Achieving supply chain integration using RFID technology

The case of emerging intelligent B-to-B e-commerce processes in a living laboratory

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Abstract

Purpose – Despite the high operational and strategic potentials of radio frequency identification (RFID) technology, very few studies have been conducted about its role as enabler of supply chain integration to achieve high-level operational efficiency. The purpose of this paper, therefore, is to be an initial effort towards bridging the existing knowledge gap in the literature.

Design/methodology/approach – This exploratory research was conducted in one retail supply chain. A multi-method approach combining a longitudinal real-life case study and a methodology integrating several steps, including a "living laboratory" strategy was used and involved all members of a product line to analyze their contributing activities and their interface with other supply chain members; the aim being to explore the impact of RFID technology on inter-and intra-organizational processes and information systems.

Findings – The results provide support to the role of RFID as enabler of better integration of timeliness and accuracy data flows into information systems, business process optimization through automation, better system-to-system communication and better inter-and-intra-organizational business process integration. Furthermore, they also validate the unique characteristics of RFID technology such as enabler of real-time multiple tags items data collection and exchange within the supply chain and the read-and-write capability that may help, for example, to reuse some RFID tags within the supply chain and therefore reduce the cost related to the purchase of the said RFID tags. Finally, the study also reveals the importance of business process renovation and complementary investments during the adoption of RFID technology, in order to achieve high level of business value from the technology.

Originality/value – The paper is original in the sense that it provides some empirical support for the enabling role of RFID technology in allowing supply chain integration.

Keywords Organizational processes, Supply chain management, Radio frequency identification, RFID technology, Electronic commerce, Business process integration, Supply chain integration, Proof of concept, Living laboratory, Retail industry

Paper type Case study

1. Introduction

Radio frequency identification (RFID) technology, which is defined as "a wireless automatic identification and data capture (AIDC) technology" (Fosso Wamba *et al.*, 2008,

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p. 615), is increasingly viewed by many practitioners (e.g. SAP, HP, IBM, etc.) and scholars (Curtin *et al.*, 2007; Fosso Wamba and Chatfield, 2009; Loebbecke and Huyskens, 2008; Ngai *et al.*, 2007a) as a means to achieve a high level of intra- and inter-organizational operational efficiency. Some scholars even suggested that the technology is "the next big thing in management" (Wyld, 2006, p. 154) or a "key to automating everything" (Want, 2004, p. 56) since it has the capabilities of optimizing multiple business processes through the improvement, automation and elimination of existing processes (Fosso Wamba *et al.*, 2008) or even allowing the emergence of new processes called "intelligent processes" or "smart processes", which automatically trigger actions or events that could allow, for example, the machine-to-machine communication, a better intra- and inter-organizational information systems integration by leveraging on collaborative technologies such as XML and web services (Fosso Wamba *et al.*, 2008). However, despite the operational and strategic potentials of RFID technology, very little studies have been conducted about its role as enabler of supply chain integration (SCI) to achieve high-level operational efficiency. Therefore, this study is an initial effort towards bridging the existing knowledge gap in the literature. More explicitly, this study draws on prior studies on RFID research agendas (Curtin *et al.*, 2007, pp. 97, 102) to examine the following three questions:

(1) What is the business value of RFID integration with key intra- and inter-organizational business processes?

(2) What is the business value of RFID integration with intra- and inter-organizational applications?

(3) Can business value be realized without RFID-focused process redesign?

In order to address these questions, this research draws on existing literature on innovation theory, supply chain management (SCM), inter-organizational information systems and RFID technology, as well as on a longitudinal case analysis of a retail supply chain (SC).

The remainder of this paper is structured as follows: Section 2 is a literature review of the diffusion of innovation theory, SCM, inter-organizational information systems and RFID technology. Section 3 describes our research methodology. Section 4 presents our results and discussions. Section 5 is our conclusion and further research.

2. Literature review

2.1 Innovation as enabler of organization transformation

In this paper, an innovation shall mean "any idea, practice, or material artifact perceived to be new by the relevant unit of adoption (e.g. adoption of RFID in the SC)" (Zaltman *et al.*, 1973, p. 10). This definition is consistent with the one provided by Rogers (2003, p. 12) where innovation is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption". In the current digital economy, innovation is viewed by many scholars as a vital driver of business renovation and economic growth (Aizcorbe *et al.*, 2009; Porter and Millar, 1985) and as a source of sustained competitive advantage for firms (Damanpour and Daniel Wischnevsky, 2006). However, the widespread adoption of an innovation and its use depend upon many factors, namely, the characteristics of the said innovation (e.g. relative advantage, complexity, compatibility, trialability, and observability), the characteristics of the organization (e.g. top management support. total resources, slack resources, employees' technical expertise and organizational structure) intending to adopt it, and finally, the environmental characteristics (e.g. competitive pressure, standard and regulation, level of trust among stakeholders) in which the organization is operating (Fichman, 2000; Rogers, 2003). For example, Rogers (1995, p. 16) posited that innovations that are perceived by potential adopters as having greater relative advantage, compatibility, trialability, and observability and less complexity will be adopted more rapidly that other innovations. Therefore, a great attention should be paid to each of these five characteristics in order to explain the rate of adoption of a given innovation, and thus facilitating its success among potential adopters. In addition, previous studies on innovation diffusion found that large firms usually have more slack resources, which are an important enabler of innovation diffusion (Rogers, 2003; Zhu *et al.*, 2006). Also, Zhu *et al.* (2006) found that competitive pressure is positively linked to e-business usage. In another study, Zhu *et al.* (2003) shown that in a high e-business intensity environment (e.g. country), managers tend to have a more balanced understanding about e-business in terms of its benefits, costs, and risks.

In this paper, we consider that RFID technology is an innovation and that it is innovative to integrate it with intra- and inter-organizational business processes and with intra- and internal information systems. As a reminder, RFID technology has the following characteristics: unique item/product level identification; no need of line of sight; multiple tags items reading; more data storage capability and data read/write capabilities (Asif and Mandviwalla, 2005; Jahner *et al.*, 2008; Tajima, 2007), enabler of real-time data collection and sharing among supply chain stakeholders (Delen *et al.*, 2007), enabler of business process innovation (Fosso Wamba *et al.*, 2008; Lefebvre *et al.*, 2006; Loebbecke, 2007). These characteristics may, therefore, be considered as influencing factors in the decision to adopt the technology. Moreover, early studies on RFID technology have already shown that even if competitive pressure (e.g. mandate from key stakeholders) appears to be an important factor at the early stage of exploration, its importance diminishes over time to make room for RFID technology characteristics such as enabler of SC visibility, customer service and asset management (Aberdeen-Group, 2007). Finally, in a more recent study, Fosso Wamba and Chatfield (2009) posited that the level of technological and organizational integration and the scope of organizational transformation feature among the critical factors that allow a successful RFID-enabled supply chain project. Therefore, this paper focuses on the role of RFID technology as enabler of SCI.

