A REVIEW OF SUPPLY CHAIN INNOVATION: PAST, PRESENT AND FUTURE

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Introduction

Studies of supply chain innovation (SCI) tend to focus on identifying antecedents for innovation (e.g., Grawe, 2009) and innovation process (e.g., Krabbe, 2007; Wagner, 2008) in a supply chain or network context but less is known about the types of innovation actually being created and how they were created. Systematic research and knowledge about SCI is under developed (Arlbjørn et al., 2011). This paper reviews past and present innovation in systems, methods, technologies and processes for supply chain applications and discusses future research in SCI.

Literature review

Research on SCI still lacks of common terminology, of agreement about the conceptual understanding, and of related empirical work (Arlbjørn et al., 2011). Following the work of Flint et al. (2005) on logistics innovation and (Arlbjørn et al., 2011) who explored SCI, this literature review aims to identify key concepts and terminologies from the innovation management literature which can be used for advancing SCI research, and then reviews the relevant literature specifically on SCI.

Innovation is about turning opportunity into new ideas and putting these into widely used practice (Tidd et al., 1997). Innovation can also be defined as the adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization (Zaltman et al., 1973). Other scholars argue that it is important to differentiate “diffusion” from “adoption” (Kimberly, 1981) and that they are not the same as “innovating” and “innovativeness” (Van de Ven and Rogers, 1988). A more process view of innovation (innovating) sees innovation as an ongoing process of leaving, searching and exploring which results in new products, techniques, forms of organization or markets (Lundvall, 1992). Innovation is a means to react to competitive and institutional pressures from the external environment. Innovation is a process of creative destruction for organizations to renew the value of their asset endowment (Schumpeter, 1934). As the core renewal process in any organization, innovation changes what an organization offers and the way in which it is created (Bessant et al., 2005). From a resource-based view, organizations often engage in different innovation acts to attain and maintain distinctive competencies required to perform continuously well (Barney, 1991; Bryson et al., 2007; Christmann, 2000).

Innovation comes in different forms, sizes and shapes. To achieve a clear understanding of innovation and to develop realistic theories of organizational innovations, it is important to differentiate between the different types of innovations and stages of innovation (Damanpour, 1987). Innovation can be differentiated based on basically three dimensions: object of change, newness, and the ways innovation is created. Based on the object of change, many types of innovation have been identified: product/service, technology/process, system, practice, market, organizational (structure), people, and so on (Schumpeter, 1934; Walker, 2004; Bantel and Jackson, 1989; Daft, 1978; Damanpour, 1991; Damanpour and Evan, 1984). Among these, product and process innovation are two commonly studied types of innovation (Walker, 2004). The literature generally recognizes the differences between technical and administrative innovation. Technical innovation is more related to products, services and production process technology (Damanpour and Evan, 1984). Administrative innovation involves organizational structure and administrative processes, which are indirectly relate to basic activities (Damanpour, 1991).

Innovation can be rather radical in one extreme and incremental in another. Innovation may have different degree of novelty, significance and uniqueness (Varis and Littunen, 2010). Concepts used to differentiate the novelty and significance of an innovation include “variation”, “reorientation”, “routine”, “nonroutine”, “ultimate” and “instrumental” innovations (Normann, 1971; Nord and Tucker, 1987). Take product innovation as an example, Anderson and Tushman (1991: 27) view product innovation as “technological discontinuities that advance by an order of magnitude the technological state-of-the-art which characterizes an industry”. Radical innovation is expected to create new value propositions for the customers. For example, online ticketing companies allow customers to purchase tickets anytime from anyway in a much quick way. Instead, incremental product innovation means “the development of products that have minor changes in attributes, and the benefits from these changes are minimal from the customer"s perspective” (Hoonsopon and Ruenrom, 2009: 156).

