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Enhancing Information Flow in a Retail Supply Chain Using RFID and the EPC Network: A Proof-of-Concept Approach

Samuel Fosso Wamba[1] and Harold Boeck[2]

[1] École Polytechnique de Montréal, samuel.fosso-wamba@polymtl.ca
[2] Université de Sherbrooke, harold.boeck@usherbrooke.ca

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Abstract

RFID technology and the Electronic Product Code (EPC) network have attracted considerable interest from businesses and academics in recent years. The interest is even stronger in the retail industry where firms such as Best Buy, Wal-Mart, Tesco, Target and Metro AG are capitalizing on the potential of these technologies. Based on a field study conducted in a three-layer retail supply chain, this paper tests several scenarios integrating Radio Frequency Identification (RFID) technology and the EPC network and evaluates, in a laboratory setting, their potential as enablers of information flow within a retail supply chain. Using an "open-loop" adoption strategy, our preliminary results indicate that RFID technology and the EPC network (i) hold some potential that can be grasped through Business Process Management (BPM), (ii) enable the synchronization of information flow with product flow in a given supply chain, and thus, (iii) provide a better level of information integration between supply chain members. The results suggest that these "new waves" of information technology (IT) could in fact provide end-to-end information flow between supply chain members.

Key words: Retail industry, RFID, BPM, EPC network, information flow, warehouse management, proof-of-concept.

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1 Introduction

The main objective of this paper is to investigate the potential of RFID (Radio-Frequency Identification) technology and the EPC (Electronic Product Code) network as enablers of information flow in a Business-to-Business electronic commerce (B2B e-commerce) context. By focusing on a single "open-loop" supply chain initiative in the retail industry, the paper examines the issues related to the determination, validation and simulation of selected B2B e-commerce scenarios integrating RFID technology and the EPC network in a university-based research laboratory setting. As the research objective is to improve our understanding of the potential of RFID technology and the EPC network, the research design corresponds to an exploratory research initiative.

This paper is organized as follows. Section 2 presents RFID technology and the EPC network, followed in Section 3 by a description of changes in the retail industry and the potential for RFID technology and the EPC network in that industry. In Section 4, a review of literatures on (i) supply chain management and information flow and (ii) information technology and information flow creates a theoretical basis for our research. In Section 5, we present the methodology and the research design of the study. In Section 6, the results and discussions are presented. Finally, in Section 7, we discuss the implications and draw our conclusions.

2 RFID Technology and the EPC Network

2.1 RFID Technology

In general, RFID technology has been considered as "the next big thing for management" [61] p. 154, and "the next revolution in supply chain" [53] p. 1. It is proposed that the technology helps to streamline supply chains. This "new wave" of IT has recently attracted growing interest from the industrial and academic communities. The interest is even stronger in the retail industry, where firms such as Best Buy, Wal-Mart, Tesco, Target and Metro AG are planning to capitalize on the potential of these technologies. However, RFID is not new. 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 technology [3].

RFID is a technology that uses radio waves to automatically identify individual items or products in real time in a given supply chain [43]. Like bar codes, biometrics and magnetic stripes, RFID technology belongs to the broader class of Automatic Identification and Data Capture (AIDC) technologies. Any RFID system is made up of three major layers: (i) a tag or transponder containing a chip, which is attached to, or embedded in, a physical object to be identified; (ii) a reader, also called an interrogator, and its antennas, which communicate with the transponder without requiring a line of sight; and (iii) a host server equipped with a middleware application that manages the RFID equipment, filters data and interacts with enterprise applications. RFID is often compared to bar coding systems, both conceptually and in terms of its operational performance. Even though both technologies belong to the AIDC family, RFID has superior operational performance. Indeed, unlike bar coding, which uses optical laser or imaging technology to scan and read a printed label, RFID technology uses radio frequency signals to read or write information on a product equipped with a tag [61]. Moreover, RFID technology (i) does not require a line of sight, (ii) can read many tags simultaneously, (iii) offers unique item-level identification (when using EPC codes) [59], (iv) is digital and read-write capable, (v) can store data or trigger access to external data, and (vi) can store more relevant data (e.g. serial number, location, lot number, status, etc.) [61]. Information can be accessed much faster and more easily with RFID than with bar coding.

2.2 The EPC Network as a Backbone of RFID Technology

The EPC network, also called the Auto-ID model, was proposed and developed by the Auto-ID Center at MIT as a standard for RFID infrastructure in terms of networking support [53], [17], [32]. This network is based on the EPC, which is a new numbering format for uniquely identifying items or products. The EPC network facilitates an "open-loop" standards-based environment, enabling end-to-end EPC information exchange within a supply chain [50]. Moreover, the vision for this network is to offer an intelligent infrastructure capable of linking objects, information, computers and people [44], and thus creating an "Internet of Things."

The EPC acts as a pointer to data on the network, unlike a standard RFID tag, which has much of the data associated with tagged items and products embedded on the tags themselves [47]. Basically, the EPC network is made up of five components [32] (see Figure 1): (i) the EPC, which can be incorporated into an RFID chip (also called an EPC tag) and attached to a physical object, product or item, can provide information such as the product's manufacturer, category, size, manufacturing date, expiration date, final destination, etc. (ii) The RFID reader identifies any EPC tag within its reading range, reads it and forwards the EPC information to the SAVANT. (iii) The SAVANT is the middleware system located between the readers and the firm's application systems. The middleware is at the core of the EPC network. Indeed, it is where business rules are configured. Based on those business rules, the middleware is responsible for data filtering and aggregation, manages real-time read events and information, provides alerts, and interacts with the EPC Information Service (EPC-IS) and the local Object Name Service (ONS). (iv) The EPC-IS is the gateway between any requester of information and the firm's AS and internal databases. It is responsible for information access and exchange within a supply chain. (v) The local ONS is an authoritative directory of information sources available to describe all EPC tags used in a supply chain [17].