2.2 SCM and inter-organizational information systems (IOIS)

A SC is "a bidirectional flow of information, products and money between the initial suppliers and final customers through different organizations", and SCM encompasses the planning, implementing and controlling of this flow (Nurmilaakso, 2008, p. 721). SC optimization is continuously viewed as a strategic means to face contemporary competition (Gunasekaran and Ngai, 2004), which is now represented as follows: "supply chain versus supply chain", instead of "firm versus firm" (Ketchen and Hult, 2007). Indeed:

> [. . .] it has become clear that an individual firm can no longer prosper in business, but rather, it is the entire network that moves raw materials through production and, ultimately, to end-users, which are the nexus of marketplace success (Lancioni *et al.*, 2003, p. 173).

SCI, which is a key dimension of SCM, involves information sharing among SC members (Nurmilaakso, 2008), the integration of key intra- and inter-organizational business processes in order to increase SC overall operational performance (Datta *et al.*, 2007; Harland *et al.*, 2007), at the same time it reduces SC costs (Datta *et al.*, 2007) and improves SC competitiveness (Datta *et al.*, 2007; Fawcett and Magnan, 2008). For example, better information sharing among the supply chain stakeholders is "often considered as a generic cure for supply chain ailments" (Sahin and Robinson, 2002, p. 510).

In the literature, there are many SCI classifications. For example, Lee (2000) acknowledged three key dimensions of SCI, namely:

(1) information integration, which is the sharing of information (e.g. demand information, inventory status, capacity plans, production schedules, promotion plans, demand forecasts, and shipment schedules) and knowledge between supply chain stakeholders;

(2) coordination, which involves the reorganization of decision rights (e.g. replenishment decisions), work, and resources to the best-positioned supply chain member; and

(3) organizational relationship linkages, which include the definition and the maintaining of tight communication channels involving IOIS (e.g. EDI, internet technologies), account teams, or executive briefings.

Rai *et al.* (2006) proposed two levels of integration, namely, IT infrastructure integration for SCM, and SC process integration for high-level firm performance. For these authors, the IT integration for SCM encompasses data consistency across SC and cross-functional application integration represents the "lower-order capability" that needs to be leveraged to develop a "higher-order" process capability such as SC process integration, including physical flow integration, information flow integration and financial flow integration (pp. 227, 229). More importantly, for the authors:

> [. . .] a well-integrated IT platform is much more than individual physical components. It required standards for the integration of data, applications, and processes to be negotiated and implemented in order for real-time connectivity between distributed applications to be achieved (p. 227).

Kim *et al.* (2009) used two dimensions of SCI: internal integration and integration with channel partners. The integration with channel partners encompasses interfirm systems integration and interfirm activity integration and may cover activities such as order placement and tracking; exchange of data on performance, point-of-sale information, and inventory data; and planning and forecasting. The authors highlighted the importance of IOIS to obtain timeliness, accuracy, adequacy, completeness, and credibility of information exchange among supply chain stakeholders to enhance SC efficiency (p. 43). Indeed, IOIS which usually involve resources shared by two or more organizations for enhancing the electronic integration of business transactions and processes (Barrett and Konsynski, 1982; Hadaya and Cassivi, 2007), are used for the transmission of information across firm boundaries (Johnston and Vitale, 1988). By considering the level of automated information processing, IOIS can be classified as a system-to-system integration, when data exchange between intra- and internal information systems of supply chain stakeholders are fully automated (e.g. EDI), or as a system-to-human integration, when data exchange are semi-automated (e.g. required human intervention at some stages) Kauremaa *et al.* (2009).

In the context of SCM, IOIS have been used to facilitate information sharing between SC stakeholders (Rai *et al.*, 2006; Saeed *et al.*, 2005); to streamline and to automate intra- and inter-organizational business processes, which in turn improve the coordination of decision making within the SC (Asoo, 2002; Sahin and Robinson, 2002), to enhance each firm comparative efficiency (e.g. to reduce administrative costs, inventory costs, coordination costs, and the supply chain total cost) (Devaraj *et al.*, 2007; Johnston and Vitale, 1988) and increase revenue (Rai *et al.*, 2006).

However, the vast majority of studies on IOIS-enabled SC tend to underestimate the organizational or process changes required to take advantage of technological capabilities. They assume that technological innovations automatically result in new processes that effectively use the new capabilities (Clark and Stoddard, 1996, p. 351).

This study builds on these previous works and investigates the business value of RFID integration with key intra- and inter-organizational business processes and applications. In addition, the study investigates the level of process redesign for a high-level realization of RFID-enabled SC benefits.

2.3 RFID technology as an emerging innovative IOIS: potentials and challenges

RFID technology is emerging as a new IOIS for SC renovation (Curtin *et al.*, 2007; Gogan *et al.*, 2007). However, the concept behind RFID technology is relatively simple and its operation principle is based on the interaction of three major components, that is, RFID tags (active, passive or semi-passive), which are electronic databases that can be attached to or embedded in a physical item/product, and RFID readers which are fixed or mobile devices (Ngai *et al.*, 2007a). They can also communicate with the tag without requiring a line of sight, retrieve information from the tag and send it to a RFID middleware (Asif and Mandviwalla, 2005). The RFID middleware, which can be considered as the back bone of any RFID system, is used to manage the whole system, and it is the place where all firm business logics are configured in order to automatically choreograph the execution of intra- and-inter-organizational business processes. Once a RFID tag is embedded into a product, it becomes "smart" or "intelligent" (Fosso Wamba *et al.*, 2006; Kärkkäinen *et al.*, 2003; Meyer *et al.*, 2009; Strassner and Schoch, 2004; Valckenaers *et al.*, 2009; Yang *et al.*, 2009). More precisely, an "intelligent product" possesses a unique identity, is capable of communicating effectively with its environment, can retain or store data about itself, deploys a language to display its features, production requirements, etc. and is capable of participating in or making decisions relevant to its own destiny (Zaharudin *et al.*, 2002, p. 8). Such a product becomes a mobile, intelligent, communicating component of the firm's overall information infrastructure, and thus positioning RFID technology as an emerging IOIS with the potential to transform the entire SC for real-time optimization (Curtin *et al.*, 2007, p. 88).

The interest in RFID technology is growing steadily among the scientific community. This rising interest can be ascertained through the vast range of studies on the topic. For example, Lefebvre *et al.* (2006) by means of a pilot study showed RFID technology enables a new business model, implies major redesign of existing intra- and inter-organizational business processes and fosters a higher level of electronic integration between supply chain stakeholders. Drawing on the organizational inertia theory by Strüker and Gille (2010) as well as a survey study among German early adopters, organizations of RFID arrived at the conclusion the size does not matter when adopting and using the technology. Indeed, for the authors, even:

> [. . .] that smaller organization size can make RFID adoption and exploitation of the productivity potential easier. Accordingly, it recommends that SMEs avoid adopting a wait-and-see position or restricting themselves to easy-to-conduct RFID automation applications (p. 972).

