Analyses on Researches of RFID Technology and EPC System: A Literature Exploratory Assessment

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I. ABSTRACT

EPC (Electronic Product Code) tags and RFID (Radio Frequency IDentification) technology are said to have potential to change the ways individuals, organizations and societies operate on the everyday basis. In the near future, it is expected that every major retailer will use RFID and EPC systems to track the movement of products from suppliers to warehouses, store backrooms and eventually to points of sale. Recent efforts in EPC tags and RFID technology attempt to achieve an appropriate kind of interaction between technical and business areas. In this paper, we explore the fundamental characteristics of RFID and EPC applications and then review the different research studies of RFID technology and EPC system that have been proposed new theories and concepts that have emerged and utilized in different business fields of manufacturing and logistics. It provides an overview of the study achievements within the domain and critically evaluates the various approaches through the use of a case study and the construction of its comparison framework. The different research studies indicated that RFID and EPC systems will become more pervasive in the future and the changes that occur over the next few years will make for a further fascinating research area.

II. Introduction

In the retail world, everyone is talking about EPC (Electronic Product Code) tags and RFID (Radio Frequency IDentification) technology as the way of the future to identify products and to improve receiving accuracy. The rapid development of radio frequency identification (RFID) technology and electronic product code (EPC) system build up a network that would allow companies to track goods through the global supply chain and run many applications simultaneously. RFID technology and EPC system have become hot topics in the fields of manufacturing and logistics. They have emerged as part of a new form of inter-organizational system that aims to improve the efficiency of the processes in the supply chain. RFID technology and EPC system have become a new and exciting area of technological development, and is receiving increasing amounts of attention. RFID and EPC are also an exciting area for research due to its relative novelty and exploding growth. RFID and EPC have led to the emergence of technological research areas that build on existing research in a host of disciplines, such as electronic engineering, information systems, computer science, and business strategy.

Through this real-time data-sharing mechanism, companies have broad and plain visibility over logistic flows and can leverage this information to optimize supply chain management. Recently, the adoption of RFID technology and EPC standards for products identification, as well as of EPCglobal network for information management, is experiencing an increasing diffusion in the logistics pipeline, where they are expected to have a major impact on labor efficiency, processes automation and accuracy [3].

III. Technology Issues

A. Radio Frequency Identification (RFID) Technology

Radio-Frequency Identification (RFID) refers to technologies and systems that use radio waves (wireless) to transmit and uniquely identify objects [15, 11]. RFID is an automated data-collection technology that enables equipment to read tags at a distance, without contact or direct line of sight [27, 28]. Examples of RFID applications include labeling of products for checkout at point of sale terminals, inventory tracking, and access control for security purposes [27]. Although the benefits of RFID may manifest throughout the supply chain, the primary benefits are evident at the retail end [7].

RFIDs were first used in WW-II as IFF (Identify Friend or Foe system). Although RFID technology is decades old, there has been renewed interest in utilizing its beneficial properties from researchers and practitioners alike. RFID technology is used to facilitate information sharing in decentralized business environments

such as supply chains [29]. However, RFID technology has received a great deal of attention over the last few years, with a ''boom'' in early 2003 due to (i) recent key developments in microprocessors and (ii) demands by Wal-Mart and the US Department of Defense (US DOD) that major suppliers should adopt and implement the technology by the beginning of 2005 [821]. The interest in RFID is highlighted by the many recent white papers published by technology providers (e.g., [14, 24]), consulting firms (e.g., [4, 2]), infrastructure providers (e.g., [10, 23]), enterprise software providers (e.g., [20]), and solution providers (e.g., [13]).

A.1. How RFID Works

A typical RFID system consists of tags and readers, application software, computing hardware, and middleware. We focus our attention on the articles that pertain directly to the RFID system, including tags, readers, antennae, and communications infrastructure, but exclude the literature on computer software. We divide the technology category into the following sub-categories.