Basically, the first three components of the EPC network correspond to those of an RFID system. However, the EPC network goes beyond the standard implementation by adding a unique product/item identification through the EPC code, the local ONS and the EPC-IS, which provide a means of sharing information more easily in a given supply chain. The EPC network evolves constantly: new standards are emerging while others are ratified. For example, the name SAVANT as designation of the middleware has changed to EPC middleware. But the present study is based on the architecture of Figure 1.

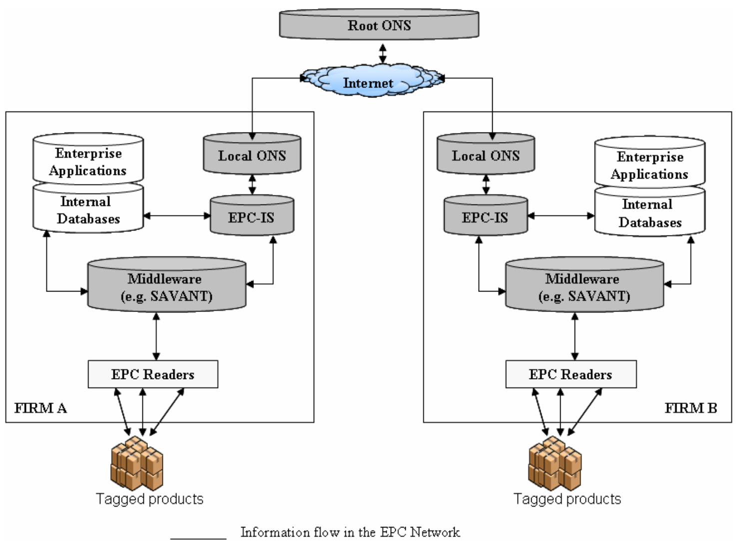

Figure 1: The EPC network infrastructure

3 The Retail Industry: Its Evolution and the Potential for RFID Technology and the EPC Network

3.1 Changes in the Retail Industry

The retail industry, like other sectors, is characterized by globalization, aggressive competition, shorter product life cycles, increasing cost pressures and the rise of customized demand with high product variants [33].

In the last 30 years, the retail industry has passed through many transformations. The traditional corner store evolved into multitude types of configurations such as the supermarket, hypermarket, discount store, convenience store, specialty retailer, gas station store and virtual store [20]. These transformations have had a huge impact on the size of stores and the number of Stock Keeping Units (SKUs) managed within those structures. For instance, the size of a traditional supermarket grew from 600 m^2 to almost 4,000 m^2 for superstores [20], and the number of SKUs in a typical US food store has risen from nearly 6,000 in the 1960s to almost 40,000 today, leading to an explosion in daily sales transactions. Therefore, capturing sales information using manual, and therefore error-prone, methods has become almost obsolete [1].

Manual capture of sales information increases transaction costs and can cause inventory inaccuracies [18]. Moreover, the retail industry is facing new challenges such as managing the short shelf-life of grocery goods, strict traceability requirements and the need for temperature control in the retail supply chain [27]. In this context, RFID technology and the EPC network are seen as enablers of supply chain optimization.

3.2 RFID and the EPC Network's Potential in the Retail Industry

In the retail industry, supply chain management (SCM) is seen as a strategic activity where RFID technology and the EPC network could enhance performance. Indeed, the link between Internet-based back-end infrastructure and the EPC network has the ability to create the so-called "Internet of Things," enabling all supply chain players to access or share real-time product information over the Net [50]. The unique potential of the combination of RFID technology and the EPC network has driven major retailers such as Wal-Mart, Tesco, Metro AG, 7-Eleven and Best Buy, to conduct several pilot projects in order to evaluate how to integrate these technologies into their business processes

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[25], [53]. For example, by adopting RFID technology, Wal-Mart stands to achieve almost $600 million in annual savings by reducing out-of-stock supply chain costs [3]. Procter & Gamble has also estimated that it could save almost $400 million annually in inventory by deploying an RFID system [53], [51].

A recent independent study conducted by the University of Arkansas at Wal-Mart stores over a period of 29 weeks has already shown significant return on investment (ROI). Indeed, the study shows that "Wal-Mart RFID-enabled stores" were 63% more effective in replenishing out-of-stocks than stores without RFID. Moreover, the results highlighted the fact that a 16% reduction in out-of-stocks was achieved, and that products equipped with EPC tags were replenished three times faster than comparable items using standard bar code technology. Finally, manual orders placed by these stores were reduced by almost 10%, contributing to the overall inventory reduction [56].

Since 2003, Metro Group in Germany has been running an RFID-enabled "Future Store," where RFID technology is used live for various applications throughout the supply chain [8]. By early 2005, Metro Group was already noticing an ROI: a 14% reduction in warehouse labor, 11% increase in stock availability, 18% reduction in lost goods, and a tag read rate at the pallet level of almost 90% [9]. Since then, this read rate has improved dramatically, reaching 100% [42]. Moreover, based on their early deployment, Metro Group found that the combination of RFID and Advanced Shipping Notice (ASN) over Metro Link electronic data interchange (EDI) would lead to potential savings of almost $10.9 billion per year [10]. In Europe, the interest in RFID technology and the EPC network is also strong. Indeed, in a survey conducted in Europe among major retailers, the results indicated that most firms that have experienced RFID technology preferred the EPC network as the networking infrastructure for information exchange [57].