Ilic *et al.* (2010), through a simulation using a real-world scenario, showed that the data volumes generated by RFID systems at the supply chain level will be much lower than what is currently predicted by many practitioners. Zhao *et al.* (2010) used the object-oriented modelling approach to highlight the synergy that may exist between business process automation and automatic data acquisition. Ngai *et al.* (2007b), on their part, used a case study of the research and development of an RFID-based traceability system to reveal that the creation of a strong internal and external motivation for improvement and the strive for cross-organizational RFID implementation start with a small RFID project scope and the transfer of RFID skills and knowledge from university to industry, and play a leading role in any successful implementation of RFID systems. In a more recent study, Ngai and Gunasekaran (2009) argued that following are among the issues and challenges in the adoption of RFID within a SC: the lack of global standards for RFID adoption; the necessity for data privacy, identity and non-refutability; the requirement of RFID data management; the lack of RFID expertise for deployment; the management commitment, the RFID cost-benefit analysis, the selection of RFID hardware and software both at firm and the supply chain levels and the difficulty for firms to evaluate their own needs and determine which processes can benefit from automation with the use of RFID and associated technologies. More importantly, the authors advocate for the imperative need to:

> [. . .] evaluate company's operations and determine how, where and when best to apply one or a combination of these technologies to benefit the organization, its customers and the entire supply chain (p. 6).

After introducing the concept of service abstraction layer in the RFID architecture-with the aims of removing the dependency on specific RFID framework, as well as a new virtual infrastructure that interfaces with various emerging identification technologies (Lorchirachoonkul and Mo, 2010) used a pilot study to test their concepts and found, among others things, that the usability of the virtualized RFID infrastructures depends on the cooperation among partners in the SC, rather than depending on the technology level.

Holmström *et al.* (2009) and Rönkkö *et al.* (2007) put forward the concept of "item-centric supply chain management" and "item-centric control and information management" enabled by the use of RFID technology as an innovative way of enhancing the tracking and tracing of assets during their lifecycle and to increase the efficiency of SC operations. However, Holmström *et al.* (2009) discovered that it was not easy at all to find out the right business areas where to start the development of a RFID-enabled business applications. And that is why it is necessary to use an appropriate roadmap when introducing RFID in a SC. In the same vein, Martínez-Sala *et al.* (2009) showed that intelligent products allow a better integration of data flows into information systems, which in turn allows a better tracking of the said products over the entire SC. Woo *et al.* (2009) proposed and validated an active architecture that tracks locations and attributes of logistics objects in a sensor-enabled logistics network. Finally, Pal *et al.* (2008) using a real-life pilot study for a proof-of-concept of RFID-enabled parking operations of a single university identified some tangible (e.g. more revenues) and intangible (e.g. better reputation) benefits from RFID technology. In addition, the authors highlighted the importance of using a proof-of-concept approach to assess the business value of RFID technology.

Our review of the RFID studies offers a starting point to analyze the business value of RFID technology. However, this review also show that very few prior studies on RFID have investigated the business value of integrating RFID technology with key intra- and inter-organizational business processes and intra- and inter-organizational applications using a "living laboratory" approach.

3. Research methodology

This study is conducted in the retail industry and involves five tightly inter-related firms of a three-layer beverage SC (Figure 2) which are currently investigating the potential of RFID technology.

3.1 Research design

As the main objective of this study is to improve our theoretical and practical understanding of the impact of RFID technology on SCI, the research design clearly falls into the realm of exploratory research. Thereafter, a longitudinal case study was conducted in 13 steps (Table I, adapted from Lefebvre *et al.* (2005)).

The case study allows us to capture the dynamic within the SC in real-life settings (Eisenhardt, 1989). Furthermore, a case study is recognized by many researchers as a relevant approach to answer research questions such as "why" and "how" things are done (Yin, 1994), and a means to focus on emerging phenomena and eventually induced theories (Benbasat *et al.*, 1987). Therefore, this approach is suitable to study RFID-enabled SCI, where research and theory are at their embryonic and formative stages (Benbasat *et al.*, 1987). As a matter of fact, a growing number of scholars are promoting the use of the case study approach in the logistics and operation management fields (Barratt, 2004; Näslund, 2002). More recently, many research studies have already proved its strength and effectiveness in the study of RFID technology (Fosso Wamba *et al.*, 2006; Loebbecke, 2007; Loebbecke and Huyskens, 2008; Moon and Ngai, 2008).

3.2 Research sites

The study was conducted in a three-layer beverage SC (Figure 2). The focal firm (Firm X) is a key player of the Canadian beverage industry, with various distribution centers (DCs) and stores. The DC where this study was conducted has a capacity of 170.000 square fits in which an average of 2.7 million cases of products are transited each year. Firm X already has a high level of IT sophistication, with bar code systems for tracking products at the case level, an enterprise resource planning (ERP), a warehouse management system (WMS), a transportation management system (TMS), a B2B Web portal, an EDI server, a local area network (LAN) and a global positioning system (GPS) system to optimize its intra- and inter organizational processes. However, despite this level of IT sophistication, the firm is still facing a lot of supply chain problems such as high warehousing management costs, and more importantly, inventory discrepancies in the quantities of products going from the DC to the major customers of the firm and that are due to the lack of internal control mechanisms. Resolving these issues was among the

Phase 1: vision, orientation, intra- and inter-firm opportunity seeking	
Step 1	Understanding of the primary motivation of supply chain stakeholders to consider the adoption of RFID technology as enabler of SCI using focus groups (Why?)
Step 2	Mutual choice of one family of products by supply chain stakeholders for RFID-enabled supply chain project followed by the analysis of activities related to the product value chain (PVC) of the said family of products (What?)
Step 3	Identification of the critical activities in the PVC: (Which activities to select? and Why?)
Step 4	Mapping of the network of firms supporting the PVC to assess the current level of SCI between the firms supporting the PVC (Who? and with Whom?)
Step 5-6	Mapping of ("as is") intra- and inter-business processes and intra- and inter-information systems for critical activities (How within and between supply chain stakeholder?)
Phase 2: intra- and inter-firm scenario building	
Step 7	Evaluation of RFID-enabled SCI opportunities with respect to the product (level of granularity), to each supply chain stakeholder and to the specific PVC activities using focus groups (Where?)
Step 8	Evaluation of various RFID-enabled SCI projects including scenario building, intra- and inter-business processes and intra- and inter-information systems redesign ("as could be") (How?)
Step 9	Mapping of intra- and inter-business processes and intra- and inter-information systems integrating RFID technology
Step 10	Validation of intra- and inter-business processes and intra- and inter-information systems integrating RFID technology with key respondents including the feasibility analysis, identification of key success factors and challenges of RFID-enabled SCI projects, assessment of ERP and middleware integration, process automation and supply chain alignment
Step 11	Simulation of several scenarios for final choice for proof-of-concept
Phase 3: scenario validation, demonstration and analysis	
Step 12	Proof-of-concept in laboratory simulating physical and technological environments, and interfaces between supply chain players. Feasibility demonstration of RFID-enabled SCI and evaluation assessment of RFID middleware and ERP integration, intra- and inter-business processes automation and intra- and inter-information systems information exchange
Step 13	Pilot project of RFID-enabled SCI in the supply chain stakeholders facilities and evaluation of anticipated vs realized business value from RFID project