There are many ways in which an organization can innovate. It is not as simple as being radical or incremental. It is about putting the “right” conditions or institutional environments in place. It involves fostering of creativity and creation of new knowledge. It is also about introducing the “right” innovation at the “right” time. Sometimes there is a first-mover (Lieberman and Montgomery, 1988) or early-mover advantage (Cleff and Runnings, 2012). First-mover advantage rises as industry fragmentation and increasing innovation velocity (Gilbert and Birnbaum-More, 1996). Market pioneers often have a higher survival risk than early followers when it comes to radical innovations (Min et al., 2006). Evidence suggests that slower market pace enables pioneering firms to achieve more enduring first-mover advantage (Suarez and Lanzolla, 2005). There is another theory which argues that small firms are better in innovation. According to the theory of disruptive innovation (Christensen, 1997), large organizations can be toppled by much smaller start-ups by allowing them to develop solutions for relatively small and unattractive markets which later become popular (e.g., the Southwest airline with the low-fare services). Anecdotally radical innovation is mainly driven by small firms or start-ups, very often without an established brand name (Markides and Geroski, 2005).

It is crucial to differentiate different stages of adoption because innovation or adoption of innovation is not a binary process. There are typically initiation stage and implementation stage (Rogers, 1983; Zaltman et al., 1973). Initiation stage involves “all activities pertaining to problem perception, information gathering, attitude formation and evaluation, and resource attainment leading to the decision to adopt”; and implementation stage “consists of all events and actions pertaining to modifications in both an innovation and an organization, initial utilization, and continued use of the innovation when it becomes a routines feature of the organization” (Damanpour, 1991: 562). Furthermore, the rates of product and process innovations are different during the stages of the development of a business (Utterback and Abernaathy, 1975). The introduction of a disruptive technology is often followed by a series of incremental innovations; the adoption of such technologies involves multiple levels (Brand and Huizingh, 2008).

Determinants of successful innovation can be broadly divided into firm-level and network-level characteristics. At a firm-level, variables such as specialization, functional differentiation, professionalism, formalization, managerial attitude toward change, managerial tenure, technical knowledge resources, administrative intensity, external communication and internal communication have been identified as determinants of organizational innovation while centralization and vertical differentiation are known to have negative effects on organizational innovation (Damanpour, 1991). Competitive intelligence, strategic leadership effective management of technology and innovation process are among other characteristics of firms with successful innovation (Guimaraes, 2011). Size and length of establishment may also affect the firm"s innovative behaviour (Avermaete et al., 2003).

Within an organization, innovation can be created by individuals and cross-functional collaboration. Beyond an organization, innovation can be created by strategic alliance or so-called network innovation (Wissema and Euser, 1991) and open innovation (Chesbrough, 2003). SCI is a unique form of innovation taking place within a supply chain. SCI is a fairly new topic within the supply chain literature; a quick search of ABI/INFORM database using “supply chain innovation” as the title as keyword found only eleven articles. SCI is defined as “a complex process which deals with uncertainty in the environment, so as to provide solutions for customer needs and find new ways to better organizational processes using new technologies” (Lee et al., 2011:1194). SCI often involves technology (method) and process innovation. SCI “combines developments in information and related technologies with new logistics and marketing procedures to improve operational efficiency and enhance service effectiveness” (Bello et al., 2004: 57).

Since SCI is a rather new topic, there is currently a lack of literature which lays down its theoretical foundations. The review of logistics innovation literature by Grawe (2009) identifies the following relevant theories: knowledge-view of the firm, dynamic capabilities, Schumpeterian innovation framework (on firm size and available resources), exploration-exploitation framework, S-curve (Chandy and Tellis, 2000), network theory and resource advantage theory. Most of these theories can be used to explain the determinants of SCI.