The enthusiasm about RFID and the EPC network is also high among major retailers in Australia. Indeed, a pilot project has just been conducted there to investigate the potential of these technologies in the supply chain and involved tracking the exchange of ownership and the movement of products through the entire supply chain from manufacturer to retailer. It demonstrated that the introduction of RFID technology and the EPC network in a supply chain can lead to cost reductions and enhance efficiency, visibility, information timeliness and accuracy [22]. Also, in a recent study, [24], using a case study approach, reported that RFID technology could minimize product shrinkage and provide end-to-end visibility across the whole supply chain.

The main thrust of this paper is therefore that RFID technology and the EPC network can act as enablers of information flow within a supply chain.

4 Supply Chain Management, Information Technology and Information Flow

4.1 Supply Chain Management and Information Flow

Supply Chain Management (SCM) is "an integrating approach to manage the overall flow of products, information and finance from the supplier's supplier to the customer's customer" [19] p. 274. It has become vital to any business's success in the context of e-commerce in general and b2b e-commerce in particular, which by definition, implies "exchanging and sharing information within the firm itself or with external stakeholders" [12] p. 254.

The flow of information between supply chain members is recognized to be a strategic activity that enhances supply chain performance. Indeed, exchanging and sharing information to improve supply chain performance is becoming critical to achieving competitive advantage [60]. The integration of information flow in a given supply chain involves many activities such as the sharing of information about production, inventory level, delivery, shipment, capacity, sales and performance within firms and between supply chain members [41], [21]. A high level of information flow integration is considered to be a key determinant of a firm's efficiency within a given supply chain. Indeed, [41] p. 1022 state that "firms can gain performance benefits from integrating information flows across the supply chain and optimizing physical stocks and flows from a supply chain-wide perspective." As a matter of fact, logistical problems are viewed as primarily information-sharing problems [15].

Information sharing, defined as "the extent to which critical and proprietary information is communicated to one's supply chain partner" [7] p. 441 is a dimension of information flow and is considered a success factor for any SCM strategy. Better information sharing in a given supply chain can enhance supply chain coordination, and thus reduce the bullwhip effect [38], defined as the demand information variability in a supply chain, which is amplified at each stage as it moves up the supply chain. Indeed, [33] suggest that by "taking the data available and sharing it with other parties within the supply chain, an organization can speed up the information flow in the supply chain, improve the efficiency and effectiveness of the supply chain, and respond to customer changing needs quicker" [33] p. 1641.

In general, four types of information are shared among supply chain members: (i) order information (e.g. order quantities and prices), (ii) operation information (e.g. inventory levels), (iii) strategic information (e.g. point-of-sale (POS) information), and (iv) strategic and competition information (e.g. demand information regarding a competitor's products) [48], [35].

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Many academic researchers have been working on the impact of information flow on supply chain performance. For example, [34] evaluated the potential of information sharing and its impact on the order fulfillment process. They concluded that more information sharing leads to greater visibility across the supply chain, and thus contributes to lower inventory levels. [38], using an experimental simulation, investigated the impact of different levels of information sharing on the inventory replenishment of enterprises in a three-stage distribution supply chain according to various performance indicators. Using analytical models, [29] arrived at the conclusion that information sharing within a supply chain could lower supply chain costs from 12%–23%. [6] used a modeling approach to analyze the value of information sharing by comparing a traditional information policy without shared information with a full information policy that relies on shared information. They found that information sharing results in a 2.2% supply chain cost reduction compared to the traditional information policy. Using a simulation approach, [37] found that supply chain integration with exchange of information enables lead times to be reduced within the supply chain. Moreover, better information sharing within a supply chain can help to reduce the bullwhip effect [14].

4.2 Information Technology and Information Flow

Over the decades, many information systems have been developed to help firms to achieve better intra- and inter-organizational information flow. Indeed, information technology enables firms involved in a supply chain to share demand and inventory data quickly and inexpensively [6]. For example, inter-organization information systems such as EDI, database management systems (DBMS) and Web-based technologies have been adopted to support inter-organizational information sharing at various stages of the supply chain and thus contribute to enhancing supply chain performance through business process optimization. EDI is considered to be “a critical IT application in re-engineering inter-organizational information exchanges for electronic orders and invoices” [30] p. 219, leading to a better management of the just-in-time materials flow among supply chain members [30]; DBMS and Web-based technologies allow accurate and timely information flows within a supply chain [63]. As well, IT-enabled information flow can lead to indirect benefits such as order cost reductions, reduced lead times, and consequently, inventory savings [21]. From an SCM perspective, IT can improve inventory management by reducing inventory levels, holding costs, and spoilage, and thus contributes to increased profitability [13]. In this broader context of SCM, IT is considered to be a critical enabler of supply chain optimization.

In the context of intra-business process optimization, Enterprise Resource Planning (ERP) systems have been adopted to achieve flexible information flows, enabling quick deliverability through shorter planning cycles, availability of up-to-date information, reduction of transmission times, elimination of double data handling and, as a result, enhanced intra-organizational communications and data visibility [15] and increased productivity of work processes [23]. Among AIDC technologies, bar coding has been used to reduce information distortion within a supply chain [5], leading to better information quality and overall supply chain performance. For example, the use of bar coding in the consumer packaged goods industry led to annual savings of almost $17 billion by 1997 [26].

In the retail industry context, in addition to information technology applications such as Materials Requirement Planning (MRP), Manufacturing Resources Planning (MRPII), Warehouse Management System (WMS) and Advanced Planning and Scheduling (APS), many firms are exploring the potential of new customer-focused concepts such as Quick Response (QR), Efficient Consumer Response (ECR), Vendor Managed Inventory (VMI), Point of Sale (POS) and Collaborative Planning, Forecasting and Replenishment (CPFR) in order to support their intra- and inter-organizational business processes and information flow [49], [52]. For example, suppliers are using VMI to monitor retailers’ inventory levels and thereby enhancing the decision-making process for replenishment frequency, order quantities, delivery mode, and the timing of replenishments [45].