Table I. Overall phases undertaken during the exploratory research study

focal firm primary motivations toward RFID adoption. As for the other players of the SC under study, there are two first-tier suppliers (with one more supplier which has joined the project) and one retailer. The suppliers are bottling plants. They mostly use a build-to-stock strategy and deliver their production to the focal firm on a daily basis. However, some of them need to make sure that the quantity of products shipped to the focal firm is within the range of their preauthorized annual quantity negotiated with the focal firm. Otherwise, they will be charged by the focal firm for the storage of the excess inventory. Having a visibility on the said excess inventory is among the top priorities of suppliers. Currently, the suppliers use basic ITs such as e-mail and fax. In addition, they use pre-printed bar codes that are being provided by the focal firm. However, they do not use any information from these bar codes for their internal purposes. Finally, the retailer involved in this study is one of the biggest North Americas' firms in its sector with about 30,000 employees, six DCs, and an advanced level of IT sophistication that is based on the use of e-mail, several databases, a LAN, an ERP and a WMS for intra- and inter-organizational business process optimization.

3.3 Data collection

Following Yin (1994) recommendations to increase construct validity, multiple sources of evidence were used in this study. They included focus groups (in steps 1, 2 and 7 of Table I), interviews (in steps 3, 5 and 6 of Table I), on-site observations, time and motions studies (in step 3 of Table I), dry-runs (in step 11 of Table I) and a proof-of-concept (in step 12 of Table I) using the "living laboratory" approach. In fact, the "living laboratory" represents a reliable research methodology for sensing, validating and refining disruptive innovations such as RFID technology in multiple and evolving real-life contexts with the aim of validating, in empirical environments within specific contexts (e.g. retail industry, warehousing), emerging applications, new services or products (Schumacher and Feurstein, 2007), by engaging all stakeholders at all stages of the project, and therefore gaining "tacit knowledge" from users and potential users and potential users (Kristensson and Magnusson, 2005). This, in turn, will ultimately increase the user acceptance of the innovation. More importantly, this approach allows a quicker and cheaper means of assessing disruptive technologies such as RFID through use-case scenarios feasibility (Seidel, 2004), the simulation of business experiments and the use of the laboratory over a prolonged period by all key stakeholders for "self-trial" learning (Loeh, 2005), joint problem solving, interaction, knowledge generation, and exchange (Bergvall-Kåreborn *et al.*, 2009; Konsti-Laakso *et al.*, 2008; Kusiak, 2007).

3.4 RFID-ERP laboratory infrastructure

Figure 1 shows the ERP-RFID laboratory infrastructure where the various RFID-enabled SCI are simulated.

The left part of the infrastructure (A) on Figure 1 is used to simulate supplier operations and is made of one conveyor belt (1), one Photo eye (2), an RFID portal (3) representing the supplier's shipping dock and equipped with two fixed antennas (3a, 3b), which are connected to a fixed symbol RFID reader (3c) and one stack light (3d) linked to this reader – which allows the confirmation of the status of the readings as the products equipped with RFID tags (or RFID-enabled products) (4) are passing on the conveyor belts. Indeed, as soon as the photo eye detects a RFID-enabled product, it activates the two fixed antennas in order to awake them; it then transmits radio waves only where necessary to enable the fixed symbol RFID reader to read or write the information on the RFID tag depending on the dedicated business rules configured in the middleware.

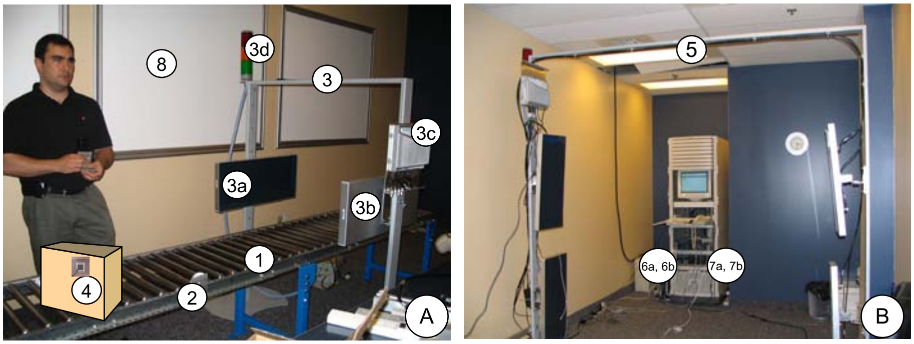

Figure 1.
The ERP-RFID laboratory infrastructure

The right part of the infrastructure (B) on Figure 1 is used to simulate the customer's receiving dock. It includes an RFID portal (5) whose technical specification is similar to that of the supplier but with two more antennas to increase the reading area.

The software part of this infrastructure is composed of two RFID middleware servers:

(1) one RFID middleware server called OMS from a Canadian-based RFID solution provider named Ship2save is used to manage the supplier's RFID hardware infrastructure (6a); and
(2) another RFID middleware server, which is called Catamaran and is developed by Shipcom Wireless and provided by Hewlett Packard, is used to manage both the focal firm and the RFID infrastructure of the retailer firms (6b).

While OMS can also be used to manage supplier transactions, Catamaran is connected to one ERP server called SAP to manage the focal firm and the retailer operational transactions (7a and 7b).

Further, we have the last component of the laboratory, which is made of the three screens on the walls (8), where all the information resulting from transactions is projected, allowing participants to follow the information flow in real-time, as each transaction is automatically performed. Moreover, a Symbol Wireless MC 900 RFID reader was used to allow real-time access to the middleware and ERP through an 802.11b wireless access point, for it to take action while on the move.

This RFID infrastructure provides the required flexibility to simulate the impact of RFID technology on multiples dyads (e.g. supplier-focal firm, focal firm-retailer) within a given SC.

4. Results and discussions

The current intra- and inter-organizational business process and the related intra- and inter-organizational information systems are now presented hereafter; and then follow the presentation and discussion of the RFID-enabled SCI scenario that is being retained in the paper.

4.1 Current intra- and inter-organizational business processes and use of intra- and inter-organizational information systems

The analysis of the current intra- and inter-organizational business processes (Appendix) provides some interesting insights:

(1) Almost all the processes are made of physical (e.g. 1.6. Pick pallet from the packaging area using a forklift in the supplier "shipping process"; 2.8. Move loaded forklift to the dedicated staging area in the focal firm "receiving process") and informational-based activities (e.g. 1.4. Link each pallet to a shipping destination using a bar code in the supplier "shipping process"; 1.1. Create a BOL in the ERP, 1.2. Enter manually data from paper BOL in the ERP in the focal firm "receiving process").
(2) The realization of the vast majority of the informational-based activities required almost always the human intervention (e.g. 1.1. Create manually a BOL in the ERP, 1.2. Enter manually data from paper BOL in the ERP during the "shipping process").

