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Exploring the impact of RFID technology and the EPC network on mobile B2B eCommerce: A case study in the retail industry

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Abstract

The main objective of this article is to provide some insights into radio frequency identification (RFID) technology and the electronic product code (EPC) network and investigates their impacts on mobile B2B eCommerce. Based on empirical data gathered from interrelated firms of a supply chain, several scenarios integrating the RFID–EPC network have been tested in a pilot project and evaluated. Through a business process approach, our results indicate that (i) this approach seems appropriate to capture the potential of the RFID–EPC network; (ii) the RFID–EPC network can improve the "shipping," "receiving," and "put-away" processes; (iii) these technologies can cancel, automate, or automatically trigger some business processes; (iv) they foster a higher level of information sharing/synchronization between supply chain members; and (v) they require to be integrated in a wider strategy.

Keywords: Mobile commerce; RFID–EPC network; Retail industry; Supply chain visibility; Intelligent processes

1. Introduction

This article draws on the radio frequency identification (RFID) technology and the electronic product code (EPC) network to investigate their real impacts on mobile B2B eCommerce, with the aim of improving our understanding of how RFID technology and the EPC network can be integrated into a specific supply chain with the main objective to understand its impact on mobile B2B eCommerce.

Section 2 presents technology issues regarding RFID technology, the EPC network, and mobile eCommerce, followed in Section 3 by the theoretical issues including a literature review on RFID technology, and two important literatures offering some theoretical base to our research. In Section 4, we present the methodology and the research design of the study. Finally, in Section 5, the results and discussions are presented where emerging technological and business scenarios integrating RFID technology and the EPC network are proposed.

2. Technology issues

2.1. RFID technology

Even through RFID technology seems to have emerged quite recently, the concept is not new.

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It has its origins in military applications during World War II, when the British Air Force used RFID technology to distinguish allied aircraft from enemy aircraft with radar (Asif and Mandviwalla, 2005).

However, RFID technology has received a great deal of attention over the last few years, with a "boom" in early 2003 due to (i) recent key developments in microprocessors and (ii) demands by Wal-Mart and the US Department of Defense (US DOD) that major suppliers should adopt and implement the technology by the beginning of 2005 (Srivastava, 2004). The interest in RFID is highlighted by the many recent white papers published by technology providers (e.g., Intermec, 2006; Texas Instruments, 2004), consulting firms (e.g., BearingPoint, 2004; Accenture, 2005), infrastructure providers (e.g., HP, 2005; Sun Microsystems, 2004), enterprise software providers (e.g., SAP, 2005), and solution providers (e.g., IBM, 2003).

RFID technology is classified as a wireless automatic identification and data capture (AIDC) technology (Fig. 1). AIDC technologies include bar coding, optical recognition, biometrics, card technology, touch or contact memory technology, and RFID technology. Wireless technologies represent an emerging area of growth and are at the core of most mobile commerce (m-commerce) applications (Ngai et al., 2007). Even though the terms "mobile" and "wireless" are used interchangeably, they actually have different meanings. "Mobile is the ability to be on the move" (Mallick, 2003, p. 4), positioning a mobile device as any terminal that can be used on the move (e.g., Personal Digital Assistant (PDA), mobile phone, or laptop), while "wireless" refers to the transmission of data over radio waves, meaning that a wireless device is any terminal that uses a wireless network to either send or receive data (Mallick, 2003). Wireless networks can be divided into four main categories: (i) Wireless Personal Area Network (WPAN), which can be used to allow PCs, PDAs, mobile phones, and Blackberries to detect each other and interact; (ii) Wireless Local Area Network (WLAN), which provides simple Internet or intranet access to PCs, PDAs, and laptops equipped with a wireless network card; (iii) Wireless Metropolitan Area Network (WMAN); and (iv) Wireless Wide Area Network (WWAN), which is the network used by most cellular phone companies and Global Positioning Systems (GPS) (location technology based on a system of satellites orbiting the earth).

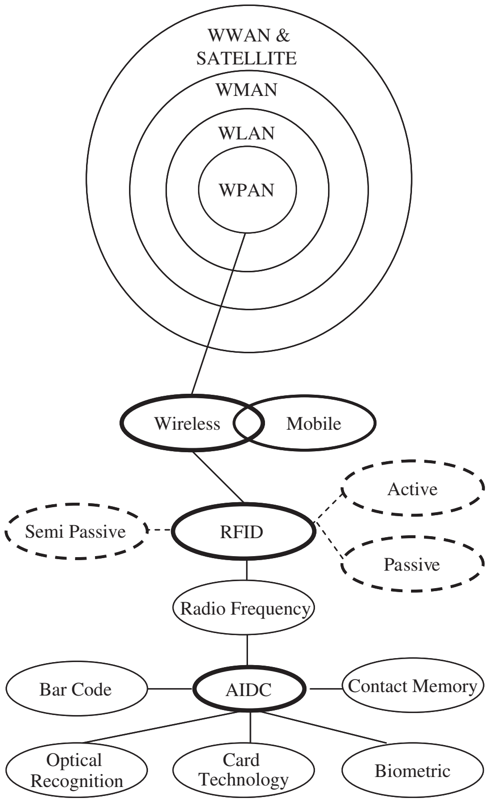

Fig. 1. Positioning RFID in the wireless landscape.

In general, wireless networks are used to access data, resources, vital information, and communication tools, anytime, anywhere.

Basically, an RFID system is composed of three layers: (i) a tag containing a chip, which is attached to or embedded in a physical object to be identified; (ii) a reader and its antennas that allow tags to be interrogated and to respond without making contact (in contrast to bar codes, which require a line of sight and must be read one at a time); and (iii) a computer equipped with a middleware application that manages the RFID equipment, filters data, and interacts with enterprise applications (Asif and Mandviwalla, 2005).

RFID tags come in a wide variety of designs and have many different functional characteristics such as power source, carrier frequency, read range, data storage capacity, memory type, size, operational life, and cost. They may be (i) either read only or read/write capable and (ii) active, passive, or semi-passive depending on the way in which they draw operating power and transmit data to the reader.

Active tags have a tiny embedded battery from which they draw power, allowing greater communication range, higher data transmission rates, and larger data storage capacity than passive tags. Because they do not contain a power source, passive tags are less expensive than active tags (Asif and Mandviwalla, 2005). However, the choice of the appropriate tags depends on the objectives of each business application.

