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Supply chain innovation: A conceptual framework

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This paper is a first step in our research to understand the role of innovation in supply chain management, and it is intended to serve as a starting point for understanding and examining the concept. Please do not distribute or quote from this paper without prior approval of the authors. Please contact Antonella Moretto at amoretto@mit.edu or James B. Rice, Jr. at jrice@mit.edu or 617.258.8584 if you have any questions.

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Abstract

In today's supply chain domain, there is a lot of attention focused on the concept of 'supply chain innovation.' This introductory paper aims to start a discussion about supply chain innovation, and as a first step we propose a conceptual framework for understanding the important factors that appear to affect the creation and implementation of innovation in the supply chain. Additionally, we have collected an assortment of examples that may serve as examples of supply chain innovation.

Ultimately, the objective of this new initiative is to identify the key elements that are driving innovation in the supply chain and provide insights to managers and researchers on productive methods for developing, introducing, and managing supply chain innovation.

1. Introduction

While innovation can be defined in many ways, most firms agree that it is essential to mitigating risk and improving future competitiveness (Pietrobelli and Rabbelotti, 2011).

Before venturing into supply chain innovation, it may be worthwhile considering various definitions of innovation. The *Cambridge Dictionary* defines the concept as "*the use of a new idea or method,*" while the *American Heritage Dictionary* describes it as "*the act of introducing something new.*" Industry publications offer a broad variety of descriptions and definitions. For example, Rogers (1995) notes: "*Innovation has been broadly defined as an idea, practice, or object that is perceived as new by an individual or other unit of adoption.*" For Drucker and Hesselbein (2002), innovation is

"*change that creates a new dimension of performance,*" while Baregheh et al. (2009) maintain it is "*the multi-stage process whereby organizations transform ideas into improved products, services or processes, in order to advance, compete, and differentiate themselves successfully in their marketplace.*" These are useful references for defining supply chain innovation although there is some debate about what constitutes 'supply chain innovation.'

Innovation can be considered along several different dimensions, two factors being the speed and locus of the innovation. Regarding speed, some innovations occur gradually over time, in contrast with other examples where both the rate of adoption and the impact are rapid. Whether gradual as well as rapid changes constitute innovation is open to argument; some have suggested that only radical and industry-disrupting changes should be considered as innovations, while others suggest that any change in the business operation falls within the definition of an innovation. Christensen (1997) added useful distinction to this discussion by proposing that innovation is driven by technologies that could be considered 'sustaining' or 'disruptive' technologies. One can consider using this framework for describing sustaining supply chain innovations as those that occur gradually over time, in comparison with disruptive supply chain innovations that occur rapidly. This may be a useful application of Christensen's seminal work.

The locus or environment of the innovation has been another factor or dimension. Innovation can occur in products, processes, technologies, organizations and in supply chains (Ulusoy, 2003). The majority of literature and study seems to relate to product innovation or changes in business structure driven by technological innovations. It is fair to say that while supply chain innovation is in demand and the subject of some discussion, the literature is not rich with useful and informed contributions.

Innovation in the Supply Chain

Supply chain innovation is emerging as a critical area for many companies. One research study conducted by Flint (2007) maintains that competing in process and supply chain is more sustainable than in products. This is due to the fact that resources allocated in supply chain generate more cost savings and have stronger impact in the long term, as opposed to the relatively high volatility of new product introductions. This viewpoint is also consistent with the definition of supply chain innovation of Bello et al. (2004), who assert that "*supply chain innovations combine developments in information and related technologies with new logistic and marketing procedures to improve operational efficiency and enhance service effectiveness.*" Over the past 20 years, the concept of innovation at the process level has been studied through diverse lenses and has taken on different names—such as change management (Voropajev, 1998), business process reengineering (Hammer, 1990), continuous improvement (Upton, 1996), and Kaizen (Imai, 1986). This demonstrates the relevance as well as the broad interpretations surrounding these topics.