(3) There is a high interdependency between the focal firm warehouse processes (e.g. between the "shipping process" and the "put-away process") and between the "picking process" and the "shipping process", but also between activities related to the said processes. For example, during the "reception process", all the following activities need to be completed by the first receiving clerk prior to the physical reception of the incoming products by the receiving forklift driver:
   - the manual creation of a copy of that BOL in the focal firm ERP (1.1.);
   - the manual data entry from the paper-based BOL in the ERP (1.2.);
   - a manual verification of the incoming quantity by looking up the purchase order (PO) (1.3.);
   - a manual generation of the receiving report (1.4.); and
   - the initiation of the unloading (1.5).

   In addition, the third receiving clerk cannot conduct his own duties (e.g. 2.5. scan the bar coding on the pallet, 2.6. confirm visually the quantity in the pallet, 2.7. manually scan the license-plate (LP) to give it life) only if the receiving forklift driver with loaded products stops near his receiving gate. Finally, if the third receiving clerk is, for some reason, unavailable for half an hour, then the receiving forklift driver needs to sit in the forklift with the incoming products and wait until he is back to continue the process. This situation often increases the waiting time during the realization of the receiving.

(4) The link between inter-organizational business processes is achieved through paper-based documents (e.g. the BOL between the supplier "shipping process" and the focal firm "receiving process", and between the focal firm "shipping process" and the retailer "receiving process").

(5) The IS integration is human-dependent (e.g. 2.12. Transmit put-away task manually from the WMS to dedicated forklift via radio frequency (RF) through a LAN in focal firm "receiving process" and 7.14. Confirm in the ERP and in the TMS departure from temporary area and initiate tracking in the GPS in the focal firm "shipping process").

(6) The focal firm's internal control mechanisms are human dependent (e.g. 1.3. Verify quantity by looking up the PO in the "shipping process", 5.15. Confirm end of picking into WMS via RF through a LAN in the "picking process" and 7.2. Scan manually pallet to associate to the shipping destination in the "shipping process"), which sometimes lead to problems such as inventory discrepancy and increased internal lead time. For example, during the "shipping process" the clerk should scan individually each of the outbound pallets to link it to the shipping destination. However, he will usually scan one pallet and multiply by the number of pallets. For the logistics director of the focal firm, "using RFID to reinforce our internal control mechanisms is among our top priorities".

4.2 RFID-enabled SCI scenario

The RFID-enabled SCI scenario that is presented and discussed in this paper encompasses six events (Figure 2.) which shall be dealt with later.

Figure 2 shows the three-layer SC under study and the six events being simulated. They are:

(1) *The shipping of RFID-enabled cases and pallets of products from the suppliers' facilities to the focal firm DC*. The RFID tagging is done at the case and the pallet levels using passive read and write electronic product code (EPC) generation 2 (Gen 2) RFID tags. More precisely, when the number of cases of RFID-enabled products to be assembled in a pallet is reached, a pallet tag is generated and followed by the creation of a "parent-children" association between the pallet tags and the cases tags, and thus allowing the tracking of the shipment at the pallet level and/or the case level. When the RFID-enabled products are read by the reader (mobile of fixed) during the shipping process, their RFID data are collected and sent to the middleware for further processing. Based on the preconfigured business rules, if the shipping order is correct, then an electronic advanced shipping noticed e-ASN is generated and sent to the focal firm using the 802.11b wireless access point (Figure 3). Consequently, this increases the level of electronic integration and information flow between the two firms;

    From Figure 3, we can notice that the suppliers now have access to timeliness, accurate and complete information on all outbound shipments (e.g. the shipment ID, the date of its creation and modification, the location where the products need to be shipped, the products' names, their quantity, etc.). This increases the visibility on the quantity of products sent to the focal firm DC, and therefore, on the exact number of excess products, the storage of which should be paid in the focal firm DC.

(2) *The reception of RFID-enabled products in the focal firm DC*. As soon as the inbound RFID-enabled products are brought into the focal firm DC, they are automatically read by the RFID reader. The collected RFID data are then sent to the middleware for further processing, which is followed by a set of "intelligent processes", namely (a) an automatic system-to-system communication between the RFID middleware and the SAP server for the real-time execution of an automatic posting of the corresponding transaction into SAP (Figure 4(i)), leading to the real-time update of the inbound inventory and an assignment of a receiving staging area to the said inventory within the SAP system (Figure 4(ii)). In addition, all information-based activities in the receiving process are now being automated, and therefore reducing the administrative costs. Furthermore, the RFID technology fosters the system-to-system integration within the receiving process. Furthermore, it is now possible to have the put-away information about the

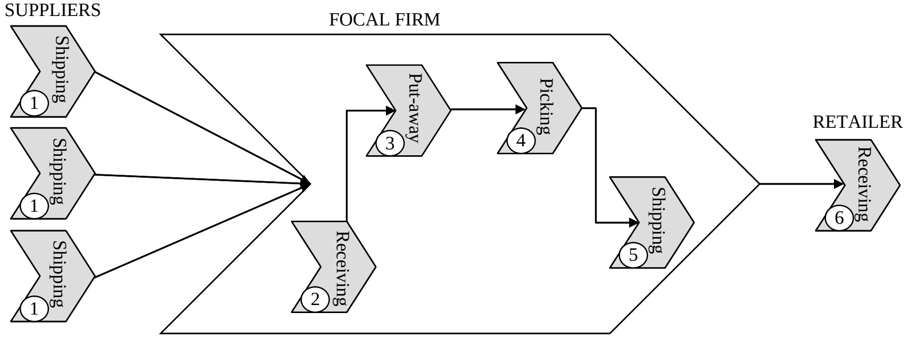

Figure 2.
The three-layer supply chain under investigation with the RFID-enabled supply chain integration scenario