Methodology

This paper is based on a review of existing literature and online forums among practitioners. The online article "The top 10 supply chain innovations of all-time" published by SupplyChainDigest (Gilmore, 2010) and its discussion forum is the main basis for identifying the relevant SCI. Although innovation has been studied extensively, there is generally no accepted way of measuring innovation. Some research is based on R&D expenditures others refer to the number of new patents (Breschi, 1999; Malerba and Orsenigo, 1995). Instead, the choice of relevant innovations for this paper is based on innovations that have relatively significant and long-term influences on contemporary supply chain management best-practices (Varis and Littunen, 2010; Gilmore, 2010). Following Zaltman et al. (1973), the analysis further classifies the types of innovation into methods, technology, process and other relevant categories. The analysis also attempts to identify the approaches (including drivers and enablers) used to develop each innovation. Particularly, the analysis identifies if the innovation was generated by a single individual or several individuals within an organization ("in-house") or a group of different organizations (of the same or different tiers or sectors). In addition, the drivers and enablers of the innovation, such as customer needs, industrial problems, internal organizational characteristics, existing of new technology from outside of the organization and so on, are identified. These drivers and enablers also serve as the platform for identifying future development of SCI.

Results

Table 1 summarises the results of the analyses of the past and present major SCI. Even though many of the listed innovations were not developed in a supply chain setting, they are included because of their relevancy and implications to today"s supply chain management. The list is by no mean complete because there may be other innovations that were not reported in the literature.

Name	Era	Types	Radicalness	Approaches
Computerized reorder point / EOQ	1910s-1600s	Methods; Technology	Radical, long-term influence	In-house, several individuals
Ford Assembly Line	1910s-1940s	Process; Methods	Radical, long-term influence	house, several individuals
Barcodes / QR codes / RFID	1960s-1990s	Methods; Technology	Radical, long-term influence	Collaboration, industrial / single individual
MRP/DRP	1700-1800s	Methods; Technology	Radical, long-term influence	In-house, several individuals
Taylorism	1980-1990s	Process; Methods	Radical, long-term influence	In-house, several individuals
Six sigma	1980s	Process; Methods	Incremental, long-term influence	In-house, single individual
FedEx Tracking System	1980s	Methods; Technology	Incremental, long-term influence	In-house, several individuals
3M"s Transportation Load Control Center (LCC)	1990s	Methods; Technology	Incremental, long-term influence	In-house, several individuals
Ocean shipping containers	1990s	Methods; Technology	Radical, long-term influence	In-house, single individual
"Supply chain"	1990s	Concept	Radical, long-term influence	Collaboration, industrial
Toyota Production System	1910s-1990s	Process; Methods	Radical, long-term influence	In-house; several individuals
ERP / APS	1990s-2000s	Methods; Technology	Incremental, long-term influence	Outsourced; various individuals
P&G"s continuous replenishment – CPFR	2000s	Methods; Technology	Radical, long-term influence	In-house and collaboration

Table 1: Supply chain innovation (past and present)

Among others, inventory is one of the main problems in supply chains. Economic order quantity (EOQ) is a mathematical solution to determine order quantity with the least total cost of holding and ordering inventory. The EOQ concept was published by a Westinghouse Engineer called Ford Whitman Harris in 1913 (Harris, 1913/1915). However, it was a much later article in Harvard Business Review by RH Wilson (1934) that made EOQ mainstream. With the development of computers in 1950s some companies started to develop computerise inventory control systems by incorporating concepts such as reorder point (ROP), EOQ and safety stock developed by the academics.

To keep track of inventory status and sales orders reorder a punch card system was developed by Harvard University in the 1930s. This system was not widely used as it was too expensive and it was not able to cope with the high level of complexity retailers at the time. The first patented barcode (called article classification…through the medium of identifying patterns) for recognising product at checkout was issued to Joseph Woodland and Bernard Silver in 1952. In the 1960s, a group of retailers (mostly grocery stores) got together and came up with a new method for tracking inventory: barcode. Several competing types of barcodes were then being developed and later they were being standardised with the Universal Product Code (UPC) in 1974. The idea for such a standardised code (called Universal Grocery Products Identification Code or UGPIC) was first developed by a company called Logicon and the effort was later completed by an engineer from IBM called George S. Laurer (Gilmore, 2010). Because barcode holds limited information Denso Wave Incorporate (led by Masahiro Hara) developed a new two-dimensional (2D) code called QR (Quick Response) code, which was being adopted by automotive industry to track their electronics Kanban (www.qrcode.com). Because consumers nowadays would like to know more about the products they are purchasing and the availability of mobile devise that can easily read QR codes, QR codes became widespread in Japan in early 2000s, and they are rather common today worldwide. This is made possible because Denso Wave decided not to exercise their pattern right for the QR codes. Taking advantage of the availability of standardised barcodes, handheld scanners, Internet, EDI and mobile networks, FedEx re-invented express shipment shipments by developing a new computerised tracking system in the 1980s that provides near real-time information about package delivery. Today, track and trace becomes a rather common application for tracing delivery.