An RFID reader may consist of a read or read/write module (Ngai et al., 2007); when requested, it can send the pre-configured location and the identification of an object to a computer, which can initiate business processes automatically (Kärkkäinen, 2003).

2.2. The EPC network

The EPC network, also called EPCglobal network, was proposed and developed by Auto-ID Center at MIT. This so-called "intelligent network" is now considered as a standard for RFID infrastructure (Floerkemeier et al., 2003; EPCglobal, 2004; Srivastava, 2004), and is expected to increase efficiency and accuracy in the supply chain (Violino, 2004). It is made up of five components: (i) The EPC starts as a 64- to 128-bit identifier. Once it is incorporated into an RFID chip (also called an EPC tag) and attached to a physical object, product, or item, it can provide information such as the manufacturer, the product category and size, the date when the product was made, the expiration date, the final destination, etc. (ii) The RFID reader identifies any EPC tag within its interrogating field, reads the EPC tag, and forwards information to the SAVANT. (iii) The SAVANT is the middleware system located between readers and the application systems (AS). Based on configured business rules, it is responsible for data filtering and aggregation and interacts with the EPC Information Service (EPC-IS) and the local Object Name Service (ONS). (iv) The EPC-IS, also called the Physical Markup Language (PML) server, is the gateway between any requester of information and the firm's AS and internal databases. The EPC-IS stores, hosts, and enables access at real time to any EPC code across the Internet (Violino, 2004). (v) The local ONS is an authoritative directory of information sources available in order to describe all EPC tags used in a supply chain (Floerkemeier et al., 2003; EPCglobal, 2004). Each firm in a given supply chain hosts a local ONS, which communicates with the root ONS within the EPCglobal network (Violino, 2004), allowing end-to-end information sharing.

Products with an EPC tag have the ability to communicate with their environment and make or trigger basic decisions relevant to their management. Such products are also called "intelligent products" or "smart products" (Strassner and Schoch, 2004).

2.3. Mobile eCommerce

Mobile eCommerce (m-eCommerce), considered to be an evolution of eCommerce (Strader et al., 2004), is defined as the wireless B2B and B2C exchange of operational and financial data within a supply chain over the complete life cycle of a business relationship (Gary and Simon, 2002; Léger et al., 2005). m-eCommerce is an emerging phenomenon and analysts predict impressive growth. Indeed, the worldwide m-eCommerce revenues were US$14 billion in 2002 (Upkar and Vetter, 2002), and are expected to reach US$554.37 billion in 2008 (Yang, 2005). This promise is driven by the rapid evolution in wireless technologies and the rapid diffusion of mobile terminals (i.e., PDA, mobile phone, Blackberry, etc.) (Strader et al., 2004). For example, more than 800 million mobile terminals were in use worldwide in 2002 (Barnes, 2002), and of this number, almost 237 million were involved in m-eCommerce during the same period (Upkar and Vetter, 2002). In 2004, wireless applications were identified as the second priority by worldwide companies in terms of intentions to adopt new technology (eMarketer, 2004). A second factor driving the growth of m-eCommerce is the expansion of eCommerce.

In the retail context, supply chain management (SCM) is seen as an important activity and one where RFID technology and the EPC network could have tremendous impacts. Indeed, the integration of wireless technologies to support business processes within a supply chain could have a significant impact on overall business operations (Kumar and Zahn, 2003), leading to competitive advantages in terms of cost reduction, supply chain responsiveness, and performance of supply chain functions (Eng, 2005). It would therefore impact the strategic management of all firms involved in the supply chain (Barnes, 2002). The main thrust of this paper is therefore to demonstrate that RFID technology and the EPC network could have huge impacts on mobile B2B eCommerce (m-B2B-eCommerce), which is defined as the wireless B2B exchange of operational and financial data within a supply chain.

3. Theoretical issues

3.1. Literature review on RFID technology

The interest in RFID is also reflected in various fields of research in the academic community such as innovation management, project management, SCM, PLM, IS, eCommerce, etc. For instance, in the field of innovation management, Sheffi (2004) positions RFID technology in an innovation life cycle and speculates on the possible paths for future adoption. Widespread adoption of RFID technology may be hindered by many technical and business challenges (Asif and Mandviwalla, 2005) such as (i) the lack of common standards that raise interoperability issues, (ii) the relatively high costs related to hardware and software as well as the cost for integration of RFID technology with legacy systems, (iii) security issues related to data access, as well as privacy and legislation issues, and (iv) the need to acquire the specialized skills required for RFID implementation. In the same line of thought, Wu et al. (2005) also examine challenges when adopting RFID technology, namely *technology challenges* with the high rate of new hardware and software introduction, *standard challenges* with the lack of a unified RFID standard, patent challenges, and intellectual properties rights, *cost challenges* related to the tags but also to the customization and configuration of the system, *ROI challenges* in term of cost reduction and value creation, and finally *infrastructure challenges* related to RFID deployment in the SC. To these challenges, Bendavid and Bourgault (2005) add "project management challenges" for "effective RFID implementation and use" in a multi-firm context that requires inter-organizational cooperation among a network of firms involved in implementing this technology. These later challenges raise considerable complexities, as individual firms with their own specific objectives for RFID adoption may be conflictual. Indeed, Yang and Jarvenpaa (2005) explore the importance of trust in the adoption of RFID as interorganizational systems (IOS) have to be collectively adopted.

One of the most investigated areas of research concern the SCM and warehousing activities where RFID has been considered as "the next revolution" (Srivastava, 2004, p. 1). At a strategic level, Gunasekaran and Ngai (2005) suggest that RFID may act as an enabler of a build-to-order SCM strategy by leveraging the advantages of other information technologies such as the Internet, eCommerce, ERP, and wireless technologies. Lefebvre et al. (2005) analyze how supply chain processes can be redesigned when using RFID and examine the impacts of RFID in terms of improvements through process integration, automation, cancellation, and the emergence of new "smart processes". Through the presentation of multiple case summaries, Angeles (2005) also illustrates the potential benefits derived from RFID technology adoption in a supply chain context, such as the reliability of the information on the movements of the physical goods, the better tracking of products in manufacturing processes, the automation of manual processes and the reduction in human-based errors, etc. Through a hypothetical example, the author suggests that RFID has the potential of generating "process freedoms and supply chain visibility" (Angeles, 2005, p. 57) at least in the case of specific distribution processes (e.g., receiving, put away, order filling, and shipping). Finally, Kärkkäinen (2003) analyzes the potential of RFID technology to increase efficiency in a supply chain of "short shelf-life products". From one case study, Kärkkäinen identifies major opportunities at the store levels in terms of (i) reduction of stock loss through increased inventory accuracy and better control of stock rotation and (ii) improved replenishment productivity through increased asset visibility.