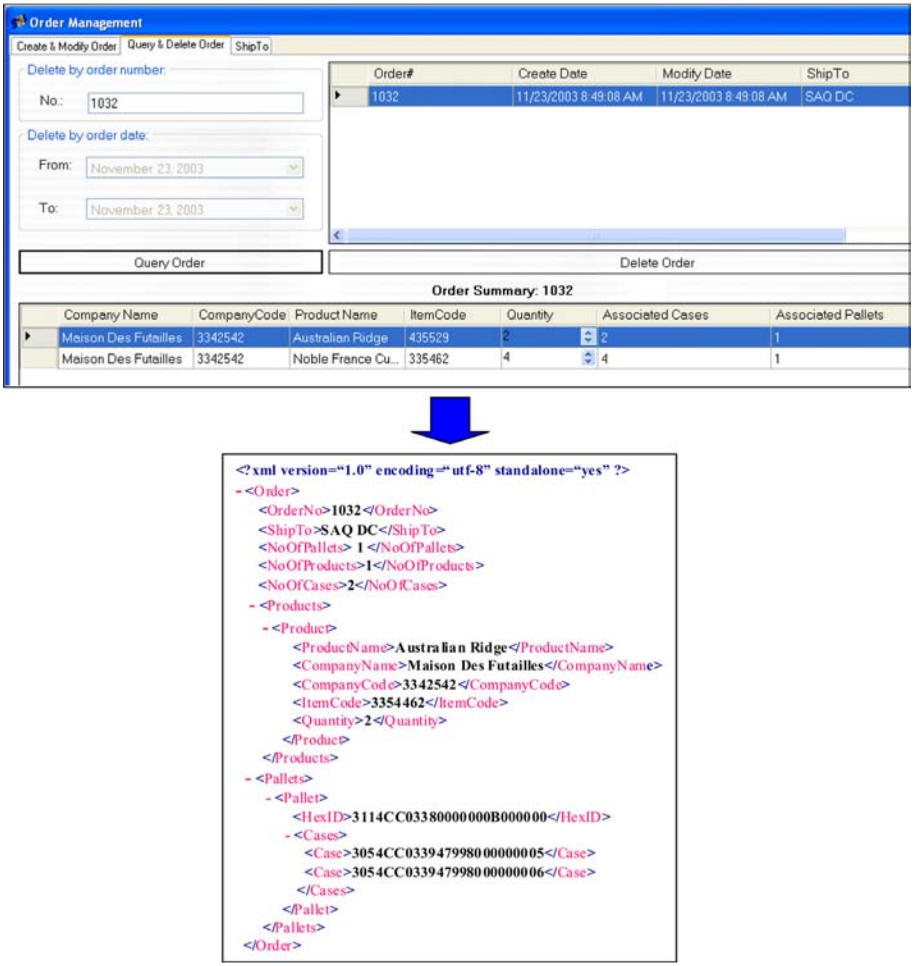

Figure 3.
Automatic validation of the supplier shipping order and generation of a XML e-ASN

"where" to put the inbound RFID-enabled products on the shelves within the focal firm DC, all of which help to avoid using the receiving staging area and to increase the level of electronic integration between the receiving process and the put-way process. This implies two important decisions by the focal firm management team that were hitherto avoided. First, the authorization of new investments to redesign the whole receiving dock and buy new agile RFID-enabled forklifts. Indeed, all forklifts use during the receiving process are smaller and have fewer features, while those used during the put-away process are two big to be also utilized during the receiving process (e.g. they cannot go inside the truck containing the inbound products). Second, there is the layoff of many employees, which is a risky decision, considering the high influence of union in the firm and the fact that it is a state-owned organization. Clearly, the RFID adoption strategy put forward by the focal firm was more oriented toward incremental than radical improvements.

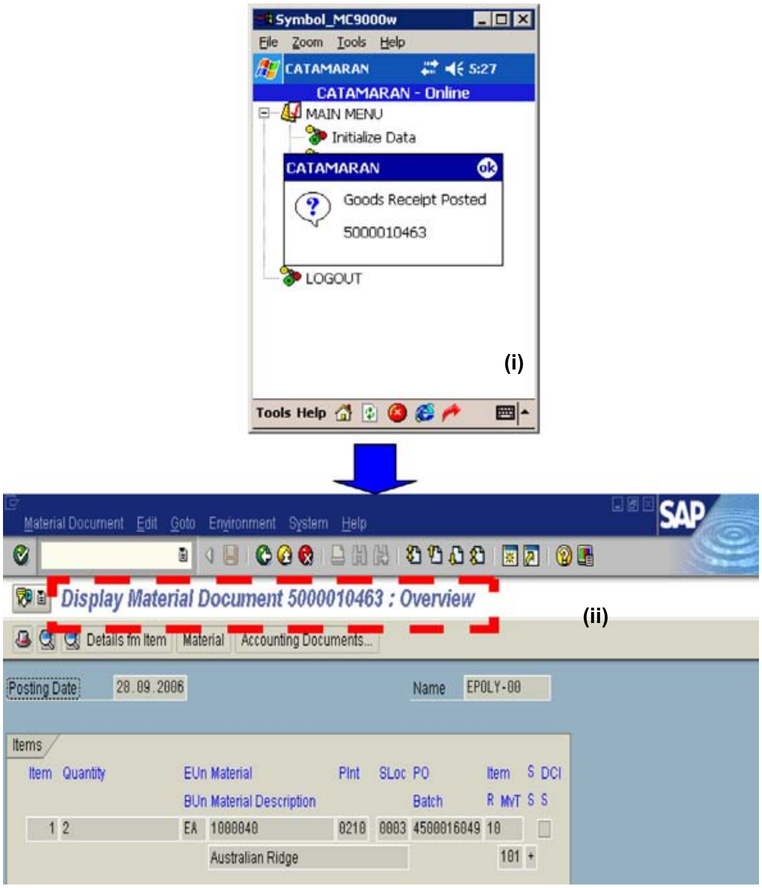

Figure 4.
Real-time communication between RFID middleware and SAP during the receiving process

(3) *The put-away of the inbound RFID-enabled products in a dedicated area on the warehouse shelves.* When the products are scanned by the put-away clerk using the wireless RFID reader, the EPC of the pallet, then the location where it needs to be stored is provided (Figure 5(a)), which is followed by another set of "intelligent processes": a real-time system-to-system communication between the RFID middleware and SAP and an automatic posting of the corresponding transaction into SAP (Figure 5(b)) allowing the automatic movement of inventory into SAP from the receiving staging area to the dedicated put-away storage location (Figure 5(c)).

(4) *The picking of a number of RFID-enabled products to fulfil a customer order.* Here, the simulation involved: (a) the re-use of the same RFID pallet tag when building the new pallet of products (Figure 6(i)), followed by the picking of the quantity of RFID-enabled cases of products to be included in the said pallet. Once all cased are picked, a single scan by the picking clerk using the wireless RFID reader allows the reading of all RFID tags on the cases (Figure 6(ii))

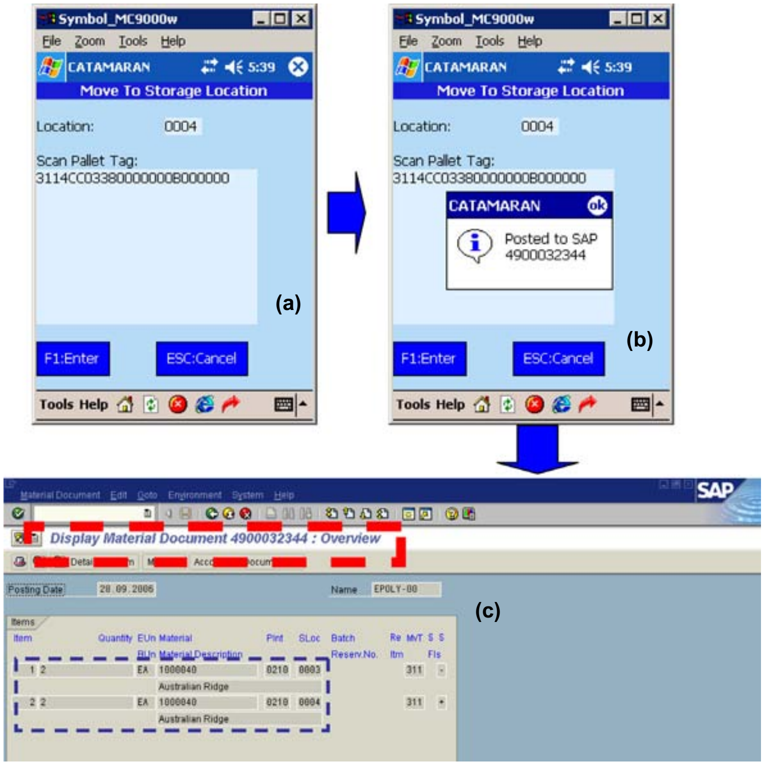

Figure 5.
Steps related to the put-away process when using RFID and corresponding transactions within SAP

