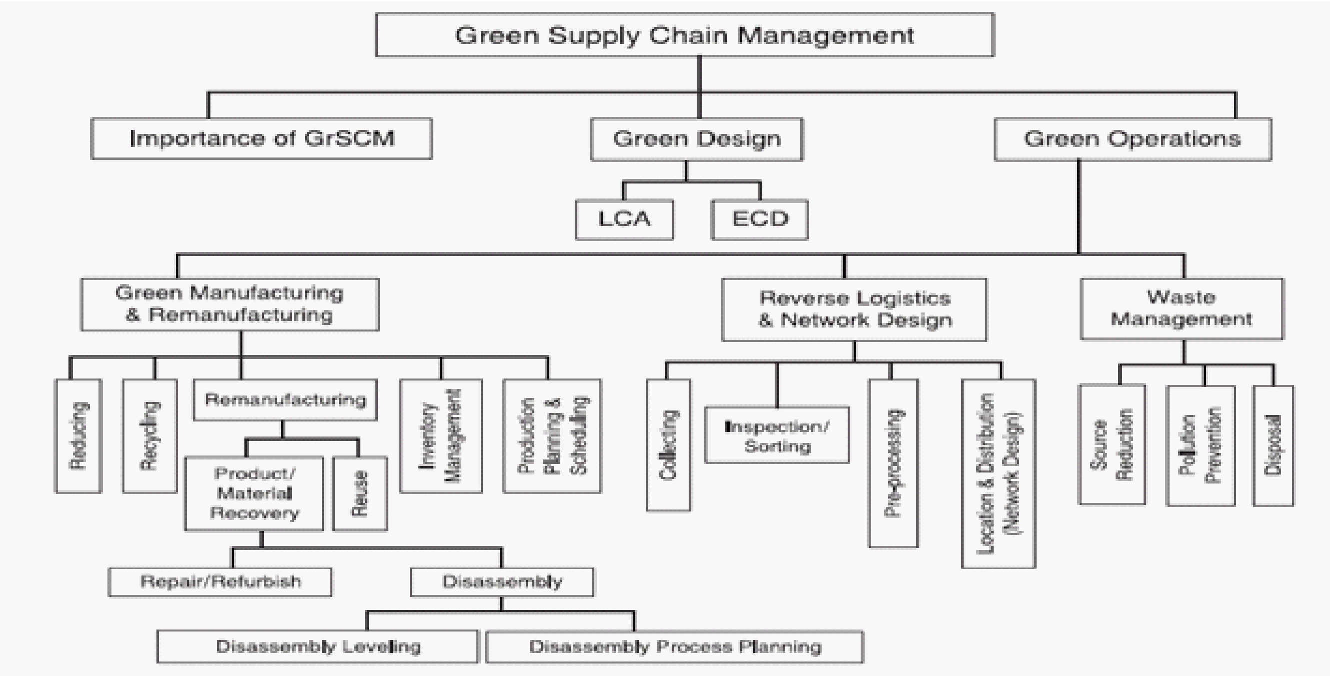
Environmental regulation stringency has increased over time and will continue to do so, due to growing consumer awareness of ecological degradation and government strictures (Carson, 1962). With this in mind, today's managers can benefit from investigating, encouraging and implementing a collaborative process with regard to all stakeholders along the supply chain. Pagell & Wu (2009) concur, stating that managers need to increase their awareness of all supply chain stakeholders, in addition to improving efficiency, and pursuing enhancement of natural, social and economic capital.

The precepts of a Green Supply Chain are not solely relegated to firms seeking to address and improve compliance of environmental standards. Implementation of them, as found both in waste reduction strategies and product design improvement, will not only facilitate resource conservation, but also increase potential for profitability (Pullman et al, 2009). A working example can be found in the reduction of hazardous material, and operational assessments to optimize remanufacture opportunities. Such efforts can profit both manufacturers, as well as partners along the supply chain. Beneficial, synergistic relationships can take place amongst all firms along the supply chain by implementing such precepts to enable productivity, improve, economic conditions and profit, as well as facilitation of good environmental performance. The end result would be achievement of the pathway towards sustainability and the Triple Bottom Line.