Thus, the benefits of IT for information flow are clearly highlighted in various research papers. A preliminary review of literature shows that very few academic papers have focused on RFID technology and the EPC network as enablers of information flow in the supply chain. However, many authors, such as [46] and [11] have called for research on this topic.

5 Methodology

5.1 Research Design

The research design consists of a longitudinal field research conducted in one retail supply and corresponds clearly to an exploratory research initiative. This appears appropriate since it enables researchers to capture a real picture of each firm. Moreover, a “case study is a research strategy which focuses on understanding the dynamics present within single settings” [16] p. 533. This research strategy allows researchers to fully understand the dynamic within a given situation, focus on emerging phenomena and eventually induce theories [4]. Case studies are also well suited to answer research questions such as “why” and “how” things are done [62]. Moreover, case study research is becoming more widely used in the logistics and operation management fields; its importance has been highlighted by many authors such as [39], [58], [54].

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The longitudinal field research entailed four case studies and was conducted in 3 phases made of 12 consecutive steps. The first phase also called the “opportunity-seeking phase” is made of the first six steps. 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, 5 and 6 reflect the current situation in terms of actual supply chain dynamics and existing intra- and inter-organizational business processes. The second phase or the “scenario building phase” is used to evaluate specific RFID and EPC Network opportunities (step 7) and assesses the potential of RFID and EPC Network applications (step 8). In the Step 8, several questions related to business and technological concerns are evaluated and need to be answered. For example: 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? 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 lead to the mapping of redesign business processes integrating the RFID and EPC Network technologies (step 9), which are validated with key respondents (step 10). The third and last phase of the research design validates the scenarios retained in the second phase, both in controlled conditions (proof of concept or step 11) and in a pilot project in real-life setting (step 12). Although the steps of the field study are displayed in a linear manner, several iterations occurred during the one-and-a-half-year period of the research.

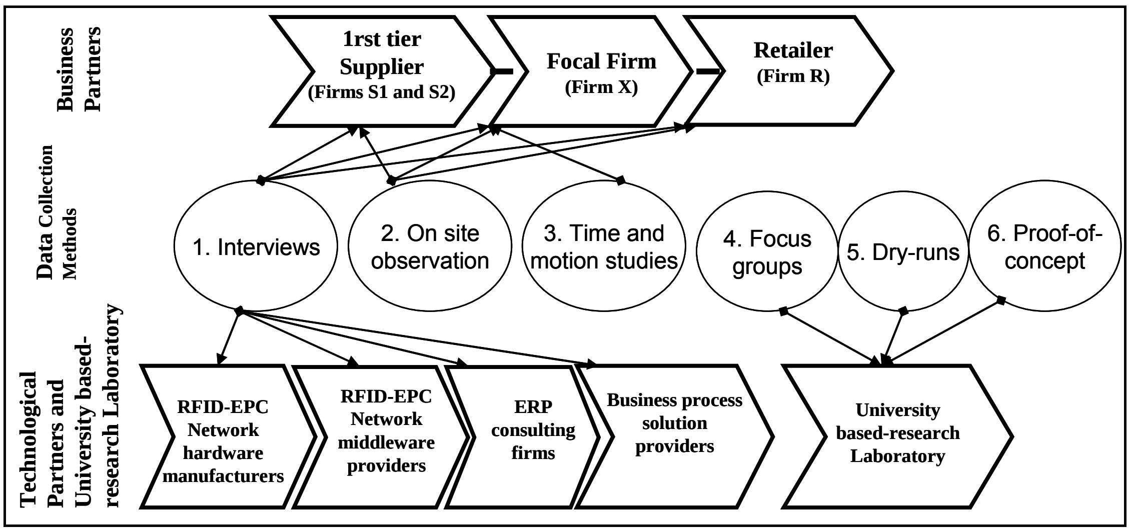

Figure 2: Participating firms and corresponding data collection methods

5.2 Research Sites

Layer 1 of Figure 2 shows the participating firms involved in the research design. These firms are briefly described in the following paragraphs.

5.2.1 The Focal Firm X’s Profile

Firm X was selected for the case study because of its high interest in projects investigating the potential of RFID technology. Firm X, which can be considered as the focal firm of the supply chain, is an important player in the beverage sector in North America; it has almost 6,000 employees and owns one large distribution center (DC) through which an overall volume of 2.7 million cases transit every year.

Firm X uses various information systems (IS) to optimize its intra- and inter-organizational business processes. For example, it uses bar code systems to track the cases through its national supply chain. In addition to bar code systems, the firm uses various business applications such as ERP, WMS and LAN to optimize intra-organizational business processes, and thus enhance information flow. The firm also uses (i) a b2b portal to facilitate business transactions with foreign suppliers; (ii) a Transport Management System (TMS) that is linked to a GPS (Global Positioning System) to improve management of its fleet of trucks; and (iii) an EDI server to communicate with some key suppliers and retailers.

5.2.2 The Two First-tier Suppliers

These two first-tier suppliers are part of the focal firm’s national supply chain and were referred by Firm X. They are bottling plants and deliver their production to Firm X on a daily basis. They rely on 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 their business applications during the receiving process. This increases document

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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.

5.2.3 The Retailer's Profile

The retailer chosen for the study is one of North America's biggest companies in its sector; it owns six distribution centers with almost 30,000 staff members. This retailer uses various IS such as e-mail, files, databases, LAN, ERP and WMS to support its intra- and inter-organizational business processes.