But there seem to be additional elements that make it difficult to define supply chain innovation. Examining a number of potential innovations in the supply chain, it seems that there are several

instances that may qualify as critical innovations, which raises the question: where is the real innovation? Does it occur when the base technology is developed? Or is it when it is functionally applied to a new application that then changes the economics of the application? Perhaps it is when the practitioner is able to adopt the innovation and bring it to full-scale use. Does it matter if the innovation occurs upstream in the supply chain, perhaps created by suppliers rather than the company itself? RFID technology is often referred to as a supply chain innovation, but was it the invention of the base technology in the 1940s, the development of the first passive radio transponder in 1973, the first RFID patent in 1983, the dramatic reductions in cost or the application of the technology to tracking and tracing that serves as the core innovation? One can argue that each of these developments is an important and necessary innovation. For the interests of practitioners who are seeking innovations that can be applied to the supply chain, we believe it may make more sense to focus on the latter stage innovation aspects that affect supply chains – the application and scaling of the innovation – that ultimately results in impact, not just potential.

To make matters more complex, should one consider the adoption of known technology in proven ways as an innovation if it is new to the organization? For example, if a company elected to adopt cross-docking and found this improved their operations, should that be considered a supply chain innovation? Our intuition is to not consider that as a supply chain innovation; it surely is a change in management practice and process but not genuinely an innovation in the supply chain. We believe that a supply chain innovation would involve the adoption of **new** processes and technologies that result in change, not just processes and technologies that are commonly used in industry but 'new' to the organization.

Several examples of supply chain innovation inside major companies serve as useful illustrations. Caterpillar (CAT), for instance, differentiated its business on service parts availability, promising access to global parts that far exceeded its competitors. By creating an integrated network that permitted them to deliver spare parts anywhere on earth within 48 hours – none other had created such a network – CAT created a competitive advantage that was linked to the reduction of customers' equipment downtime. The core innovation for FedEx was the development of a hub-and-spoke system that enabled a new service offering that promised and delivered speed and reliability for package delivery. This development served an untapped market for rapid delivery, and arguably created more demand for the services as they became more affordable and reliable, adding value to customers with logistics—low-cost overnight delivery. Dell's make-to-order, customer-direct supply chain approach has had a disruptive impact on the PC industry by offering state-of-art products at lower costs with a dependable yet relatively high service level. Saturn (automotive OEM) elected to achieve preferred supplier status by offering excellent service levels achieved through the efficient management of its after-sales process. Apple, Ikea, Wal-Mart, Carrefour, Zara, HP, Benetton, and Amazon are just a few examples of companies that have used supply chain innovations to disrupt their industry and serve as an anchor for improved business performance. Despite all these success stories, however, a clear assessment of the core driving factors behind supply chain innovation has yet to be conducted.

2. Purpose of this research initiative

As noted above, this paper is the first step in our research to understand the role of innovation in supply chain management. The academic approach we have taken allowed us to undertake a thorough literature review and to explore definitions of the concepts involved. In the second stage of the research we will solicit input from practitioners to create a more detailed map of supply chain innovation, and seek to get to better understand the core elements that enable supply chain innovation.

Our analysis to date has helped to identify some preliminary research questions that need to be addressed. First, our initial effort aims to understand how supply chain innovations are created. It examines the systematic ways in which companies can identify and manage potential supply chain innovations. To that end, we pose the first research question:
How can companies systematically pursue supply chain innovation?

Second, our study intends to examine and learn from previous innovations in order to identify potential key factors and possible best practices that may be used more broadly in industry. For this purpose, we pose the second research question:
What are the key success factors and core components of supply chain innovations? Is there a conceptual framework that provides theoretical as well as practical insights?

Finally, several researchers point out that the critical phase of innovation is not in the "creation of ideas" but rather in the implementation of the innovation in practice. To address this issue, we pose the third research question:
How can managers implement supply chain innovation inside their companies to create impact?

3. Conceptual framework

As a starting point to consider these research questions, we developed a conceptual framework to catalogue, compare, and prepare an initial taxonomy of supply chain innovation. This could be a useful tool to compare and contrast different innovations as well as segment the various drivers, barriers, and critical elements to consider in pursuing supply chain innovation. Moreover, a preliminary list of supply chain innovations has been drawn up to describe what supply chain innovation has meant in the past.