followed by an automatic creation of a "parent-children" association between the pallet tag and the RFID cased tags (Figure 6(iii) and (iv)).

Figure 6 shows that besides the automatic data collection capabilities, RFID technology offers a mechanism to ensure that each case of product is associated with the right pallet and that each pallet is linked to the right picking order, all of which increases the DC internal control. Furthermore, Figure 6 shows a support to the reuse capability of read-and-write RFID tags.

(5) *The shipping of outbound RFID-enabled pallet of products to the customer's order*. Once the shipping clerk scans the said pallet, the pallet EPC is provided (Figure 7(a)), which automatically triggers a real-time communication between the RFID middleware and SAP for an automatic posting of the corresponding transaction into SAP (Figure 7(b)), thus allowing another automatic adjustment of the inventory movement (Figure 7(c)).

(6) *The reception of the RFID-enabled pallet of products in the retailer stores*. Similarly, during the receiving process in the retailer facilities, once the receiving clerk scans the incoming pallet, two automatic actions are performed: (1) the pallet EPC is provided (Figure 8(i)), and a real-time communication is performed between the RFID middleware and SAP for an automatic posting of the corresponding transaction into SAP (Figure 8(ii)), thus allowing an automatic update of the inventory in the system (Figure 8(iii)).

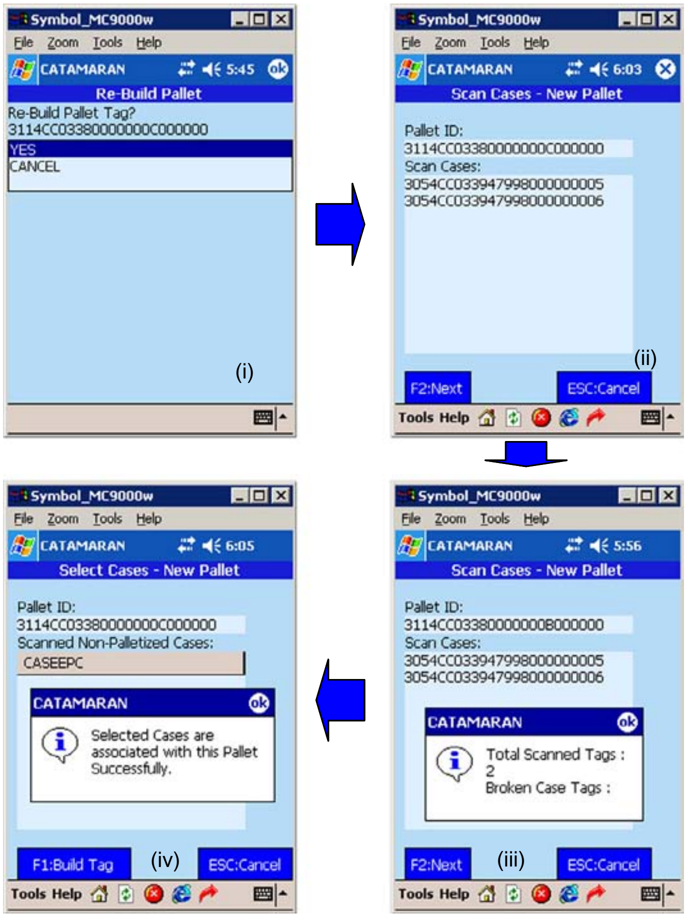

Figure 6. Steps involved in the building of a new pallet during the picking process

Figures 7 and 8 show that the interaction between RFID-enabled pallet and RFID reader allows system-to-system integration, real-time collection of accurate and complete data and automatic information flow within SAP. This new capability may improve the firm internal coordination and decision-making process.

5. Conclusion and further research

In this paper, we used a multi-method approach combining a longitudinal real-life case study and a methodology integrating several steps, including a "living laboratory" strategy, to assess the role of the RFID technology as enabler of SCI.

In terms of practical implication, our approach allows all supply chain stakeholders to identify the intra- and inter-organizational opportunities offered by the RFID technology in their specific context. Also, it takes into account all business and technological requirements of each supply chain stakeholder to simulate the impacts of the technology

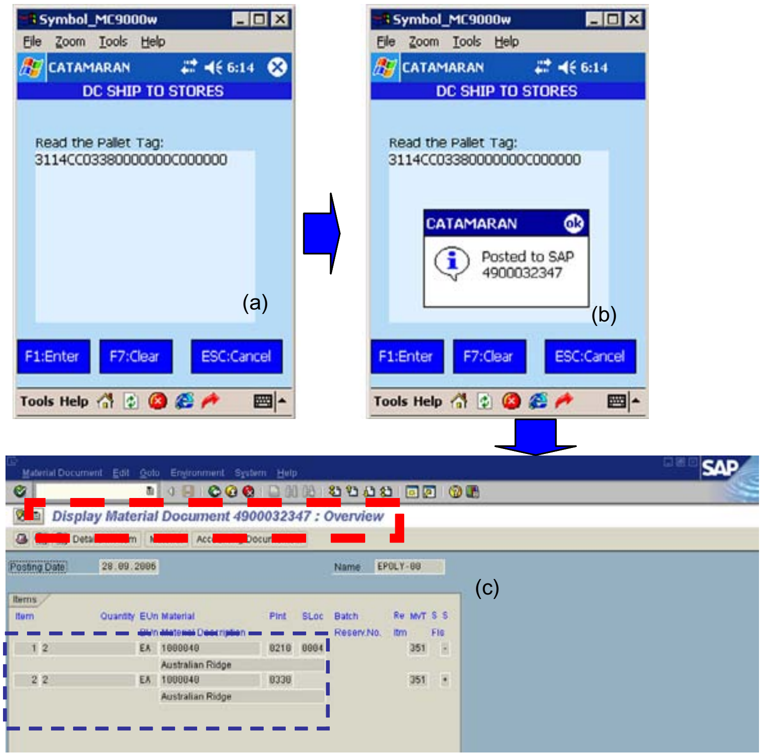

Figure 7.
Steps involved in shipping process when using RFID technology and corresponding transactions within SAP

in a controlled environment, which may in turn accelerate their adoption decision. In addition, the "living laboratory" strategy approach properly fills the gap that is being identified in the current RFID literature by many authors (Holmström *et al.*, 2009; Ngai *et al.*, 2008) on the necessity to develop methods, techniques, models and strategies to assist potential adopters of RFID technology during their adoption decision process. The RFID-enabled SCI scenario presented and discussed in this paper provides support to the role of RFID as enabler of better integration of timeliness and accuracy data flows into information systems, business process optimization through automation, better system-to-system communication, and better inter- and intra-organizational business process integration.