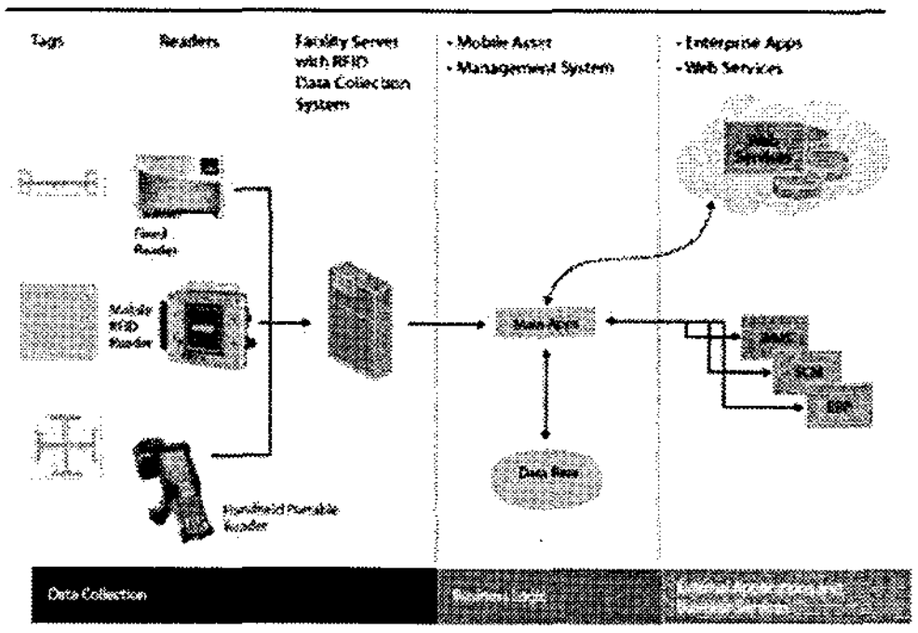


Figure 1: How RFID Works [25]

A.1.1. Tags and antennae

An RFID tag consists of an integrated circuit with memory, which is essentially a microprocessor chip. RFID tags can be active (with batteries) or passive (without batteries). The tag has an identity (ID) that can be broadcast to a reader that is operating on the same frequency and under the same tag protocol. This specific area of research includes tag design and testing, performance analysis, manufacturing processes, materials and process development, and power sources for passive tags. The antennae are the conduits for the communication of data between the tag and the reader. An RFID antenna has a reading range both sideways and in front of the antenna. Antenna design and placement play a significant part in determining the coverage zone, range, and accuracy of communication of a tag, because the antenna both draws energy from the reader's signal to energize the tag and sends the data that are received from the reader. We therefore include articles that focus on RFID chips and tag antennae.

A.1.2. Reader

An RFID reader is a device that can read data from and write data to compatible RFID tags. Communication between tag and reader enables the location information of an item to be recorded and transferred to a server through a computer network, thus allowing the movement of the item to be tracked and traced. To ensure the compatibility of the communication, the tag and reader must work at the same specified working frequency and comply with specific regulations and protocols. Readers come in four types: handheld, vehicle-mounted, post-mounted, and hybrid. The first three are used to read either passive or active tags, whereas the hybrid readers can switch between passive and active modes.

A.1.3. Communication infrastructure

The communication infrastructure is a collection of wired and wireless network communications that carries out a series of information transfer actions that deliver the data that are stored in a tag to the reader. This category includes articles on the relevant communication criteria and protocols, safeguards, and network connectivity issues.

A.2. RFID applications

Heinrich [9] pointed out that RFID is likely to be among the most exciting and fastest-growing technologies in terms of scope of application in the next generation of business intelligence [9]. Based on the various industry areas that are featured are as follows.

- Animal detection.
- Aviation.
- Building management.
- Construction.
- Enterprise feedback control.
- Fabric and clothing.
- Food safety warranties.
- Health.
- Library services.
- Logistics and supply chain management.
- Mining.