The idea of an assembly line was first developed by Henry Ford (and his production chief, Charles Sorensen) back in 1910s at the new Detroit factory (Eisenstein, 1988). The idea actually came from the flow systems of meat packaging operations in the Midwest. Instead of moving around to pick up parts and assemble these parts onto a stationary vehicle Ford assembly lines moved the vehicle and parts to allow assembly workers to focus on assembly tasks and subsequently reduced the cost and lead time of the assembly operations significantly. It was Ford assembly line systems that revolutionised contemporary production systems for large-volume products in almost all sectors.

Computerised Material Requirement Planning (MRP) systems were initially developed during early 1960s when American Bosch started to examine bill-of-material explosion and calculate material requirements (Peeters, 2009). IBM (e.g., Oliver Wight, Joseph Orlicky, and others) documented this method and later developed a bill-of-material processor (BOMP) which then further developed the Production Information and Control Systems (PICS). Many consider PICS as the "mother of all MRP systems" (Peeters, 2009). Concepts such as dependent and independent demand, time-phased demand (bucketed), net demand and gross demand were all developed by IBM. IBM commercialised PICS (called COPICS) since late 1960s, and companies such as General Electrics and Royal Philips Electronics became some of the early adopters, who also developed their own systems (Peeters, 2009). This innovation was partly driven by the availability of new technology at the time called disk storage (methods to randomly access to information in a storage) and computer for solving complex bill of material explosion problems. IBM"s efforts to further develop MRP systems have in fact contributed to the early development of Enterprise Resource Planning (ERP) systems in the 1970, when MRP was becoming popular.

During the 1970s computerised inventory control and MRP became rather common. To solve conflicts between manufacturing and distribution managers (Masters et al., 1992), Whybark (1975) outlined the concept called Distribution Requirement Planning (DRP). Andre Martin (Martin, 1983) from Abbott Labs Canada applied MRP and inventory control concepts and developed the first computerised DRP system (Gilmore, 2010). During mid-1970s some bespoke-DRP software systems were available in the market thought many companies attempted to develop their own systems. A study of the adoption by Masters et al. (1992) suggested task complexity (of bill of material, distribution systems and market structures) was a key driver for DRP adoption while organizational size was an important predictor (in addition to experience with MIS/MRP) of the successful adoption.

Taylorism was developed by Federick Taylor (Taylor, 1911) as he implemented scientific management inside the factories in the 1980s and extended its influence until 1920s. He applied time studies on the factory floor and established “standard times” for manufacturing tasks. He also established incentive systems and piece-rate pay to promote productivity. The ideas of empiricism, work ethics, elimination of waste, standardization, and best practices were established during the Taylor‟s era. Taylorism was rather radical because many of the techniques were controversial at the time and they significantly improved the productivity of manufacturing processes.

Six Sigma (Tennant, 2001) is a set of techniques and tools for process improvement developed Motorola by (Bill Smith, senior engineer) in 1986 and this technique has now been applied by large and small manufacturing and service organizations. Six Sigma is not just a set of statistical tools for measuring process capability; it consists of methods and processes for managing process improvement. However, it was described as “nothing new” by Joseph Juran, another quality management guru that the idea of “facilitators” was not new but it was being adopted and called belts with different colours. Six Sigma was criticized as over-relying on statistical tools while the effectiveness of using “black-belts” as change agents and emphasis on learning have been widely recognized (Gilmore, 2010). Since many similar methods were already being developed by other quality management gurus and Six Sigma is considered an incremental innovation but nonetheless it has long term implications to today‟s manufacturing and supply chain management.