Figure 1 illustrates the conceptual framework.

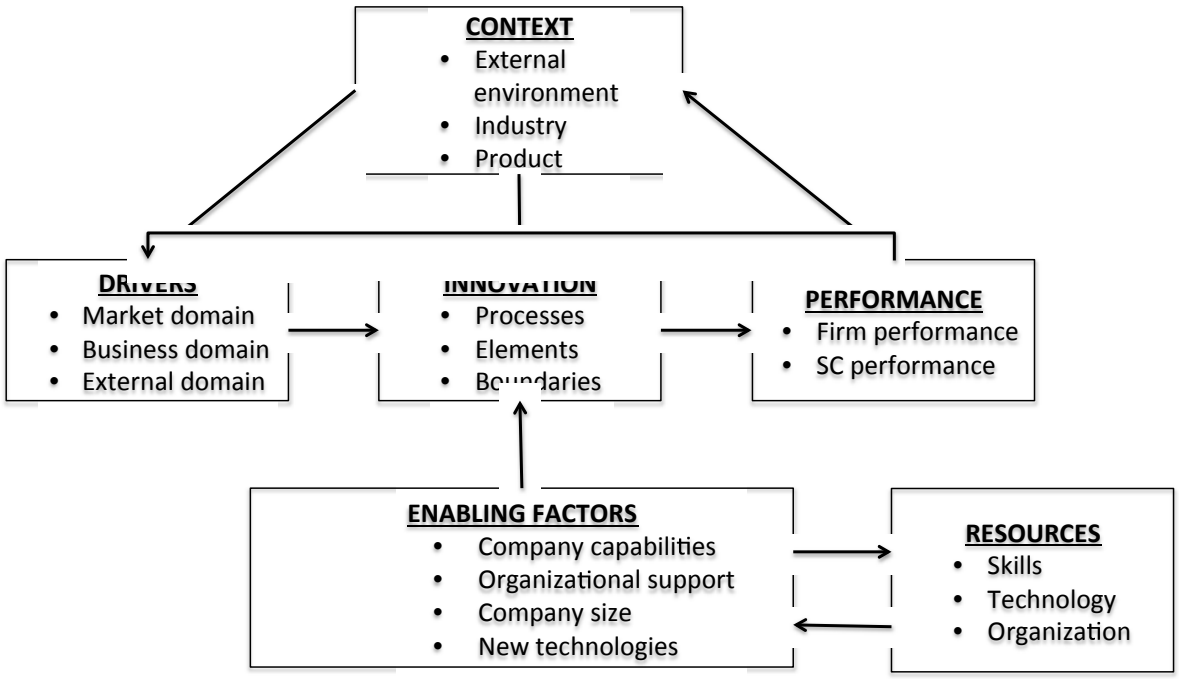

FIGURE 1: THE CONCEPTUAL FRAMEWORK

3.1. Key elements of the conceptual framework

The conceptual framework includes six key elements.

The drivers of supply chain innovation are the factors that motivate and in some cases force companies toward adopting innovations in the supply chain. The main **drivers** identified comprise three groups:

- ***Market domain*** – the globalization of markets. This implies competition that is no longer limited to local or regional environments, but instead takes place in global markets with global competitors (Roy and Sivakumar, 2010). Furthermore, this includes market uncertainty—those unpredictable changes in customer requirements, technological development, and the behavior of competitors (Li and Atuahene-Gima, 2002)—and is evidenced in the significant uncertainty following the 2008 financial crisis. It also includes sustainability, which is requiring many companies to reshape their supply chain to comply with emerging regulations and to stay in step with environmental, social, and economic progress (Zhu et al., 2011).
- ***Business domain*** – the product variety of the company. It serves as a proxy for the level of complexity—and for a crisis related to business policies rather than external factors—which the company must be able to handle to be competitive in the marketplace (Hoole, 2006; Roy and Sivakumar, 2010). In order to compete, the company may need to redesign or revamp its supply chain processes.
- ***External domain*** – the impact from external factors. This includes governmental support and stakeholder pressures. Innovation is achieved through financial incentives, financial resources, or training programs (Scupola, 2009; Tornatzky and Fleischer, 1990), and may require the supply chain to deliver specific capabilities.