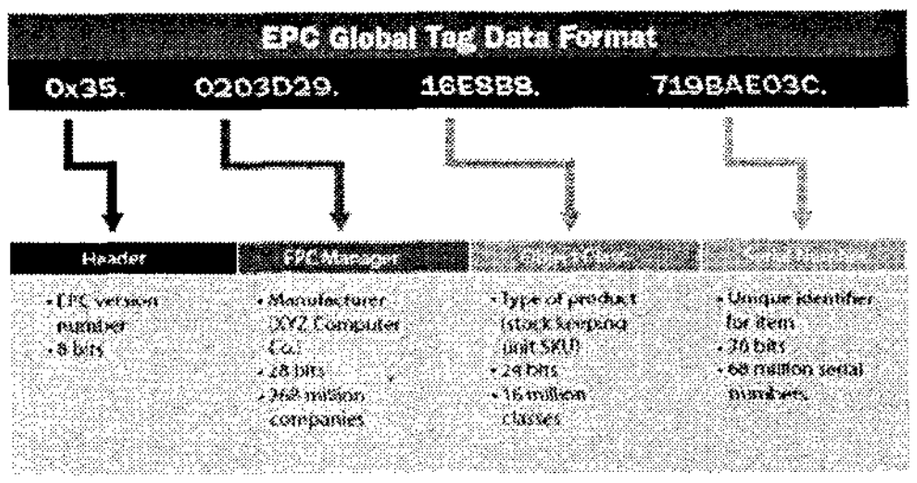
- Municipal solid waste management.
- Museums.
- Retailing.

B. Electronic Product Code (EPC)

The Electronic Product Code (EPC) was created by the Auto-ID Center as an eventual successor to the bar code. The aim was to create a low-cost method of tracking goods using RFID technology. The benefits of RFID are that it doesn't require line-of-site, which means goods can be scanned through packaging and without needing people to scan items. EPC tags were designed to identify each item manufactured, as opposed to only the manufacturer and class of products, as bar codes do today [17]. EPC data collected are then passed to and shared through the EPCglobal network. The latter has been defined as "a way of leveraging the internet to access a large amount of logistics information that can be shared among authorized partners" [6]. This so-called "intelligent network" is now considered as a standard for RFID infrastructure [6, 8, 27], and is expected to increase efficiency and accuracy in the supply chain [27].

B.1. How EPC Works

It is made up of five components: (i) The EPC start as a 64- to 128-bit identifier. Once it is incorporated into an RFID chip (also called an EPC tag) and attached to a physical object, product, or item, it can provide information such as the manufacturer, the product category and size, the date when the product was made, the expiration date, the final destination, etc. (ii) The RFID reader identifies any EPC tag within its interrogating field, reads the EPC tag, and forwards information to the SAVANT. (iii) The SAVANT is the middleware system located between readers and the application systems (AS). Based on configured business rules, it is responsible for data filtering and aggregation and interacts with the EPC Information Service (EPCIS) and the local Object Name Service (ONS). (iv) The EPC-IS, also called the Physical Markup Language (PML) server, is the gateway between any requester of information and the firm's AS and internal databases. The EPC-IS stores, hosts, and enables access at real time to any EPC code across the Internet [26]. (v) The local ONS is an authoritative directory of information sources available in order to describe all EPC tags used in a supply chain [6, 8]. Each firm in a given supply chain hosts a local ONS, which communicates with the root ONS within the EPCglobal network [26], allowing end-to-end information sharing. Products with an EPC tag have the ability to communicate with their environment and make or trigger basic decisions relevant to their management. Such products are also called "intelligent products" or "smart products" [22].



EPC differs from UPC bar code. UPC = a class of product; EPC = specific instance of a product.