Another incremental innovation developed by 3M focused on solving distribution problems. 3M pioneered the idea of a centralised transportation planning system for achieving network optimization in 1980s. Instead of having each factory or warehouse (called load centre) to makes their delivery plan, Roy Mayeske, at the time the Executive Director of 3M Transportation, led a project to develop a centralised transportation planning systems for creating network synergies (Gilmore, 2010). Today, centralised transportation or distribution planning applications are becoming an important system for planning and optimising logistics activities, appreciated by especially large logistics service providers. There may be further room for improvement, as there is still a need to integrate such transportation planning systems with the manufacturing or ERP systems.

The first shipping container was invented and patented in 1956 by an American named Malcolm Mc Lean (Levinson, 2006). Mc Lean was a trucker and he owned the trucking fleet in the South and the fifth largest trucking company in the USA by 1956. Before the invention of ocean containers, cargo was loaded and unloaded in odd sized wooden crates. The process was very slow and there were no standardised loading units. After observing this slow and inefficient process for 20 years, Mc Lean developed some standardised way of loading cargo from trucks to ships and warehouses. He later purchased a new shipping company called Sea-Land Shipping and experimented better ways to load and unload trucks and ships. After many experiments, his final design is what we know now as the shipping container. Only by early 1970s the globally accepted ocean containers (ISO containers) were standardised by the US Navy. This innovation changed the lives of everyone because the cost of loading cargo was significantly reduced by using ocean shipping containers and over 90% of today‟s global trade is enabled by this rather “simple” and “cheap” solution.

The concept “supply chain” itself is considered as an innovation for some supply chain practitioners (Gilmore, 2010). The idea came from consultants named Oliver and Webber (1982) who highlighted the interdependency among suppliers and customers along a supply chain and therefore the need for considering the entire supply chain as a single entity rather than fragmented responsibility for various segments in the supply chain (Houlihan,1987). In a way the birth of “supply chain” concept revolutionises the ways managers manage their businesses.

Toyota Production Systems (TPS) is more than a series of methods and processes; it is a culture. TPS was pioneered by Pioneered by Taiichi Ohno and a few colleagues in Toyota. It is hard to specify a year when TPS was established; TPS has been developed based on a lot of trials and errors since early 1910s. TPS is guided by principles called “The Toyota Way”, which emphasises continuous improvement and respect for people (Liker, 2004). According to Liker (2004) there are 14 principles of Toyota Way: long-term philosophy; the right process will produce the right results; add value to the organization by developing your people; and continuous solving root problems drives organizational learning. TPS utilises principles of lean manufacturing and just-in-time (JIT), and emphasises that quality take precedence. Some of the TPS principles and methods come from Ford assembly Line and Total Quality Management. While many organizations have attempted to imitate TPS few managed to learn the two TPS paradox: the first paradox refers to the empowerment of workers to inspect, stop the line, performing more tasks, and even redesign their own jobs (Ward et al., 1995), and the second refers to the delays in making product design decisions and the use of set-based concurrent engineering approach for product development (instead of point-based concurrent engineering).

Continuous replenishment can be considered the precursor of ECR and CPFR. In fact the earlier computerised continuous replenishment application was developed by IBM during 1980s and applied in several sectors. P&G in 1987 bought a mainframe with such an application and modified it for consumer goods for retail (Gilmore, 2010). They then implemented the continuous replenishment application with their customers such as Schnuck"s Markets and Kmart (Gilmore, 2010). Though the collaboration with Kmart was not successful, later collaboration with Wal-Mart helped Wal-Mart to gain significant advantage, leading to the development of ECR and CPFR.