Mathematical and simulation models may also assess the impacts of RFID on supply chain dynamics. For instance, Fleisch and Tellkamp (2005) demonstrate the potential benefits of RFID in a retail supply chain environment for reducing inventory inaccuracies while at the same time also reducing supply chain costs and out-of-stock levels. Gaukler (2005) also investigates the improvement of inventory replenishment decisions considering "information visibility" as a key dimension to an RFID-enabled supply chain.

In the product life-cycle management (PLM) perspective, some authors explore various options for optimizing end of life operations (e.g., sorting of recyclables products) by linking specific product information (e.g., dismantlement instructions) to materials and products through the use of RFID tags (see, for instance, Saar and Thomas, 2003).

Taking a broader PLM perspective, Kiritsis et al. (2003) propose a model integrating RFID technology for product information management with the use of smart embedded systems. Their model enables the capture of data at any point in the supply chain and the feedback of information and knowledge, from middle of life operations (e.g., service, maintenance) and end of life operations (e.g., recycling) back to the designers and producers for the optimization of beginning of life operations.

Another area of research lies in the information system literature where eCommerce applications are proposed. Kärkkäinen et al. (2003) propose a ''product centric approach'' as a flexible information collection and sharing approach for supply chain members. In this later approach, product information management is based on centralizing information to the individual products, where ''software agents share information in a peer-to-peer fashion'' (p. 151): each unique object is assigned to a unique identification, namely the domain name service (DNS) of the Internet. Recently, Ngai et al. (2007) present the findings of one case study where an RFID (prototype) system is integrated with m-commerce technologies (e.g., wireless devices, wireless accessible web portals, SMS gateway, etc.) to improve inefficiencies related to container depot management (i.e., customer service, order management, container management, real-time and alert monitoring).

Finally, multiple (research) questions remain (see Curtin et al., 2007) such as (i) development, adoption, and implementation of the RFID technology, (ii) its actual and potential use, and its evolution, and (iii) its impact on business policies and practices and market dynamics. Our work attempts to partially fill this gap by answering the following question ''how does integration of RFID technology and the EPC network impact mobile B2B eCommerce?''

3.2. Measuring the impacts of IT

Two particularly important literatures offer some theoretical base to our research question, namely (i) business value of information technology (IT) and (ii) business process re-engineering (BPR).

3.2.1. Business value of IT

Firms are making huge investments in information technology to improve their efficiency. Indeed, investment in IT represents almost 46% of all capital investment in the US economy (Devaraj and Kohli, 2003). Worldwide investments in RFID technology may rise from \$363 million in 2004 to almost \$3000 billion in 2010 (eMarketer, 2005). However, the assessment of the impacts derived from these investments remains a challenging and controversial task. Opinions on the real value from the investments in IT diverge considerably. For example, Brynjolfsson and Hitt (1996), using a microeconomics-based view, reported significant return of investment of IT at the firm level. Mooney et al. (1996) arrived at the same conclusion using a process-view approach. However, Willcocks and Lester (1994) suggested that there is no clear link between IT spending and firm gains in terms of market share or profitability. Despite this controversy, many studies try to assess the value arising from IT adoption. For instance, Brynjolfsson and Hitt (1996) arrived at the conclusion that IT investments can lead to cost savings, improve quality in service and better customer service. However, to fully grasp the real value of IT, IT investments are not sufficient without complementary investments: firms have to invest on time, organizational change and knowledge, work routines, and new processes. Along the same lines, Ross (2002) from empirical evidence showed that IT investment has ''a positive impact on market performance as a result of better coordination in the value chain. Additionally, coordination productivity seems to benefit from increased investment by reducing, say, working capital requirements'' (Ross, 2002, p. 591).

Barua et al. (1995) point out that IT investment can have huge impacts on firm capacity utilization, inventory turnover, quality, price, new product development, market share, and return on asset (ROA). Finally , De Boer et al. (2002) demonstrate that eCommerce adoption can lead to the reduction of purchasing prices, transaction and process costs and can increase transaction speed, thus contributing to the overall operational efficiencies.

3.2.2. IT adoption and BPR

Many studies on IT highlighted a link between IT adoption and BPR. Indeed, IT investments can drive changes in business processes. For example, IT investments can enable new processes, enhancing informational and coordination capabilities, thus leading to cost reduction and better customer service (Hammer and Champy, 1993). Moreover, Riggins and Mukhopadhyay (1994) showed that the alignment of business processes to EDI adoption lead to better information sharing, and thus high firm performance. In the supply chain context, Kohli and Sherer (2002) stated that in order to fully capture the benefits from IT investments in the supply chain, supply chain actors need to conduct major changes in their business processes (Kohli and Sherer, 2002). Moreover, "when the process approach is used, other factors that affect the translation of IT assets to impacts are investigated more clearly" (Kohli and Sherer, 2002, p. 7).

In this study, a process-oriented approach coupled with a "Living Lab" approach has been chosen. Indeed, a process-oriented approach is useful to measure the impact of RFID technology and the EPC network because it has been promoted as an ideal approach to study the impact of IT at a more detailed level by "investigating how IT use or action in one stage affect a downstream IT and other organisational effects" (Byrd and Davidson, 2003, p. 244). Further, a "Living Lab" approach is a methodology designed for "sensing, prototyping, validating and refining complex solutions in multiple and evolving real-life contexts" (Mulder et al., 2006, p. 1) and seems particularly relevant to simulate impacts of RFID technology on business processes (Bendavid et al., 2007). This methodology is well indicated for "self-trial" of an emerging technology by private and academic players (Loeh, 2005).