Figure 2: How EPC Works [25]

B.2. EPC Benefits

The EPC is a unique serial number embedded in a microchip or tag attached to each individual product, case, pallet or other item. Using a proven technology called radio frequency identification (RFID); the code can be read by sensors over short distances. EPC numbers identify items with pinpoint accuracy and remarkable detail. With an EPC, each individual box of corn flakes or coffee filters, for example, becomes identifiable and distinct from the next. Among the benefits as the technology is refined: [16]

- Checkout lines will move much faster as EPC readers capture the entire contents of a shopping cart in seconds and, with the shopper's consent, debit his or her bank account.
- Consumers will seldom find products out of stock since the technology can signal retailers when shelves need to be replenished.
- Product freshness and quality will be enhanced as EPC systems alert retailers when sell-by or use-by dates expire. The same protection can be extended to medications.
- EPC-driven recalls can quickly identify every single product affected, enabling companies to remove them from the market and notify customers not to consume them and return the items for refunds.
- The technology can sharply curtail shoplifting and counterfeiting of foods, drugs, DVDs, computers

and other valuable consumer goods, improving product integrity and reducing costs.

- Retailers, wholesalers and suppliers will learn quickly and exactly which products are selling, which are not and at what rate, enabling them to meet consumer demand with unprecedented speed and precision. This knowledge will increase sales and eliminate billions in inventory waste — a multibillion-dollar benefit for industry and consumers.
- Years from now, EPCs could become the foundation for smart kitchens. For example, microwaving a pasta dish may require no more effort than placing the package in the oven and closing the door. The EPC will instruct the oven how to rotate the dish, how long to cook it and ding when the meal is ready.

III. RFID Technology and EPC System Studies

Research Study #1

Exploring the impact of RFID technology and the EPC network on mobile B2B eCommerce: A case study in the retail industry [19]

by Samuel Fosso Wamba_, Louis A. Lefebvre, Ygal Bendavid, E´ lisabeth Lefebvre

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

This study builds on previous theory such as the (i) business value of information technology (IT) and (ii) business process re-engineering (BPR) to better understand the benefits and impacts of RFID technology and the EPC network. Moreover, the research highlights the link between the adoption of these technologies and BPR at the firm level and at the supply chain level. Dramatic changes in business processes can be observed when integrating RFID technology and the EPC network to enterprises' information systems. But to fully grasp the real benefits of these technologies, alignment of business processes are required as was the case with the adoption of previous technologies such as EDI (see [18]).

Research Study #2

Economical assessment of the impact of RFID technology and EPC system on the fast-moving consumer goods supply chain [5]

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This paper describes a research whose aim is to quantitatively assess the impact of radio frequency identification (RFID) technology and electronic product code (EPC) system on the main processes of the fast-moving consumer goods (FMCG) supply chain. A three-echelon supply chain is examined, composed of manufacturers, distributors and retailers of FMCG. A questionnaire survey was performed to collect both quantitative and qualitative data related to logistics processes of each player. Starting from these data, a feasibility study has been carried out in order to assess the economical suitability of RFID and EPC adoption in the FMCG supply chain, both for each player and for the FMCG supply chain as a whole. Results of the feasibility study show that RFID and EPC implementation is still not profitable for all echelons examined. Specifically, both from a ''non-integrated'' and from an ''integrated'' scenario, RFID adoption with pallet-level tagging provides positive revenues for all supply-chain players. Conversely, adopting a case-level tagging, substantial costs arise for manufacturers, involving negative economical results. Outcomes of this study provide an economical justification to the RFID and EPC implementation in the FMCG supply chain.

While all benefits related to RFID and EPCglobal network have been computed on the ground of existing literature, future researches will be addressed to the development of an RFID Lab where all supply-chain processes mapped and reengineered in this research will be full-scale replicated. Experimental campaigns will determine how and to what extent potential saving

for each process and for each supply-chain partner could be achieved.