6. CONCLUSIONS AND FUTURE RESEARCH

Supply chains progressively developed during the Agrarian Period, Industrial Revolution, and Post Industrial Revolution into the more complex systems found today. At first they were somewhat simple, with only a few suppliers, competitors and customers. As the Industrial Revolution took place, SCs became more complex, focusing on efficiency and economy of scale, with little regard for the effects of environmental pollution. Eventually, technological

Figure 3 Classification Based on Problem Context in Supply Chain
(Srivastava, 2007)



Green Operations have a specific focus – the reduction of ecological burdens (Figure 3). These include all aspects for product manufacture/remanufacture, usage, handling, logistics, and waste management after production including re-use, recycle, and closed-loop supply chain logic (Srivastava, 2007). Green manufacturing reflects the use of appropriate material and technologies. Remanufacture pertains to how worn-out products are restored to like-new condition with a focus on reducing environmental burden.

During manufacturing, each supplier along the chain is required to conform to all environmental stipulations by the focal firm. After manufacturing, final assembly takes place and compliance confirmation occurs, such as with eco-labeling. When final assembly takes place, green products are delivered to customers with assurance of state-of-the-art compliance, along with governmental, and industry criteria standards. It follows that good product stewardship is integral to green operations which embrace sound environmental management principles, thereby facilitating supply chain sustainability (Vachon & Klassen, 2006).

Inherent within such operations are three of the Supply Chain Business Processes discussed by Lambert & Cooper (2000), encompassing customer relationship management (CRM), customer service management (CSM), and supplier relationship management (SRM). These processes are customer-focused reflecting a set of activities intended to produce specific value outputs for the customer. CRM seeks to identify consumers who are critical for the firm's operational success; whereas, CSM has been found to be integral in assisting customers with their specific product applications. In SRM, suppliers are also believed to have an important role in supply chains, such that in well-managed chains the focal firm will seek long-term alliances with a core group of them. These coalitions not only optimize the exchange of information, but also facilitate product improvement and development to better accommodate directives from consumers.

5. MANAGERIAL IMPLICATIONS

Today's managers could benefit from a close examination of their product/service type and range to ensure a good fit with the Triple Bottom Line and their supply chain. As noted by Pagell & Wu (2009), there is no definitive set of practices managers can apply towards pathways of supply chain sustainability. Pagell & Wu (2009) contend that managers not only need to be continuously cognizant of sustainability goals, but also to impress upon everyone in the firm that sustainability is a daily operation at every level of the firm. Although the green supply chain can apply changes led to the Post Industrial Revolution where manufacturing shifted to accommodate growing customer demands for improved variety, economy of scope, and time-to-market. Environmental accountability followed, reflecting economic benefits, as well as those for the society (Triple Bottom Line)

Two major drivers influenced accountability of environmental pollution: consumers and the federal government. During the 1960s, due to the efforts of Rachel Carson (1962) and other groups concerned about environmental pollution issues, the Environmental Movement commenced which was then followed by promulgation of the Environmental Protection Agency in the early 1970s. Additionally, as consumers became more affluent and knowledgeable about environmental degradation, they increased demand for green products and corporate accountability, which was consistent with government environmental strictures. Green Supply Chains then evolved.

Greening a supply chain is no longer considered a costly burden since benefits have been shown to take place from both the overall focus and monetary investment in them. Rao & Holt (2005) found that when greening of production takes place, a minimization of pollution occurs saving raw materials, water, and energy. The greening of production also facilitates competitiveness and economic performance of the firm with improved sales, enhanced market share, along with the ability to exploit new market opportunities, and achievement of better profit margins. Consequently, firms with a solid foundation in green production not only enhance their competitive advantage, but also are less likely to be imitated by competition. With knowledge about Green Supply Chains, management is better positioned to exploit opportunities provided by them while focusing on green products to accommodate growing consumer demand, and environmental compliance.