3.3. Context of the study

3.3.1. Current context of the retail industry

A recent study by the US Census Bureau estimated that US retail and food services sales for October 2005 amounted to about $352 billion, an increase of almost 5.7% from October 2004 (Vargas, 2005). Indeed, the retail industry represents one of the largest industries worldwide. For example, in the United States, it is the second-largest industry in terms of both the number of establishments and the number of employees, with $3.8 trillion in sales annually and 11.7% of US employment (Vargas, 2004). In the European Union, the food and beverage industry, which is part of the retail industry, is the world's largest, with about 3 million employees and nearly $814 billion in sales annually (Eleni and Vlachos, 2005).

During the last 30 years, the retail industry has passed through many transformations. For example, traditional cornerstones have evolved because of a variety of grocery store alternatives such as (online and physical) supermarkets, hypermarkets, discount stores, etc. (Geuens et al., 2003). In addition, this industry is facing similar trends to those affecting other sectors, for instance, the globalization of markets, aggressive competition, increasing cost pressures, and the rise of customized demand with high product variance.

Nonetheless, the industry also faces specific challenges such as management of the short shelf-life of grocery goods, strict traceability requirements, and the need for temperature control in the retail supply chain (Kärkkäinen, 2003). Retailers must also deal with a growing number of stock keeping units (SKUs). For instance, in a typical food store in the USA, the number of SKUs has risen from nearly 6000 in the 1960s to almost 40,000 today. As a result, the number of daily sales transactions has exploded. Therefore, capturing sales information using manual, and therefore error-prone, methods has become almost obsolete (Abernathy et al., 2000).

Furthermore, manual capture of sales information increases transaction costs and can cause inventory inaccuracies (Fleisch and Tellkamp, 2005). Among the cases presented in the literature, that of Procter & Gamble, which spends between $35 and $75 to process each customer invoice, is a classic representation of these inefficiencies. Indeed, this kind of processing involves numerous human interventions at different levels such as order taking, data entry, processing of the order, invoicing, and forwarding (Kärkkäinen, 2002).

3.3.2. RFID and the EPC network's potential in the retail industry

The most significant interest in RFID and the EPC network is in the retail industry. Indeed, major retailers such as Wal-Mart, Tesco, Metro AG, and 7-Eleven are very interested in the potential of RFID technology (Jones et al., 2005) and the EPC network (EPCglobal, 2004; Srivastava, 2004). For instance, by adopting RFID technology, Wal-Mart stands to achieve annual savings of almost (i) $600 million in out-of-stock supply chain cost reductions; (ii) $300 million in improved tracking through warehousing and distribution centers (DCs); and (iii) $180 million in reduced inventory holding and carrying costs (Asif and Mandviwalla, 2005). Procter & Gamble has also estimated that it could save almost $400 million annually in the inventory by deploying an RFID system (Smith, 2005; Srivastava, 2004).

3.3.3. Applications of RFID and EPC networks in the retail industry

In 2003, Metro Group opened its first "Extra Future Store," where RFID technology is used live for various applications throughout the supply chain (Collins, 2004).

In addition, the use of RFID technology and the EPC network for product tracking in the retail supply chain can lead to a tremendous reduction in inventory levels and better collaboration among supply chain players. For example, Scottish Courage, a British beverage firm, is using RFID technology to track its 2 million keys at any point in the supply chain. As a result, the firm has eliminated shrinkage, reduced key cycle times, and improved delivery for outgoing and incoming stock (Srivastava, 2004). Marks and Spencer is also using RFID technology to track 3.5 million reusable trays, dollies, and cages throughout its refrigerated food supply chain, leading to a substantial reduction (almost 80%) in the time taken to read a stack of multiple trays while increasing data accuracy and reliability. The overall result is a faster and more cost-effective SCM system (Jones et al., 2005).

Moreover, a recent pilot study in an Australian consumer goods supply chain including Proctor & Gamble, Gillette, a pallet supplier named CHEP, and a retailer named Metcash demonstrated that the EPC network has the ability to increase visibility among the whole supply chain through a better sharing of RFID-collected data, thus leading to a more efficient supply chain (Collins, 2006).

Many impacts and benefits are also expected from RFID and the EPC network within distribution warehouses. A distribution warehouse, also called a distribution center, collects products from different suppliers and sometimes assembles them for delivery to a number of customer warehouses (Van Den Berg and Zijm, 1999). Four separate processes are usually identified in a distribution warehouse, namely receiving, put-away, picking, and shipping (Van Den Berg and Zijm, 1999), all of which can benefit from RFID technology and the EPC network (Capone et al., 2004; Keith et al., 2002; Lefebvre et al., 2005; VeriSign, 2005).

This paper focuses on a single "open-loop" supply chain initiative in the retail industry to explore issues related to the integration of RFID technology and the EPC network among different partners.

4. Methodology

Our study builds on previous work (Strassner and Schoch, 2004; Subirana et al., 2003) and focuses on a three-layer supply chain.

4.1. Research design

Since the main objective of this case study is to improve our understanding of the potential of RFID technology and the EPC network in the context of warehousing activities in one specific supply chain, the research design corresponds to an exploratory research initiative. As stated by Eisenhardt (1989, p. 533), "case study is a research strategy which focuses on understanding the dynamics present within single settings." This research methodology is well suited to learn about a given situation and eventually inducing theories from it (Benbasat et al., 1987). Furthermore, a case study can be used to (i) analyze an emerging phenomenon and (ii) answer research questions such as "why" and "how" (Yin, 1994). Moreover, many authors emphasize the importance of qualitative research such as case studies in logistics (e.g., Näslund, 2002) and operation management (e.g., Stuart et al., 2002).

The field entailed four case studies and research was conducted in 12 consecutive steps. The first six steps correspond to an initial phase that could be broadly termed the "opportunity-seeking phase." Step 1 represents the starting point, with a thorough assessment of the corporate motivations underlying the adoption of RFID technology and the EPC network. Steps 2 and 3 allow a sharper focus on specific critical activities that will be targeted by an RFID and EPC network implementation. Steps 4–6 reflect the current situation in terms of actual supply chain dynamics and existing intra- and inter-organizational business processes.