Research Study #3

Traceability of food products: General framework and experimental evidence[1]

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Traceability is becoming a method of providing safer food supplies and of connecting producers and consumers. Recent diseases such as bovine spongiform encephalitis (BSE) and the questions concerning genetically modified organism (GMO) mean systems that enable control of each link in the food chain have become particularly relevant. Furthermore, although EU law no. 178 came into effect on the 1st January 2005, at the time of writing the regulatory situation is very confused. The aim of this paper is to analyze legal and regulatory aspects of food traceability, and to provide a general framework for the identification of fundamental mainstays and functionalities in an effective traceability system. Possible technical resources were clarified by analyzing assessment criteria obtained from studies of alphanumerical codes, bar codes, and radio frequency identification (RFID). Finally, the paper presents the traceability system used by Parmigiano Reggiano (the famous Italian cheese) which was developed using the proposed general framework. Based on an integration of alphanumerical codes and RFID technology, the system is working well with very good results for both cheese producers and consumers. Some interesting observations concerning development trends and traceability system costs close the paper.

Moreover, although usually created for safety reasons, a food traceability system presents manufacturers with an opportunity as the design and management of a traceability system improves process control, indicates cause and effect when the product fails to conform to standard, improves planning so that raw material use is optimized, and improves grounds for implementing IT solutions to control and manage production. Nevertheless, the reduction of TAG costs will produce widespread diffusion of RFID systems in food. As a result, food processing companies do not need to consider traceability as an economic burden but can view it as an opportunity for system growth.

Research Study #4

Radio frequency identification technology: An exploratory study on adoption in the South African retail sector [12]

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Radio Frequency Identification (RFID) technology has recently gained widespread media coverage in South Africa. The purpose of this study was to conduct an exploratory investigation into RFID adoption in South African retail organizations, and to identify factors that have an impact on the adoption status. Quantitative and qualitative data were gathered from a sample of leading retailers in order to assess relevant factors. The findings showed that as at 2005 many retailers had not yet adopted RFID or even conducted pilot studies, but intended to in the future. This positive intention was explained by technological factors (e.g., perceived benefits), organizational factors (e.g., top management awareness and interest), and external factors (e.g., the efforts of standards-making bodies). That none of the organizations had yet reached the stage of conducting pilot studies was again explained by technological factors (e.g., cost), organizational factors (e.g., the lack of organizational readiness), and external factors (e.g., lack of global standards). The implications of these and other findings are discussed.

The reasons related to the perceived immaturity of the technology at the time, the complexities related to the business process changes associated with any deployment, as well as the large volumes of data that would be generated through RFID systems. In addition, the RFID tag costs were perceived as being too high to realize the potential benefits, and there was no concrete resource commitment to pilot studies or implementation. Costs and standards were perhaps the two main factors that were holding back pilot studies and implementation of the technology, as retailers did not want to waste financial resources and base decisions on equipment and software which would quickly become obsolete. Furthermore, retailers were cognizant of the integration challenges posed, and the changes in business processes that would be needed as a result of RFID implementation.

IV. The future of RFID technology

http://www.epic.org/privacy/rfid/
Other proposed uses of RFID technology include:

Tracking apparel: Clothing maker Benetton planned to embed retail items with RFID tags.

The implanted devices would enable Benetton to track individuals and inventory their belongings by linking a consumer's name and credit card information with the serial number in an item of clothing. Privacy advocates noted the potential abuses of a system, and Benetton agreed not to tag clothing with tracking devices—for now. However, Marks & Spencer, one of the largest retailers in the UK, announced that it will begin tagging apparel items with ultra high frequency (UHF) tags beginning in Fall, 2003. UHF tags are a new generation of RFID technology that provide faster data transfer speeds and longer read ranges. Marks & Spencer has already used tracking devices extensively in its food supply division.

Tracking consumer packaged goods (CPGs): Gillette, Wal-Mart, and the U.K.-based supermarket chain Tesco are teaming up to test specially designed shelves that allow for real-time tracking of inventory levels. The "smart shelves" will be able to read radio frequency waves emitted by microchips embedded in millions of shavers and other products. Wal-Mart plans to test the Gillette shelf initially in a store located in Brockton, Mass. If the technology is successful, Wal-Mart also plans to join forces with Procter & Gamble to test a similar system with cosmetic products, and has encouraged its top 100 suppliers to use wireless inventory tracking equipment by 2005. So far, Wal-Mart executives say the company plans to use RFID chips only to track merchandise, and will remove the tags from items that have been purchased. However, Wal-Mart's decision to implement RFID technology will likely propel the ubiquity of the tags in CPGs.