Some authors address the importance of the external **context** of the company's competitive situation and its competition, as this context can influence the new investments and efforts necessary for a specific supply chain innovation (Bello et al., 2004). Based on previous studies, there are three main contextual factors:

- ***External environment*** – the characteristics of the country where the company operates (Bello et al., 2004; Pietrobelli and Rabellotti, 2011).
- ***Industry*** – some innovations have been especially applied in a specific industry (e.g., the introduction of efficient consumer response in the food industry, the introduction of quick response in the fashion industry, etc.).
- ***Product*** – both the core business of the company (e.g., product versus service) and the position in the product lifecycle (de Reuver and Bouwman, 2011).

Some studies have also analyzed the factors that make one company more inclined to pursue, adopt, and succeed at implementing supply chain innovation. These **enabling factors** are the elements that have the capacity to simplify and accelerate the introduction of supply chain innovations in the firm. There are four main enabling factors:

- ***Company capabilities*** – the skill level and competence of the employees (Ulusoy, 2003) as well as their ability to develop dynamic capabilities, such as the use of internal and external competencies to drive changes with a long-term perspective (Teece et al., 1997). Dynamic capabilities are said to create temporary advantages as well as long-term competitive advantages (Eisenhardt and Martin, 2000; Teece et al., 1997).
- ***Organizational support*** – the extent to which a company supports employees in adopting one particular technology or new system (e.g., incentives, technical resources, etc.) (Jeyaraj et al., 2006; Lee et al., 2005).
- ***Company size*** – the capability of larger firms to allocate resources to invest in supply chain innovation, suggesting more leverage is possible with firms that have more resources (e.g., Frambach and Schillewaert, 2002; Kimberly and Evanisko, 1981).
- ***New technologies –*** the new developments in hardware or software that may enable modifications in the process or industry structure, depending on the adoption and application. Many recognize that technology can enable a change in supply chain design and/or performance, but rarely does a technology constitute the change in and of itself. More often, modifications in the process and application are necessary to leverage the technology. For example, radio-frequency identification (RFID) is often said to be an innovation. However, the actual supply chain innovation was the change in tracking and tracing capabilities that was enabled, not the technology itself.

The fourth framework element concerns the **resources** available inside the company that could strongly influence the eventual development of the enabling factors mentioned above. In particular, we consider three traditional types of resources: ***skills***, ***technology,*** and ***organization***.

The fifth element of the framework is the actual **innovation**, or the characteristics that describe the specific supply chain innovation. We have identified three main elements of innovation:

- ***Processes*** – the supply chain processes involved in the specific supply chain innovation (e.g., Ulusoy, 2003). This entails adopting a concept of extended supply chain that includes all the processes, from product development to delivery of products to customers. Different types of innovation involve different processes of the supply chain—procurement, inventory management, demand management, order fulfillment, production, logistics and distribution, and product development.
- ***Elements*** – those elements influenced by the supply chain innovation. These include introducing a new technology to automate the process, a modification in the way internal processes are realized, a new product/service or the modification of an existing one, changing the internal micro- or macro-structure of the organization, new projects, and re-allocation of normal tasks among the internal actors/employees.
- ***Boundaries*** – a supply chain innovation can be introduced with different implications in the internal or external supply chain—or at the national or global level—through the involvement of suppliers and partners (Bello et al., 2004).

Finally, according to Rogers (1995), two of the main characteristics of an innovation are relative advantages. An innovation should be perceived as a favorable improvement compared to the previous situation or system, and it should be able to generate results that can be observed. Along with creating improvement and being observable comes the last element of the framework: **performance**. This includes two key components: ***firm performance*** (Roper et al., 2008)—labor productivity, sales growth, employment growth, and cost decreases; and ***supply chain performance***—cost, time, quality, service level, and flexibility.