The second phase—scenario building—evaluates specific RFID and EPC network opportunities (step 7) and assesses the potential of RFID and EPC network applications (step 8). Step 8 represents a turning point where both business and technological concerns are evaluated. For business concerns, several questions need to be answered: How will firms in the network handle their respective activities? What would change in terms of strategy, activities, processes, organizational structure, and informational flow? Which products and product levels should be targeted? Which applications should be adopted? In parallel, some questions address the technological concerns: How will the existing IT infrastructure be impacted? What are the characteristics of the product to be tagged? How much information is required? Which application is to be used (i.e., read/write, distance, speed, security, etc.)? The answers to these questions allow one to map redesigned business processes integrating the RFID and EPC network technologies (step 9), which are validated with key respondents (step 10).

The third and final phase of the research design validates the scenarios retained in the second phase, both in controlled conditions (proof of concept—step 11) and in a real-life setting (step 12). Although the steps of the field study are displayed in a linear manner, several iterations occurred during the $1\frac{1}{2}$ year period of the research.

4.2. Research sites

Four firms participated in this field study, namely a focal firm we call Firm X, two first-tier suppliers, and one retailer.

4.2.1. Firm X's profile

Firm X is one of the largest North-American-owned beverage companies, with almost 6000 staff members and annual revenues of approximately \$2.8 billion. The firm owns many large distribution centers. An overall volume of 15 million cases transits through the firm every year. Of this amount, 2.7 million cases pass through the docks of the distribution center where the field study was performed. Firm X relies on bar code systems to track the cases, confirming the ubiquitous presence of bar codes in the retail industry. Indeed, the use of bar codes in the consumer packaged goods industry had led to annual savings of almost \$17 billion by 1997 (Kambil and Brooks, 2002). However, the bar code systems often require manual intervention and a line of sight is necessary in all cases.

In addition to bar code systems, the firm uses various business applications such as enterprise resource planning (ERP), warehouse management system (WMS), transportation management system (TMS), and a B2B Web portal. The TMS is linked to a GPS. Firm X also has a LAN to optimize its intrabusiness processes and communications. Finally, it also uses an EDI server to communicate with some suppliers and retailers.

4.2.2. Two first-tier suppliers' profiles

These two first-tier suppliers are bottling plants that deliver their production to Firm X each day. They use a paper system, e-mail, and fax to exchange business documents with Firm X. In both cases, employees in Firm X have to re-enter delivery documents sent by these suppliers into Firm X's business applications during the receiving process. This increases document-processing errors and results in inaccurate data. These two first-tier suppliers use bar codes provided by Firm X to identify pallets, and do not have any means of tracking their products once they leave their facilities.

4.2.3. The retailer's profile

The retailer chosen for on-site observations is one of North America's biggest companies in its sector, with almost 30,000 employees and six distribution centers. In addition to e-mail, the firm uses files, databases, LAN, ERP, and WMS to support its intra- and inter-organizational business processes. One of the biggest challenges facing the relationship between this retailing firm and the focal Firm X is the recurrent discrepancy between the quantities sent by Firm X and those received at the retailer's dock. The elimination of this inventory discrepancy was one of the initial motivations leading Firm X and the retailer to look into the potential of the RFID and EPC network technologies.

In addition, the managers of all four firms involved in this field study had already been approached by some consulting companies and were aware of the other potential benefits to be derived from the implementation of RFID systems (and EPC network opportunities). Their initial motivations were focused on the reduction of inventory and warehousing costs within the supply chain. During the first focus group (which also included academic researchers and private and technological partners) (step 1), they clarified their initial strategic intent with the need to reduce lead times and to respond faster to changing market demands. In other words, their primary motivations dealt with issues related to a lean and agile supply chain.

4.3. Data collection

Data collection for the case study was based on:

(i) *Focus groups* conducted in the university-based research center with nine functional managers and IT experts. The focus groups allowed the team to reach a consensus on strategic intent with respect to the use of RFID and the EPC network in one product value chain (steps 1–3) and to evaluate different scenarios and select the "preferred" or "as could be" scenario (steps 7–9). Each step of the methodology was evaluated and agreed upon with members of the focus groups.

(ii) *On-site observations* in the four research sites were performed in order to carry out the process mapping required for steps 5, 6, and 9. While some steps required more interactions (e.g., step 6, where the research center explained to partners its approach and methodology for identifying RFID and EPC network opportunities), others (e.g., step 7) were mostly partner "preferences." For example, the Director of the Logistics and Distribution division (Firm X) mentioned that tracking had to be done at the pallet and box level in order to maintain visibility of the boxes (from suppliers) while they are de-palletized and re-palletized for mix pallets (in Firm X), prior to being shipped to different customers.

(iii) *Semi-structured interviews* in the four research sites with managers and operational personnel in order to obtain more detailed information and resolve any potential inaccuracy in the mapping of existing business processes (steps 5 and 6).

(iv) A "*Living Lab*" approach was adopted, whereby business and technological processes integrating RFID technology were validated with key respondents and selected scenarios where simulated (steps 10 and 11). Recall that a "Living Lab" approach is designed to support different research settings including the simulation of business experiments and the use of the laboratory over a prolonged period by private and academic partners for "self-trial" learning (Loeh, 2005).

The researchers acted as observers, interviewers, and facilitators (for focus groups and laboratory simulation). They also developed and presented the detailed scenarios that were developed from the empirical evidence gathered in the four research sites. Industrial reports and internal documents such as process documentation, procedures, ERP and middleware screens, and a wide range of other technical or non-technical documents were also used when available.

5. Results and discussion

In this paper, we present and discuss the empirical results of steps 5, 6, and 9–11 of the methodology using the suppliers' "shipping" process and Firm X's "receiving" and "put-away" processes. These three steps build on the results obtained in the previous ones and represent the validated output of phases 1–3 of the field study, namely opportunity seeking, scenario building, and scenario validation, whereby a "*proof of concept*" (POC) was conducted, in a laboratory setting, simulating actual physical environments and interfaces between supply chain players.

All five steps also correspond to the mapping of current business processes (actual situation) (steps 5 and 6) and redesigned processes integrating RFID technology and the EPC network (steps 8 and 9), which were validated with key respondents (step 10) and simulated in a laboratory setting (step 11). The process view retained here provides (i) "a more dynamic description of how an organization acts" (Magal et al., 2001, p. 2) and (ii) a structured approach and a "strong emphasis on how the work is done" (Davenport, 1993, p. 5), which enables field participants to validate the research outputs. The process view is also increasingly used to evaluate the impact of information technology (Subramaniam and Shaw, 2004).