One current trend of SCI is the development of more "intelligent" systems based on the current revolution of Internet, cloud and mobile technologies. Advanced Planning Systems (APS) and business intelligence applications are being developed to enable advanced supply chain planning taking into account market and operations intelligence and at the same time capable of exploring what-if scenario using real-time information. While marketing experts are developing methods to market products by capturing Big Data from social media, supply chain experts are now starting to explore the possibility of using data available in the Internet to manage the supply chains. Another growing trend is the use of robots (intelligent machineries) to replace for example warehouse and assembly workers. For example, Amazon has ordered a lot of robots for moving goods in their warehouse, and Microsoft has acquired companies specialised in robots, and so on. Finally, supply chain experts are now getting more involved in eco-innovation, aiming to cut down environmental damages and labour issues owing to the various supply chain activities. In addition to technological solutions, new forms of collaboration in vertical, horizontal, multi-stakeholder are being formed to address environmental and climate change issues.

Discussion and conclusion

The above analysis shows that most of the high-impact with long-term influence SCI was actually developed in-house by a small number of individuals to solve problems they face. Often when standardization across an industry is necessary organizations started to collaborate and innovate new solutions together (e.g., barcodes). All of the innovations involve development of new methods to solve problems related to the management of inventory, tracking of items, planning, production and performance. In many instances technologies that were developed from other industries (e.g., IT) presented new opportunities to innovate new ways of managing the supply chains. When it comes to process innovation (which may also include systems) there seem to be common to learn from other industries or competitors. Somehow the willingness to invest in trial and error appears to be one of the major enablers of some of the radical innovation. In some cases the individuals involved in leading the innovation (change) are rather unique and extraordinary in the ways they insist better ways must out there somewhere.

The above analysis concludes that most of the famous innovations in production, inventory and logistics technologies, systems and processes such as Taylorism, Toyota Production System (TPS), Ford Assembly Line, Six Sigma, DRP, MRP, ERP, computerized EOP, EOQ, SM"s load control center (LLC), P&G"s continuous replenishment, FedEx tracking system and automatic picking system (APS) invented in before 1990s have now become the basis for many manufacturing and service organizations for managing their operations and supply chain. 2000s can perhaps be called the "collaboration" era, where VMI, cross-docking ECR, CPFR and different forms of (vertical) collaboration are being implemented. The next era of SCI depends largely on technology advancement. Nowadays SCI is largely relying on technology companies and R&D centres, meaning manufacturing and service organizations need to collaborate with such organizations in order to gain first- or second-mover advantage. Even though the use of smart robots and vehicles, Internet-based information technologies (cloud, Big Data, Web 2.0) are emerging, the rate of adoption appears to be rather slow. There is a need to demonstrate to supply chain managers how they are different from the current legacy systems. In addition, eco-innovation is another avenue for supply chain managers to explore, so that they provide new platforms for achieving even better market access, and supply chains cost and eco-efficiency. In order to achieve eco-innovation which decouples growth from environmental impacts, there is a need to develop disruptive technologies and this can no longer be achieved by several individuals in an organization. Driven by globalization and global uncertainties there is a need to collaborate vertically, horizontally and bilaterally. Network-enabled innovation is therefore a new way for achieving innovation (Narasimhan and Narayanan, 2013).

This paper contributes to SCI literature by mapping out the major SCI in the past and present and identifying some future SCI and their challenges. Though this paper put more focus on SCI that has significant long-term influence in today‟s practices, there are many other innovations taking place within many organizations. The CSCMP supply chain awards provide good examples of organizations achieving various types of innovations (in process, technology, network structure and organization). A recent analysis of 36 nominees for the 2005-2009 CSCMP awards by Arlbjørn et al. (2011) reveals that radical innovations have been achieved largely via technology innovation while very few are related to network (structure) innovation. Some detailed analysis of logistics innovation process based on case studies of large logistics companies by Flint et al. (2005) reveal that logistics innovation is a customer value-oriented social process that often requires investment in training and modification of business environment.

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