Tracking tires: Tire manufacturer Michelin recently began fleet testing of a radio frequency tire identification system for passenger and light truck tires. The RFID transponder is manufactured into the tire and stores tire identification information, which can be associated with the vehicle identification number (VIN). Critics argue the tags could ultimately become tracking devices that can tell where and when a vehicle is traveling.

Tracking currency: The European Central Bank is moving forward with plans to embed RFID tags as thin as a human hair into the fibers of Euro bank notes by 2005, in spite of consumer protests. The tags would allow currency to record information about each transaction in which it is passed. Governments and law enforcement agencies hail the technology as a means of preventing money-laundering, black-market transactions, and even bribery demands for unmarked bills. However, consumers fear that the technology will eliminate the anonymity that cash affords.

Tracking patients and personnel: Alexandra Hospital in Singapore recently began a new tracking system in its accident and emergency (A&E) department in the wake of the Severe Acute Respiratory Syndrome (SARS) scare. Under this system, all patients, visitors, and staff entering the hospital are issued a card embedded with an RFID chip. The card is read by sensors installed in the ceiling, which record exactly when a person enters and leaves the department. The information is stored in a computer for 21 days. Officials say that the technology enables health care workers to keep tabs on everyone who enters the A&E department, so that if anyone is later diagnosed with SARS, a record of all other individuals with whom that person has been in contact can be immediately determined. Other hospitals in Singapore are expected to adopt similar technology.

Payment systems: In 1997, ExxonMobil developed the wireless payment application known as Speedpass. Since then, six million consumers have utilized the payment option at 7,500 Speedpass-enabled locations. Now, a wide range of merchants and retailers are looking for ways to implement radio frequency (RF) wireless payment systems. Sony and Phillips are leading the way. The two corporations will soon begin field testing an RFID system called Near Field Communication (NFC), which will enable RFID communication between PCs, handheld computers, and other electronic devices. The companies envision that consumers will log on to their personal online portal by swiping their smart cart—embedded with a Sony or Philips RFID—which will be read by a RFID reader plugged into the USB port on the computer. Next, consumers would shop online, say, for tickets to a local event. The consumer would pay for the tickets online, download them to their PC and then transmit them with NFC technology to an RFID tag in their mobile phone. Then, at the event, consumers would wave their cell phone near a reader in the turnstile, and be automatically admitted.

V. Conclusions

RFID is an emerging technology that has been successfully applied in supply chain management, manufacturing, and logistics, but its range of application extends far beyond these areas. There is tremendous potential for applying it even more widely, and increasing numbers of companies have already started up pilot schemes or successfully used it in real-world environments. The introduction of radio frequency identification

(RFID) technology to the supply chain management, manufacturing, and logistics industry equipped with new electronic produce codes (EPCs) has generated some new challenges for data management and fascinated different researches in Information Technology areas. Thus, by building RFID and EPC applications on top of this supply chain, application and data integration cost can be greatly reduced. The emerging widespread adoption of RFID will result in enormous amounts of data because it dramatically improves efficiencies within the supply chain. We anticipate that the increasing interest of researchers and the rapid growth of the body of knowledge on RFID will lead to a reduction in the proportion of conceptual or descriptive analyses in favor of empirically based studies.

This study highlights the fact that the majority of research has been focus shifts from the technical issues to the business issues, and as RFID begins to be applied to various locations along the value chain. However, despite the numerous opportunities for RFID, it seems that there is still a long way to go before its extensive global application is achieved. There are many challenges that need to be overcome and a host of problems to be solved to expedite the widespread implementation of RFID. RFID technology is significantly changing the current business applications.

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