In Firm X's strategic plan for 2007, top management highlighted the importance of increasing productivity, and thus it is pushing the management team to explore the potential of emerging technologies such as RFID to achieve this goal. Also, Firm X's supply chain faces a recurrent inventory discrepancy. For example, "the claims by the retailer due to the discrepancy between the quantities sent by Firm X and those received at the retailer's dock can reach six zeros in terms of dollars," said one logistics manager at Firm X, positioning the elimination of this inventory discrepancy as a major driver for the exploration of RFID technology (and the EPC network). Their other motivations include the need to reduce lead times, respond faster to changing market demands, increase supply chain information flow and move toward an agile supply chain.

5.3 Data Collection

In the multiple case study approach chosen for the field study, both qualitative and quantitative data were collected using: (i) focus groups, (ii) on-site observations, (iii) interviews, and (iv) time and motion measures. In addition, other quantitative data were collected during the PoC including the dry run with managers from the selected supply chain members and their technological partners in the university based-research laboratory (Layers 1 and 2 of Figure 2).

5.3.1 Focus groups

Various focus groups were conducted in the university-based research center with functional managers from key supply chain members and IT experts. The main objective of these focus groups was to reach to a consensus on strategic intent with respect to the use of RFID technology and the EPC network. Several additional rounds of focus groups were conducted during the intra- and inter-firm scenario building. The preferred scenario (To-be) was retained so it could be simulated during the dry run and finally during the PoC.

5.3.2 On-Site Observations

On-site observations were conducted in the four research sites in order to analyze the current intra- and inter-organizational business processes and information flow related to the chosen product value chain and thus enable researchers to understand the supply chain dynamic and the business environment. Thereafter, all intra- and inter-organizational business processes were mapped (As-is) using the Aris Toolset and validated through several iterations by all managers from the four firms. The Aris Toolset is a tool for designing business processes and creating information technology enterprise architectures. The tool offers extensive functionality for distributed business process management, and can be used at various stages of research ranging from definition through analysis to the optimization and implementation of business processes [2].

5.3.3 Interviews

Semi-structured interviews were conducted with (i) managers and operational personnel of all business partners and (ii) RFID and EPC network experts from technological partners. Each interview lasted approximately two hours and allowed open-ended probing. All data gathered during these interviews were recorded in a database and reviewed by key informants of our business and technological partners in order to facilitate the mapping of existing business processes and assess the feasibility of various scenarios integrating RFID and EPC network.

5.3.4 Time and Motion Measurements

Time and motion measures were recorded on four occasions. Data collected through the time and motion measures were used during the mapping of the "As-is" and the "To-be" intra- and inter-organizational business processes using Aris Toolset.

The scenario retained represents the shipping of an order from one supplier facility, its receiving, put-away, picking (full and mixed pallets) and shipping at Firm X's DC and finally the receiving at the retailer location.

5.3.5 Dry-Runs and Proof-of-Concept

This scenario is further tested in a proof-of-concept in a laboratory setting where researchers validate it feasibility, thus bridging the gap between theories and practices (see [55] and [36] for similar approaches).

Prior to the PoC, two dry-runs were conducted in order to test the retained scenario by simulating the physical and technological environments and the interfaces between supply chain members. All steps of the feasibility demonstration were monitored in real time (middleware communication with readers, middleware integration with

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ERP, process automation, information flow, human resources impact at the supply chain level) in order to identify potential misalignment and make the required adjustments before the PoC. The final demonstration of the scenario was conducted in front of top managers of the firms involved in this research.

Other sources of evidence such as industrial reports, annual reports, Firm X's Web site and internal documents such as process documentation, procedures, ERP screens and a wide range of other technical and non-technical documents were also used when available.

6 Results and Discussion

6.1 Actual Inter- and Intra-Organizational Business Processes

Figure 3 presents the actual inter- and intra- organizational business processes in the three layers of the retail industry supply chain. Processes are drilled down from the more general (e.g. RECEIVING PROCESS) to the more detailed (e.g. 2.5. scan pallet) and are interrelated in the three layers. For example, in terms of inter-organizational business processes, the shipping process in the two suppliers (layer 1 of Figure 3) is linked to the receiving process of the focal firm (Firm X). In the context intra-organizational processes, the receiving process and the put-away process of Firm X are interrelated (layer 2 of Figure 3) and likewise for the next layer of the supply chain. However, in this paper, we will present and discuss only the impacts of RFID and the EPC network on information flow using inter- and intra-organizational activities related to the information flow within the supply chain (Figure 4).