5.1. Current context

All of the firms investigated are facing the same imperative affecting the retail industry as a whole (see Section 2.1). On the other hand, additional company profiles helped us grasp the real impact of RFID technology and corresponding EPC networks on their respective activities.

While each company focuses on reducing the transaction costs of its own operations, there is no a priori integrated vision in the network and no overall supply chain optimization strategy. The two first-tier suppliers use bar codes provided by Firm X to identify pallets, and have no means of tracking their products once they leave their facilities. For full pallets (same product), Firm X uses these bar codes to track them in the warehouse and during the shipping process to the customer. However, for mixed pallets (different products), Firm X has to apply new bar codes. Also, while information is gathered and managed locally, there is no continuous information flow among the supply chain members, leading to ‘‘silos thinking’’ and, consequently, to ‘‘silo optimization.’’ In addition to bar code information systems, various business applications are used, ranging from simple ones like paper-based information systems (e.g., fax) or e-mails to more integrated ones such as ERP, WMS, TMS, GPS, and the B2B Web portal.

In the current context, the actual inter- and intra-organizational processes are presented in Fig. 2, which drills down from the more general to the more detailed. Based on this analysis, the following observations are made: (a) the overall ‘‘shipping’’ and ‘‘receiving’’ processes consist of 12 and 17 second-level processes, respectively, and (b) most existing processes involve numerous interventions by employees such as data input (e.g., 1.2 in the ‘‘receiving’’ process), pallet scans (e.g., 2.5 in the ‘‘receiving’’ process), or visual count of boxes in each pallet (e.g., 2.6 in the ‘‘receiving’’ process).

5.2. Retained scenario integrating RFID and the EPC network

The retained scenario (steps 8 and 9), integrating RFID technology and the EPC network, was thoroughly validated with the focus group (step 10) and simulated in laboratory settings (step 11). Based on this proposed scenario and the actual situation, a comparison was made and the following observations allowed us to analyze the impact and understand the resulting opportunities (see Fig. 3).

RFID systems offer a standardized SKU, which can be shared by all actors in the EPC network. The EPC tag can effectively act as a standard for the integration of inter-organizational applications. Indeed, the EPC tag offers a global unique object

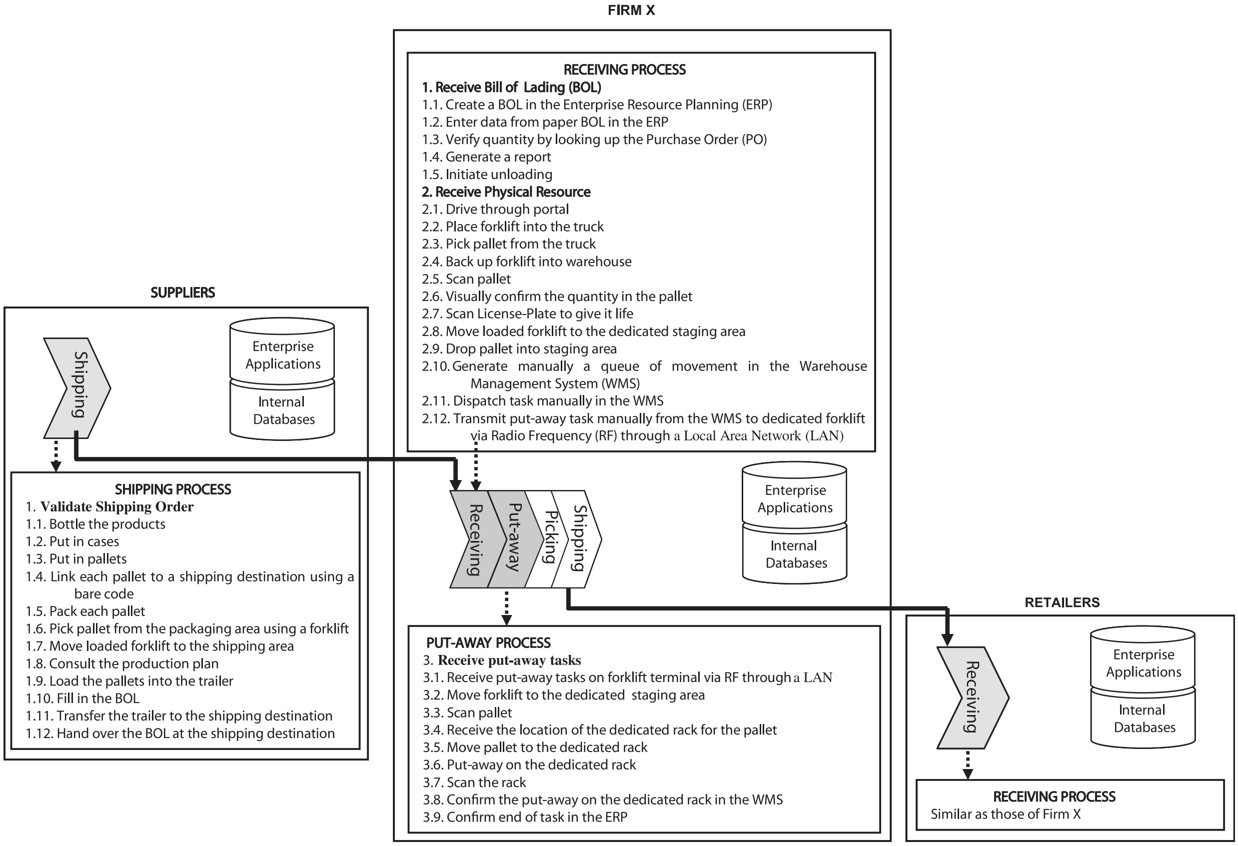

Fig. 2. Actual inter- and intra-organizational processes.