Future research could reflect on green supply chains and sustainability from a Resource-Based View (RBV), as discussed by Barney (1991), positing that firms with valuable, rare, inimitable, and non-substitutable (VRIN) resources have greater potential for achievement of sustainability. Understandably, some supply chains will have more stringent requirements to achieve a 'green' product/service. Given such constraints, an exploration of whether or not their inimitability may, indeed, be more secure could offer better insight into long-term sustainability. Given that, one approach could be to develop a rubric to categorize a scale of potential inimitability based upon the type of industry, extent of constraints and facilitators.

Other research directions could reflect on the necessity of the more dynamic processes required to adjust to rapid changes necessitated by Green Supply Chains and whether or not RBV could accommodate them. When rapid changes occur, the resource mix may need to be adjusted with dynamic capabilities in order to continuously maintain competitive advantage (Ambrosini et al, 2009).

Another area of future exploration could be investigating the role of Absorptive Capacity (AC), which enhances competitive advantage and is based on knowledge resources (Malhotra et al, 2005). Exploring the role of AC in Green Supply Chains is warranted since the basic premise of AC is knowledge selection and transfer, which these chains require in order to meet changing consumer requirements. Notably, Absorptive Capacity enhances employee creativity, planting the seed for both new concepts, and products. Future exploration could help differentiate not only the types of employees to seek, but also the varieties and scale of green firm production necessary to compete effectively and longitudinally.

Even in dynamically-changing environments, sustainability is integral for firm survival. Knowing this, additional research could also be performed to define/distinguish appropriate guidance and expectations necessary in order to identify where to not only seek/monitor results of sustainability initiatives, but also how to best respond in order to support/foster sustainability (Pullman et al. 2009).

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AUTHOR'S BIOGRAPHY

David M. Nelson - PhD Candidate in the Department of Information Operations, and Technology Management at the University of Toledo with expected graduation in fall, 2013. The dissertation is Antecedents and Triple Bottom Line Consequences of Green Supply Chain Strategy. Dave earned an MS from the University of the Pacific, an MBA from Purdue University. His research interests reflect Supply Chain Sustainability, Green Supply Chain Strategy, Triple Bottom Line and Corporate Social Responsibility, Mr. Nelson has authored papers in the International Journal of Logistics Systems and Management, Journal of Operations and Supply Chain Management, Biodiesel and an Alternative Energy study under the auspices of the U.S. Department of Transportation.

Erika Marsillac - Assistant Professor of IT/DS/MSCM at Old Dominion University. She received her PhD in Manufacturing Management from the University of Toledo, and holds a BA from Pennsylvania State University, and two MBAs from Goldey-Beacom College. Her research interests include green supply chain management, sustainable manufacturing, and international partnerships. She has published in the Journal of Manufacturing Technology Management; Journal of Operations and Supply Chain Management; International Journal of Technology, Policy and Management; International Journal of Logistics Systems Management; Electronic Journal of Business Research Methods; Performance Improvement Journal; and Social Responsibility, Entrepreneurship and the Common Good.

S. Subba Rao - PhD. in Operations Research and recently retired as Professor of Information, Operations and Technology Management at The University of Toledo where he served as the Director of the Ph.D. program for several years. With research interests encompassing Operations Research/Management, Modeling, Quality, and Supply Chain Management, Dr. Rao has authored over 60 papers in global publications: Operations Research, Naval Research Logistics Quarterly, Journal of Optimization Theory and Applications, IEEE Transactions, Journal of Applied Probability, OPSEARCH, Total Quality Management, Journal of Quality Management, OMEGA, European Journal of Operations Research, and International Journal of Quality and Reliability, as well a comparable number of publications in conference proceedings, presentations and technical memoranda.