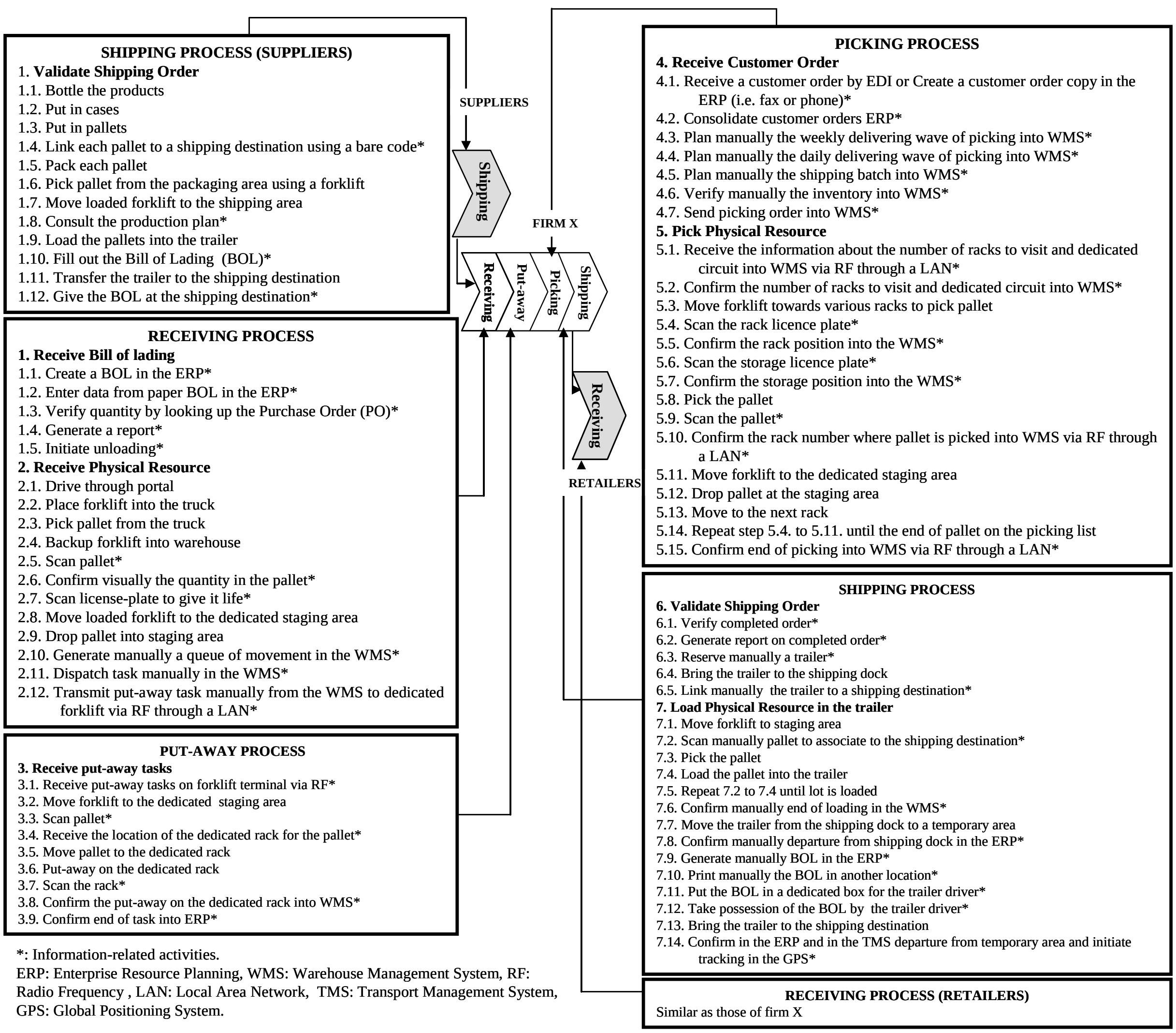

Figure 3: Actual inter - and intra organizational business processes

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6.2 Actual Inter- and Intra-Organizational Information Flow

Figure 4 presents actual inter- and intra-organizational activities related to the information flow within the supply chain. Analysis of these activities leads to the following observation: almost all information-flow-related activities required a human intervention. For example, in the "shipping" process at the supplier facilities, an employee needs to manually fill out the Bill of Lading (BOL). Also, in the "receiving" and "shipping" processes at the focal firm's DC, there are numerous human interventions such as data entry from the BOL in the ERP during receiving and manually verifying the completed order during shipping. Finally, the "receiving" process at the retailer's facilities also requires a lot of human interventions (e.g. manually verifying quantity received).

Despite the fact that supply chain members used bar codes to track and trace products, numerous problems related to the use of that technology were noticed during the on-site observations. For example, during the "picking" process for a mixed pallet at the focal firm's DC, the employee must scan each box in the pallet.

However, he usually just scans one box and multiplies his observations by the number of similar boxes, which creates the potential for errors when the cases do not contain the same type of product. Moreover, although there is a dedicated employee to verify and confirm all quantities shipped from Firm X's DC to the retailer during the "shipping" process, there are often complaints from the retailer due to incomplete quantities at its receiving dock. Resolving inventory discrepancies is becoming a top priority for Firm X's management team.

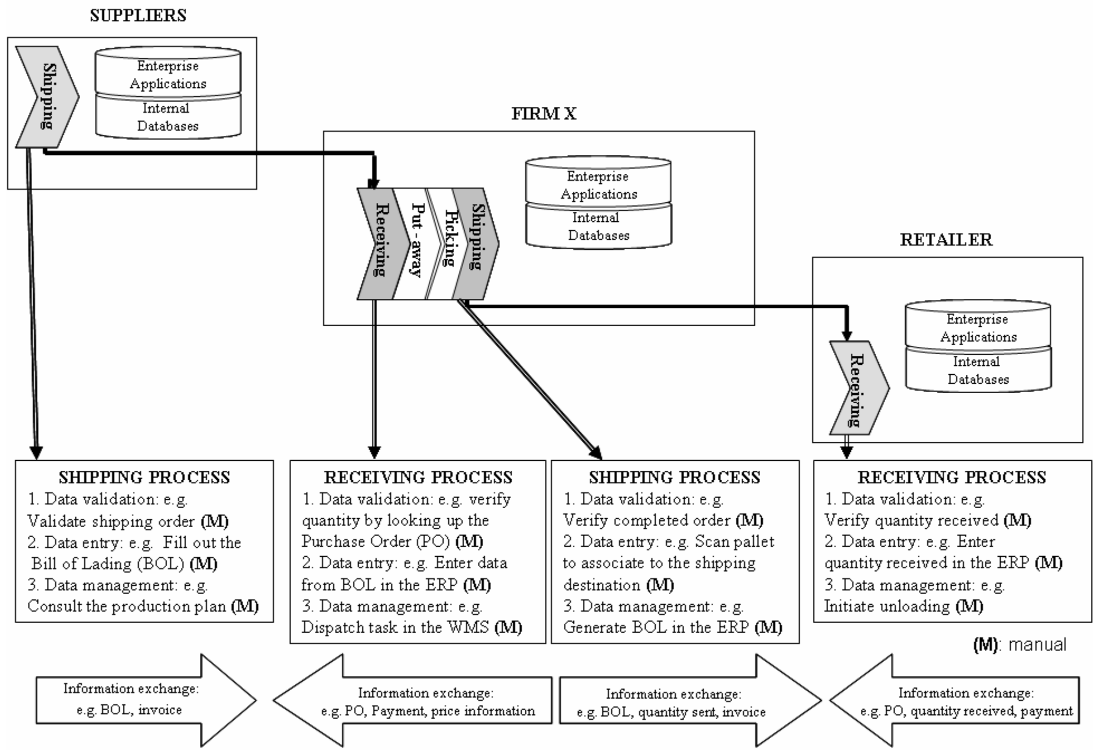

Figure 4: Actual inter - and intra-organizational information flow

6.3 Inter- and Intra-Organizational Information Flow Integrating RFID and the EPC Network

Prior to the simulation of the retained scenario integrating RFID and the EPC network, some technological assumptions were made.