3.1.1. A dynamic conceptual framework

In developing the framework and considering different factors, we propose that the framework is not static, because there are observable interactions between the framework elements. The performance of the firm will likely change the context of the environment. As a result of the early adoption of an innovation, the firm may gain a distinct new competitive advantage, and this advantage could change the context of the environment. For example, a firm with more market share may have greater profits, which can be used to fund additional investment in the adoption of the innovation. That, in turn, may increase the performance of the innovation.

A slightly different interaction between the framework elements could come as a result of recognizing a need. For example, if the enabling factors are not commensurate with the requirements for adoption of the innovation, the firm may need to acquire additional resources/technology or change policy/practice. This will modify the enabling factors such that the firm may then be able to adopt the innovation.

It is not surprising that the framework is not static, as the very thought of innovation suggests change. Further, in order to accommodate and adopt change, the system must change. Therefore, it is appropriate to consider that the framework operates as a system.

3.2. Main supply chain innovations

After developing the Supply Chain Innovation (SCI) Framework as a foundation, we collected and organized a select set of examples of SCI adopted and implemented in recent years. While the list is not comprehensive, it does present potential ways to segment SCI and thus enable further analysis and characterization. Based on their affinities, these examples have been aggregated in 14 groups. Table 1 summarizes these supply chain innovations.

Group	SCI	Description
Product delivery and flow	Containerization	Intermodal system of transporting the general cargo or product in lots, which are too small for the traditional bulk transport system, using ISO standard containers.
	Cross-docking	Direct flow of merchandise/product from receiving to shipping, thus eliminating additional handling and storage steps in the distribution cycle.
	Multi-drop	Direct flow of merchandise/product from the manufacturer to the final stores.
	Multi-pick	Direct flow of merchandise/product from multiple warehouses to one single store.
	Intermodality	Adoption of different and combined transport modality
	Point-to-point overnight deliveries	Direct flow of products quickly delivered in one business day.
Inventory Mgt theory and integrate within the firm	Economic order quantity (EOQ)	Framework to compute the level of inventory that minimizes total stock holding cost and ordering costs.
	Material resource planning (MRP)	Model that uses dependent demand models to develop a manufacturing and inventory program.
	Distribution resource planning (DRP)	Model that uses dependent demand models to develop a stock replenishment program that works through out the network.
Integration and collaboration across the supply chain	Vendor management inventory (VMI)	Planning and management system in which the vendor is responsible for maintaining the customer's inventory levels.
	Continuous replenishment program (CRP)	Practice of partnering along the supply chain, which requires a replenishment process based on actual and forecast product demand.
	Collaborative planning, forecasting, and replenishment (CPFR)	According to CPFR, manufacturer and retailer agree on common business objectives, forecasting plans, replenishment plans, management of exceptions through electronic collaboration.
	Consignment stock	The vendor places inventory at the customer's location while retaining ownership of the inventory.
	Quick response (QR)	Model of supply chain optimization used in the fashion industry focused on shortening the retail order cycle.
New forms of work orgzn (NFWOs)	Toyota production system	Integrated socio-technical system that organizes manufacturing and logistics for the automobile manufacturer.
	Just in time (JIT)	Production strategy oriented to improving the ROI through the reduction of in-process inventory and carrying costs.