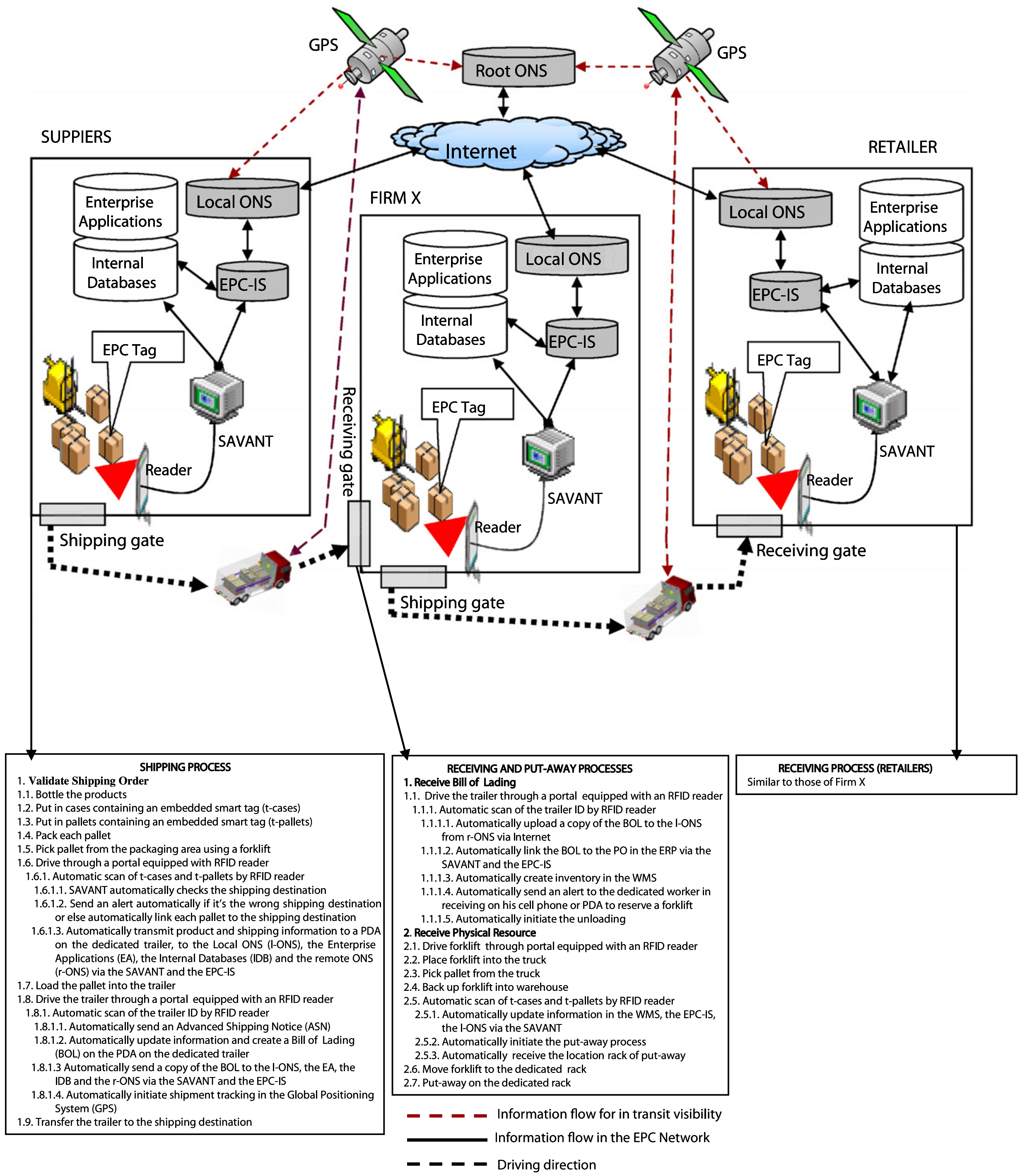

Fig. 3. Impact of RFID and the EPC network on the "shipping," "receiving," and "put-away" processes.

ID along the entire supply chain. The real impact of RFID technology and the EPC network can be assessed only if various dimensions are taken into consideration, such as the supply chain members' strategy, the way they redesign their inter- and intra-organizational processes and their information flow, the level of information system integration they have in mind, and the organizational structure

Table 1
RFID and EPC network impact matrix

Category	Observed impact on various dimensions
Strategy	• From "firm-oriented" to "network-oriented" strategy • From "spot" relationship to "systematic" relationship
Processes	• Integration of intra-organizational processes • Integration of inter-organizational processes • Optimization by means of automated processes • Optimization by means of canceled processes • Optimization by means of emerging processes
Information flow	• Synchronization of product and information flow • Visibility of product information (place and condition) in the whole supply chain • Sharing of information among all the supply chain players
Information technology infrastructure	• Requirement for hardware capacity, able to "digest" the tremendous amount of data generated by RFID tags • Requirement for software such as middleware to manage (filter, aggregate, redirect) product information • Requirement for network infrastructure (readers, antennas, motion captors, wireless connections, etc.) • Requirement for network integration with existing IS
Human and physical resources	• Human resources: (i) redefinition of roles within the network and (ii) requirement for new competencies • Physical resources: (i) optimization of premises by eliminating unnecessary locations and (ii) optimization of asset management by means of better tracking, tracing, and maintenance

changes needed to support these changes. All these dimensions are summarized in Table 1 and discussed below.

5.2.1. *Strategy redesign*

To achieve the real potential of RFID and the EPC network, collaboration among all the supply chain members included in the electronic business model is imperative to allow overall supply chain optimization. As an example, in the scenarios investigated, RFID tags were programmed and applied on products at the suppliers' facilities. This implies a joint agreement on the specific types of information required, but also on different standards regarding tags and readers, the frequency of their use, the speed of reading, etc. In this context, we see a move from a "firm-oriented" strategy to a "network-oriented" strategy. This strategy redesign is in accordance with new performance improvement concepts such as vendor-managed inventory, point of sale and collaborative planning, forecasting, and replenishment.

Moreover, because of the mutual dependence created by asset investments, agreement on standards and joint decision-making, the relationship evolves from a "spot" relationship to a more "systematic" relationship. As is the case for Wal-Mart and its top 100 suppliers, Firm X had to select preferred suppliers and customers to build scenarios and evaluate the impact of RFID and the EPC network on its overall supply chain. The development of this win–win partnership was facilitated by the research design followed by the research teams and the companies.

5.2.2. *Business process optimization*

In the context of our study, and as is true of many technology implementations, the business process approach seems quite appropriate to capture the real potential of RFID and the EPC network. Adoption of these technologies "forces" supply chain members to change the way they handle their respective business activities, by integrating activities, canceling, automating, or automatically triggering some intra- and inter-organizational business processes.