6.3.1 At the supplier facilities

The product tagging (box and pallet levels) is conducted in each supplier's facilities. Tagging is done by an automated RFID printer applicator which encodes, prints the tags and then attaches them to boxes as they pass through the conveyor. A tag is applied at the pallet level. The shipping dock is equipped with an RFID door portal equipped with four antennas, and linked to middleware that communicates with the supplier's EPC-IS and the local ONS. All data collected by the RFID door portal are communicated in real time to the supplier's ERP via its EPC-IS.

6.3.2 At Firm X's DC

At Firm X's DC, the receiving and shipping docks are equipped with an RFID door portal with four antennas, and linked to middleware with direct communication to Firm X's EPC-IS and the local ONS. As soon as products pass through the receiving or shipping docks, data are collected by the dedicated RFID door portal and sent in real time to Firm X's ERP and WMS via its EPC-IS.

6.3.3 At the retailer's facilities

At the retailer facilities, the RFID infrastructure is similar to that at Firm X's DC.

Based on those technological assumptions, two dry runs and the final PoC were conducted in a laboratory setting.

For the retained scenario, the potential impacts of RFID technology and the EPC network on information flow were investigated at the process level (middle of Figure 3) and at the activity level, at the focus on the activities of the "receiving process" (bottom of Figure 5).

In the scenario, as soon as pallets of products pass the supplier shipping dock with its RFID door portal, RFID tags (pallet and box levels) are automatically read and all data collected are automatically transmitted to the middleware, which triggers the validation of the shipping order. When the order matches the PO in the ERP, the supplier's inventory is automatically decreased in the supplier's WMS, actual quantities in the shipping order are confirmed to the shipping employee and an electronic ASN (e-ASN) is automatically sent to Firm X. All information contained in the e-ASN (quantities, date and time of shipment, etc.) is now available and can be shared (depending on access authorizations) with the whole supply chain via the remote ONS. This increases visibility among all supply chain members, making it possible to adjust their inventories and have the right product in the right place at the right time.

In case of mismatch, an error message is sent to an employee in order to fix the problem and avoid false shipment of products.

During the "receiving process" at Firm X's DC, products are automatically detected and read by the RFID door portal; the data collected are transmitted to Firm X's ERP via the middleware. All information related to the products is validated using the e-ASN, which was downloaded in advance from the remote ONS of the EPC network to Firm X's local ONS and then to its ERP and WMS. During this process, quantities are validated and updated without any human intervention. Also, it was possible during the PoC to (i) automatically send a "confirmation of delivery" to the supplier in which the received quantities are indicated, and (ii) in parallel, automatically authorize the payment of those products, thereby enhancing the "cash-to-cash" flow.

All benefits generated by RFID and the EPC network at the supplier's shipping dock and Firm X's receiving dock were also simulated at Firm X's shipping dock and the retailer's receiving dock.

All information-flow-related activities (e.g. validate shipping order and fill out the BOL in the supplier's "shipping process"; verify quantity by looking up the purchase order and enter data from the BOL in the ERP in Firm X's "receiving process"; verify completed order and scan pallet to associate with the shipping destination in Firm X's "shipping process"; and verify quantity received in the retailer's "receiving process") are now automatically performed using RFID readers, avoiding the possibility of human errors. Therefore, the quality and integrity of information in the supply chain are improved.

In the second step of the analysis, the impact of RFID technology and the EPC network was investigated, with a focus on the activities of the "receiving process" (bottom of Figure 3). The results in that part of Figure 3 indicate that RFID technology and the EPC network could reduce the total time required to perform information-related activities in the "receiving process" from 370 s to 7 s, with total saving of almost 98.11%. Almost all information-related activities in that process would be automated. The human resources involved in that process are also impacted. Information-related activities in Firm X's "receiving process" are now followed up by two employees: (i) one employee who spends half of his time receiving bills of lading (e.g. create a bill of lading in the ERP, enter data from paper BOL in the ERP, verify quantity, etc.), and (ii) another employee with half of his time reserved for the receiving of physical resources related to the "receiving process." Using RFID technology and the EPC network, the total cost related to this information tracking drops from $55,000 per year to $0 per year.