	Total quality management (TQM)	Integrative philosophy oriented to constantly improving the quality of products and process at the manufacturing and logistics level.
	Total quality environmental management (TQEM)	Application of TQM concepts with attention to the environment.
	Lean production	Production practice oriented to eliminate all waste, thus realizing the final product through value-added activities.
	Continuous improvement (Kaizen)	Philosophy or practice oriented to the continuous improvements of processes in manufacturing, engineering, and business management,
	Six sigma	Business management strategy oriented to improve the quality of the final products due to the removal of all causes of defects and minimizing the variability in the process.
	Self-directed work teams (or high-commitment work systems)	Managerial practices of creating work teams or groups of employees with varying skill sets, the team having broader responsibility for operations, often assuming the traditional role of line management; therefore operating with minimum of supervision
Retailing Mgt	Fast retailing	Business model oriented to reducing the internal process time, allowing companies to deliver new products with shorter time-to-market.
	Lean retailing	Adoption of Information and Communications Technology (ICT) to adjust the supply of products offered to consumers at each retail outlet in order to match actual levels of market demand, reducing their exposure to the risks of selling perishable goods.
	Efficient consumer response (ECR)	Model of supply chain optimization used in the food industry oriented to continuous improvement through providing consumer value, cutting non-value-added activities and costs, and minimizing inefficiency.
	Category management (CM)	A grouping of like products (e.g., pet food) that is treated as a self-contained business unit run by a category manager in collaboration with trading partners.
	Network marketing organizations	Retail-selling channels that use independent distributors not only to buy and resell products, but also to recruit new distributors into a growing network over time.
Supply chain model	Agile supply chain	Supply chain model that aims at being responsive and flexible to customer needs, but shares the risks of supply shortages or disruptions through the pooling of inventory or other capacity resources.
	Lean supply chain	Supply chain model that aims at reducing the waste in the supply chain and creating the highest cost efficiencies.
	Leagile supply chain	Supply chain model that aims at combining the benefits of the lean and agile approach due to the joint adoption of two approaches in different parts of the supply chain.
	Responsive supply chain	Supply chain model that aims at being responsive and flexible to the volatile needs of customers.
	Risk hedging supply chain	Supply chain model that aims at pooling and sharing resources in a supply chain in order to share the risks of supply disruption.
	Accurate response	Determining what forecasters can and cannot accurately predict, and then making the supply chain fast and flexible so managers can postpone decisions about the most unpredictable items.
Supply chain communications	Electronic data interchange (EDI)	Structured transmission of data or documents between organizations through electronic systems due to a shared language and format.

	Real-time visibility	Systems buyer-supplier that guarantees constant and updated information sharing about operational information, such as order, inventory level, production planning, etc.
	Computer-assisted ordering (CAO)	Retail-based system that automatically generates orders for replenishment when the inventory level drops below a pre-determined reorder level.
Track and trace	Barcode/ Scanner	Optical machine/readable representation of data.
	Radio-frequency identification (RFID)	Technology that uses radio waves to transfer data from an electronic tag.
	Global positioning system (GPS/GPRS)	Technology that allows the constant monitoring of vehicles.
	Workflow	Technology that allows the constant evolution of processes/documents.
Pricing	Dynamic prices	Methodology of price definition that implies the dynamic modification of the prices according to the real evolution of the demand.
Optimization/ automation software	Transportation management systems (TMS)	Technology that allows the analysis of various routing solutions on the basis of inbound and outbound orders.
	Warehouse management systems (WMS)	Technology that allows the control of movements inside the warehouse and the consequent management of associated transactions.
	Advanced planning and scheduling (APS)	Technology that allows the optimal allocation of raw materials and production capacity to meet demand.
	eSourcing/ eProcurement	Technology that allows the automation of the respective phases of the sourcing and supply of the purchasing process through a web-based approach.
Supply chain design	Late customization (postponement)	Business strategy that minimizes risks by customizing products as late as possible, allowing companies to customize products according to real market demand.
	Disintermediation	Supply chain design model oriented to the elimination of all the intermediate stages between the manufacturers and the end customers.
	Reverse logistics	Process of planning and implementing a cost-effective flow of raw materials from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.
	Short supply chain	Supply chain design model oriented to reducing the distance along the supply chain that results from the commercial disintermediation of the outbound supply chain and the supplier proximity at the inbound level. Direct store delivery (DSD) is an example.
	Vertical integration	Supply chain model oriented to achieving a high level of control of all activities/processes obtained as a result of the direct control of all value-added activities in the value chain.
	Offshoring and outsourcing	Phenomena of reducing supply chain costs that result from the delocalization of manufacturing in low-labor countries or the externalization of non-core activities to external suppliers.
	Global value chain	Supply chain model that considers the interlinked management of activities from concept to the end of like products among international players.
	Innovation networks	Linkages among organizations—companies, universities, and regulatory agencies—to create, capture, and integrate the many different types of skills and knowledge needed to develop and bring complex technologies to market.