In terms of theoretical implication, our results are consistent with the results of prior research on IOIS (Asoo, 2002; Robey *et al.*, 2008; Saeed *et al.*, 2005; Sahin and Robinson, 2002) and early studies on RFID technology (Holmström *et al.*, 2009; Martínez-Sala *et al.*, 2009; Rönkkö *et al.*, 2007). The same results also provide support to unique characteristics of RFID technology such as:

- enabler of real-time multiple tags items data collection and exchange within the SC; and
- the read-and-write capability that may help, for example, to reuse some RFID tags within the SC and therefore reduce the cost-related to the purchase of the said RFID tags.

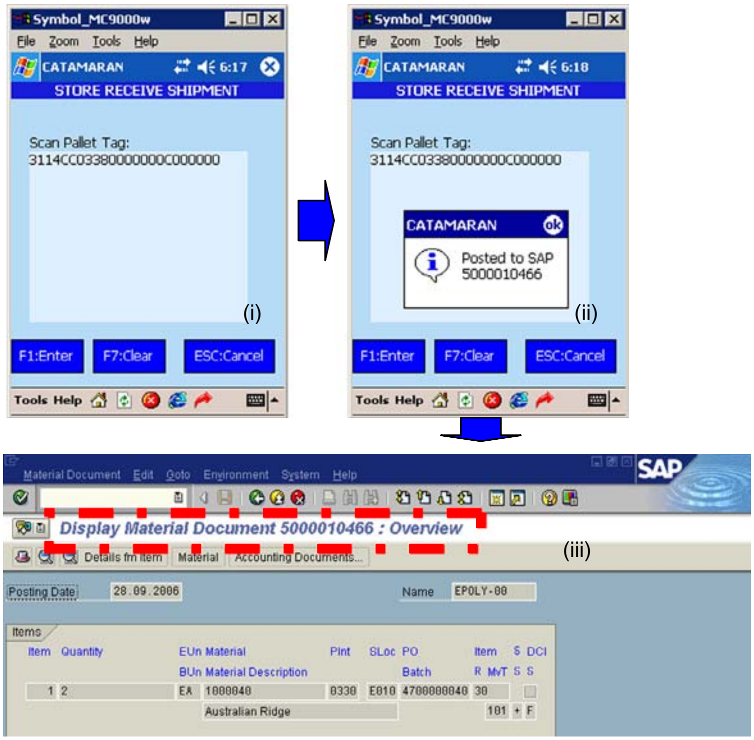

Figure 8.
Steps involved in the retailer receiving process when using RFID technology and the corresponding transactions within SAP

This last results is consistent with the observation made by Ngai *et al.* (2007b). Also, the study confirms that RFID could transform all warehousing processes, namely the shipping, receiving, put-away, picking and shipping processes. This result is consistent with earlier studies on RFID technology (Lefebvre *et al.*, 2005; Loebbecke, 2007). Moreover, the study highlights the importance of business process renovation (BPR) and complementary investments during the adoption of RFID technology in order to achieve a high level of business value from the technology. For example, because the focal firm strategy for RFID adoption was more oriented toward incremental improvements than toward radical changes, the firm was not willing to conduct the appropriate level of BPR and authorize the new required investments that were conducive to the realization of higher levels of operational benefits from RFID technology. Prior research on IOIS had already highlighted the importance of BPR for higher levels of operational benefits from IT (Riggins and Mukhopadhyay, 1994) and early studies on RFID technology (Fosso Wamba and Chatfield, 2009).

This research study is bounded in three ways. First, the study was conducted in a three-layer SC. Further research needs to be done in more complex SCs to assess the role of RFID as enabler of SCI. Second, the study was carried out in a laboratory setting which is a controlled environment. Further research works using data from a real-life supply chain integrating RFID technology are highly welcome. Third, a cost-benefit analysis was not achieved. Further research should provide some tools, guidelines and strategies to assess the cost-benefit of RFID-enabled SCI projects.

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Appendix

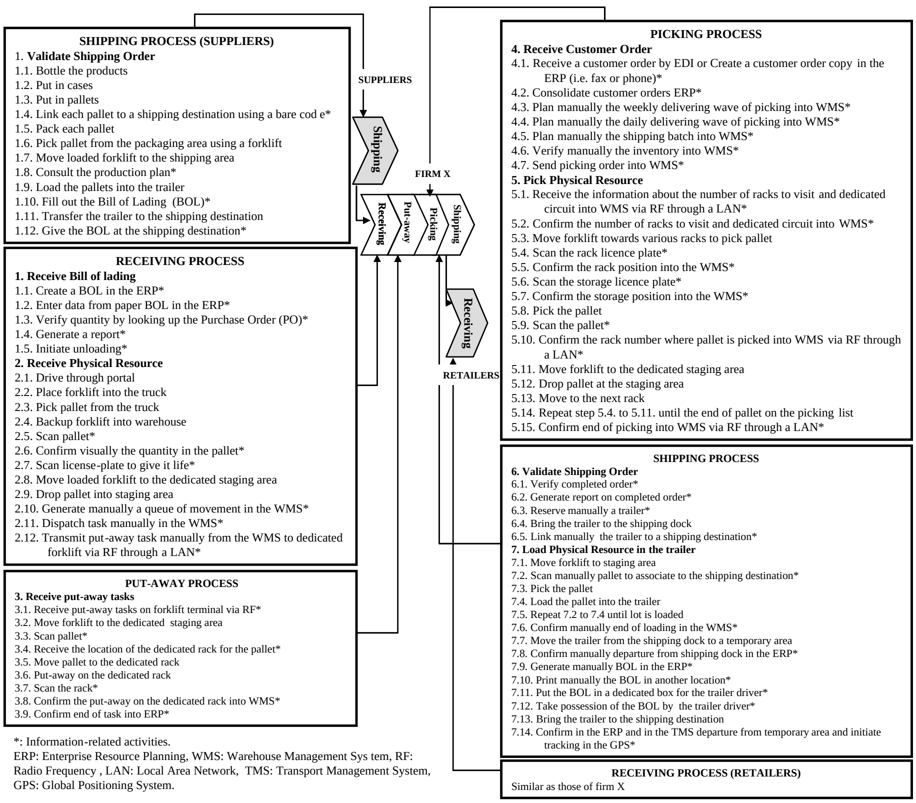

Figure A1.
Current intra- and inter-organizational business processes

About the author

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