5.2.2.1. Integration of intra-organizational activities. Among the validated scenarios (see Fig. 3), the integration of intra-organizational activities such as receiving and put-away allowed the merging of these two processes into a single one that is now mostly automated.

5.2.2.2. Integration of inter-organizational activities. The same optimization logic was applied to integrate inter-organizational activities, such as shipping from the supplier to the receiver at Firm X and then from Firm X to the retailer.

5.2.2.3. Optimization by automating existing processes. The introduction of RFID and the EPC network allowed various business processes to be optimized through automation. These include data entry (e.g., 1.2), verification (e.g., 1.3), and reporting (e.g., 1.4) in the "receiving" process, and other paper-based activities (e.g., 1.10 in the "shipping" process). This automation provides accurate information at a very high level of granularity (pallet, box), thus allowing the possibility to measure efficiency in real time, and increase the transparency of the flow of assets and products. This can have a huge impact on operational improvements by removing manual checks and thus eliminating mistakes caused by (human) error-prone methods.

5.2.2.4. Optimization by canceling processes. RFID and the EPC network also enabled some processes to be canceled such as paper-based document manipulation (1.12 in the "shipping" process or 1.1 in the "receiving" process). All the supply chain members noticed that this impact could certainly free their employees from non-value-added activities and allow them to concentrate on their core activities.

5.2.2.5. Optimization by creating emerging processes. Finally, RFID and the EPC network allow the emergence of new types of business processes such as "smart processes" triggered by automated events (e.g., 1.1 in the "receiving" process, i.e., truck arriving at the receiving dock, or 1.8 in the "shipping" process, i.e., truck leaving the shipping dock). For example, as soon as the truck leaves the supplier's facilities, an advanced shipping notice (ASN) is automatically sent to the DC of Firm X via the EPC network, also allowing "in transit visibility" through GPS or LBS tracking between the supplier and Firm X. Furthermore, "smart processes" can also be triggered by other processes. For example, by conducting the process of "driving through an RFID portal (i.e., 1.6 of the "shipping" process), products are automatically checked (1.6.1.1) and alerts are sent to the relevant employees to perform specific activities (1.6.1.2).

5.2.3. Information flow

RFID technology and the EPC network allow:

(i) *Synchronization of product and information flow*, which provide reliable data (real time and accurate) by integrating the unique information on the products (through RFID tags). This favors the merging of "the physical market place and the virtual market space" proposed in the early vision of Rayport and Sviokla (1995, p. 1) and recently reformulated by Strassner and Schoch (2004, p. 7), specifically in the case of RFID technology, by reducing the media breaks between "the physical world and the digital world."
(ii) *End-to-end visibility* of product information (place and condition) in the whole supply chain (intra-organizational, inter-organizational, and in-transit information). Therefore, any supply chain member can access product information from the remote ONS via the local ONS, at any time and from any place, and then take action in real time.
(iii) *Information sharing* among all the supply chain players, using the same tags, but with different levels of information access.

5.2.4. IT infrastructure

With the intention of streamlining their supply chain processes and controlling costs like leading retailers around the world, the supply chain members studied are relying more on the use of information technologies such as ERP, WMS, and TMS to support intra- and inter-organizational business processes, decision-making, workflow management, and automatic information exchange with their supply chain partners. In the event that AIDC such as RFID and EPC network technologies are integrated, many IT infrastructure requirements have to be taken into consideration.

(i) First of all, the hardware capacity has to be upgraded to be able to "digest" the tremendous amount of data generated by RFID tags.
(ii) Second, software parameterization and implementation such as middleware to manage (filter, aggregate, redirect) product information has to be configured and integrated with existing applications.
(iii) Third, there is a requirement for network infrastructure upgrade including, among other things, readers, antennas, motion captors, wireless connections, etc. Besides the physical components, the adoption of RFID and EPC network technologies raise the problem of software development and integration with the existing internal firm infrastructure.

More importantly, supply chain players will need to adjust their external infrastructure in order to support collaboration and information sharing.

(iv) Finally, RFID and EPC network technologies have to be considered jointly with existing IS. RFID technology and the EPC network can enable firms to leverage their existing IS investments by providing them with accurate, standardized, and real-time information, moving from a batch-based processing philosophy to a real-time execution and decisions philosophy.

5.2.5. *Organizational structure*

Taking a rather focused view of organizational structure by focusing on human and physical resources alone, the following comments come to mind.

5.2.5.1. Human resources. There is a need to redefine roles within the network, and for "process owners" to be defined. Moreover, there are requirements for new competencies such as data analytics and real-time management and responsiveness (alert managers) allowing for "management by exception."

5.2.5.2. Material resources. Premises can be optimized by eliminating unnecessary locations such as the temporary staging area (e.g., 2.9 in the "receiving" process), or security stock(s) along the whole network, reducing the so-called "bullwhip effect."

Asset use (e.g., pump truck, forklift, and trailers) can also be optimized by better tracking (real time), better maintenance (predictive and preventive), and reduced breakage.

6. Conclusion

In presenting RFID technology and the EPC network, this paper highlighted many SCM opportunities, especially in terms of business process optimization, through a reduction in information handling by employees, which can contribute to cost savings. RFID technology and the EPC network can improve, among other activities, the "shipping," "receiving," and "put-away" processes. They can cancel, automate, or automatically trigger certain business processes, and foster a higher level of information sharing and synchronization between supply chain members. Moreover, they need to be integrated in a broader strategy, moving from a focal firm focus toward network collaboration, and from a spot relationship to a long-term relationship.

These technologies may help retail companies to enhance product availability, which is a major concern and still represents almost US$31.3 billion in opportunities each year in terms of cost reduction related to inventory shrinkage (Srivastava, 2004). Indeed, the EPC network can provide the product EPC code at any point in the supply chain, in real time, thus improving the chain's end-to-end visibility.

Our study builds on previous theory such as the (i) business value of information technology (IT) and (ii) business process re-engineering (BPR) to better understand the benefits and impacts of RFID technology and the EPC network. Moreover, our research highlights the link between the adoption of these technologies and BPR at the firm level and at the supply chain level. Dramatic changes in business processes can be observed when integrating RFID technology and the EPC network to enterprises' information systems. But to fully grasp the real benefits of these technologies, alignment of business processes are required as was the case with the adoption of previous technologies such as EDI (see Riggins and Mukhopadhyay, 1994).

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