Product configuration	Three-dimensional concurrent engineering (3DCE)	Joint management of decisions related to product features, production process, and supply chain design.
	Design for supply chain	Design rules oriented to the development of new products that consider the constraints and needs of the supply chain.
	Co-design	Joint design of either new products or new manufacturing process with external partners (e.g., suppliers, traders, 3PL).
	Early supplier involvement	Supply chain practice oriented to the early involvement of suppliers in the new product development (NPD) process, with the final goal of anticipating constraints and reducing the loops in the process.
	Computer-aided design (CAD)/ Computer-aided manufacturing (CAM)/ Product data management (PDM)/ Product lifecycle management (PLM)	Technologies for the NPD process that simplify the concept phase by considering the external elements in the NPD process and sharing information among departments.
Sustainable supply chain	Environmental supply chain management	Supply chain program focused on the internal supply chain of a firm that considers the set of supply chain management policies held in response to environmental concerns related to the design, acquisition, production, distribution, use, reuse, and disposal of goods and services.
	Green supply chain management	Supply chain program focused on the whole supply chain that considers the set of supply chain policies able to simultaneously ensure the environmental and economic success of the company.
	Green purchasing strategy	Supply chain program in the purchasing function that aims at enhancing an effective reduction of source use, by considering the whole inbound supply chain.
	Environmental purchasing	Supply chain program in the purchasing function of a firm that considers the set of purchasing policies held in response to environmental concerns that relate to the acquisition of raw materials.
	Sustainable supply network strategy	Supply chain action program oriented to the strategic and transparent integration and achievement of an organization's social, environmental, and economic sustainability goals. This involves system coordination of key inter-organizational business processes to improve the long-term economic performance of the company and its supply chains.
	Logistics social responsibility	Supply chain action program that examines the processes along the whole supply chain, defining practices related to the environment, ethics, diversity, working conditions and human rights, safety, philanthropy, and community involvement.
Contract design	Traditional types of contracts	Supply chain tool adopted to ensure the sharing of risks and benefits among parties.
	Composite contracts	Supply chain tool adopted to maximize supply chain profit by ensuring the sharing of risks and benefits among parties that result from combining different aspects of different traditional contracts.

TABLE 1: INNOVATIONS IN SUPPLY CHAINS

The list of innovations provided above demonstrates the inherent difficulties in this research area, due to the high level of heterogeneity of innovation at the supply chain level. Each radical and incremental innovation entails a different level of criticality in implementation. Furthermore, we must define the difference between radical and incremental innovation. Is it simply a matter of the time limits for adoption or the rate of adoption—perhaps measured in terms of percent adoption in the industry—or can the radical or incremental nature be determined by some other impact measurement? Should we consider innovation as what is new for the market or for the specific company?

In addition, the previous framework includes innovations with different boundaries and different levels of complexity. For example, it is possible to go into much greater detail when identifying specific innovations, such as the implementation of the ECR. This also pertains to the introduction of CM, barcode, cross-docking, CAO, and EDI. Other factors also need to be addressed: Is it appropriate to consider ECR as one supply chain innovation or as a combination of smaller supply chain innovations? Is it proper to consider the barcode as an innovation or as just one small improvement in an enabling technology? Are there any time limits on adoption that may determine whether a change could be considered an innovation if it occurs over a long time period?

Many questions still remain, and this segmentation is an initial attempt to understand the most effective means of analyzing supply chain innovation.

4. Concluding remarks

Despite the importance of this issue to both practitioners and researchers, we have yet to see a common framework for cataloguing main supply chain innovations. A detailed model and in-depth analysis are needed to assist companies in understanding and implementing innovation in the supply chain. Much work clearly remains to be done in this area. We hope that this paper will set the foundation for further study and analysis.

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