7 Implications and Conclusion

This paper assesses the impacts of RFID technology and the EPC network on information flow within one retail supply chain. Our study shows that RFID technology and the EPC network could effectively enhance information flow within a supply chain by automating almost all information-based activities, synchronizing information and product flows and allowing end-to-end information visibility in the supply chain, and thus reducing potential human errors, document handling and processing costs. However, all these benefits can only be realized if supply chain members' strategy concerning the adoption of RFID technology and the EPC network is integrated into a broader strategy that involves moving from a "focal firm focus" or "closed-loop" optimization toward "network collaboration" or

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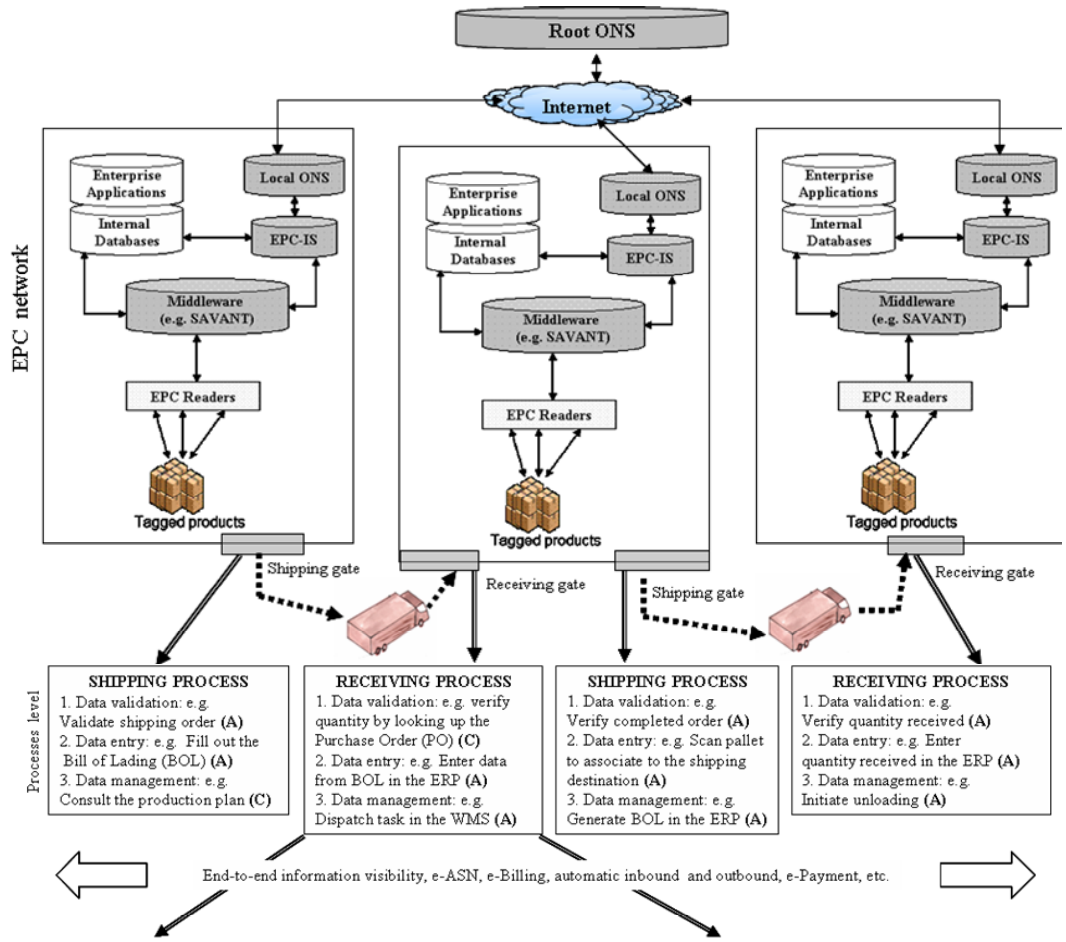
"open-loop" optimization. Information sharing among supply chain members is therefore the most critical issue. It raises many questions, such as who owns the RFID tag? Who owns the information? Who can update the data? To what extent will one firm allow another supply chain member to check strategic information such as the level of inventories for a specific product? How should real-time data be used for decision making? Which information to collect at the focal firm and at the supply chain level? And finally, how to configure business rules in the middleware to convert this raw data into "business intelligence".



Activities level — Information-related activities

RECEIVING PROCESS	TIME (in s)		HUMAN RESOURCE	
1. Receive Bill of Lading (BOL)	Without RFID-EPC netowrk	With RFID-EPC network	Without RFID-EPC netowrk	With RFID-EPC network
1.1. Create a BOL in the ERP				
1.2. Enter data from paper BOL in the ERP				
1.3. Verify quantity by looking up the Purchase Order (PO)	360	5	1/2	0
1.4. Generate a report				
1.5. Initiate unloading				
2. Receive Physical Resource				
2.5. Scan pallet	3			
2.6. Visually confirm the quantity in the pallet	1	1		
2.7. Scan license-plate to give it life	3			
2.10. Manually generate a queue of movement in the Warehouse Management System (WMS)			1/2	0
2.11. Dispatch task in the WMS	3	1		
2.12. Transmit put-away task from the WMS to dedicated forklift via Radio Frequency (RF) through a Local Area Network (LAN)				
Total	**370**	**7**	**1**	**0**
% saving		**98.11**		**100.00**
Estimated ($) amount	**N/A**	**N/A**	**$55K per year**	**$0K per year**

(A): Automated; **(C):** Cancelled

Figure 5: Inter- and intra-organizational information flow integrating RFID and the EPC network

The empirical evidence provided in this paper points to the overriding importance of inter-organizational issues either at the technical level (i.e. interoperability between the legacy systems of the different supply chain members) or at the strategic level (i.e. the decision rules to be configured in different middleware applications). The proof-of-concept approach allowed the participants in this research initiative to identify these issues, discuss them and offer different solutions. It seemed particularly appropriate to examine the dynamic among supply chain members and to gain a better understanding of the technical and non-technical issues related to the adoption of inter-organizational technologies such as RFID technology and the EPC network. Further research needs to be conducted in a real-life setting in order to validate the results from the university-based research laboratory. For example, a longitudinal approach in which the firms under study are revisited after their adoption of RFID technology and the EPC network would be helpful to compare the predicted results with the actual results.

The supply chain under study is only integrated at three layers, which is not necessarily the case in some more extended supply chains. Consequently, similar studies need to be conducted in larger and more complex supply chains before the results can be used to make policy suggestions.

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