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Improvement of Supply Chain Performances Using RFID Technology

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1. Introduction

As markets become more global and competition intensifies, firms are beginning to realize that competition is not exclusively a firm versus firm domain, but a supply chain against supply chain phenomenon (***a, 2008). Under these circumstances, an increasing strategic importance to any organization independent of size or of sector, is to deliver information, goods and services in full, on time and error-free to customers.
From demand forecasting, to the sourcing of raw materials, right through to manufacture and dispatch- visibility in the supply chain is becoming an important facet of any modern operation (Coltman et al., 2008). But at this moment, the interconnectivity between various links in the supply chain is incomplete and inaccurate, every link in the chain being an individualistic entity with different processes. This leads to poor product visibility and stock transparency across the supply chain. For companies looking at multiple markets, the lack of visibility in their supply chain can lead to tremendous loss of revenue.
But even if information technology is used within a supply chain to share information on end-customer demand and inventory levels, there is still often a discrepancy between this information and the real physical flow of products. This discrepancy frequently derives from the missing real-time or near real-time data in concordance with the physical flow of goods. The result is inaccurate inventory information. Reasons why information system inventory records are inaccurate include external and internal theft, unsaleables (e.g. damaged, out-of-date, discontinued, promotional, or seasonal items that cannot be sold any longer), incorrect incoming and outgoing deliveries (Raman et al., 2001; Fleisch & Tellkamp, 2003), as well as misplaced items (Raman et al., 2001). Thus, even when inventory records are accurate, misplaced items mean that they were not out of stock, but rather misplaced in storage areas or in the wrong location within the store.
The phenomenon of inventory inaccuracy is well-known. As Raman et al. (Raman et al., 2001) show in their case study, most retailers cannot precisely identify the number of units of a given item available at a store; thus for more than 65% of stock keeping units (SKUs) in retail stores, information on inventory in the inventory management system was inaccurate (i.e. the information system inventory differed from physical inventory). The difference was on average 35% of the target inventory. In a second case study, the authors found that a median of 3.4% of SKUs were not found on the sales floor although inventory was available

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in the store. In the first case, inventory inaccuracy reduced profits by 10 %, while in the second case, misplaced items reduced profits by 25%.
Inventory record inaccuracy and misplaced items can lead to a substantial decrease in profits due to lost sales, additional labor costs, and higher inventory carrying costs. All these problems may also have a long-term negative impact on firm image.
RFID technology can be a solution to these problems by tracking and tracing products at any point across the supply chain. Thus, RFID will have a significant impact on every facet of supply chain management—from the mundane, such as moving goods through loading docks, to the complex, such as managing terabytes of data as information about goods on hand is collected in real time (Caton, 2004).
For the perishable goods industry, demand management is crucial. In the United States, up to 20 per cent of foods are discarded due to spoilage in the supply chain (Rangarajan et al., 2005). Monitoring and control of time-sensitive products can be facilitated by the application of RFID technology.

2. RFID and supply chain

2.1 RFID technology overview

RFID technology is classified as a wireless Automatic Identification and Data Capture (AIDC) technology that can be applied to the identification and tracking of entities. An RFID device called RFID tag or transponders can be attached to a product as a means of identification. This tag contains an integrated circuit for storing information (including serial number, configuration instructions, activity history, etc.), modulating and demodulating a (RF) signal, and other specialized facilities. The circuit is attached to a miniature antenna within a set upon a label to permit attaching the tag to the desired physical object. The RFID tag transmits their data in response to an interrogation received from a read-write device called RFID reader or interrogators. This device decodes the tag signal and transfers the data to a computer through a cable or wireless connection. The tags and readers are designed with a specific operating frequency. Given the wireless communication between the RFID chip and the RFID reader, all data may be read from a distance. The reading range varies in accordance with the operating frequency, the size of the reader antenna, the orientation of the RFID tag towards the antenna, the tag position with respect to the antenna core, as well as with the tag type.
RFID tags come in a large variety of designs; they can be classified in many different ways and multiple criteria could be used. Thus, RFID tags can be categorized in accordance with the following criteria:

- power source
- operating frequency
- data storage
- memory size

Each of them is briefly presented below.
Tags use a variety of power sources:

- *active tags* - contain their own power source (a battery) that is used to run the microchip's circuitry and to broadcast a signal to a reader when prompted;
- *passive tags* – with no internal power source. Instead, they draw power from the reader;
- *semi-passive tags* - which use a battery to run the chip's circuitry, but communicate by drawing power from the reader.

Because the active and semi-passive tags contain more hardware than passive RFID tags, they are more expensive. Active and semi-passive tags are reserved for costly items that are read over greater distances. Yet, this flexibility does have a cost; active tags require more maintenance and have a limited life span due to onboard power supplies (5-10 years). Passive RFID tags have lower production costs, meaning that they can be applied to less expensive items. In fact, improved passive tag technology is responsible for the current wave of RFID adoption, as costs are reduced and operating ranges increase.

In some cases, active tags and tags with sensors can be used to monitor product quality. Thus tags can record temperature, humidity, pressure, shock/vibration, leakage and other data that could help determine the physical condition of the items monitored. For example, companies handling fresh produce such as vegetables can ensure product freshness by ensuring first expiry first out (FEFO) instead of the regular first in first out (FIFO).

A factor that also influences the cost of RFID tags is *data storage*. There are three storage types: read-write, read-only and WORM (write once, read many) (Gibson & Bonsor, 2005). A read-write tag's data can be added to or overwritten. Read-only tags are programmed with a serial number or other unalterable data when they were made and cannot be added to or overwritten. WORM tags can have a user-defined secure read-only area that may contain additional data (like another serial number) added once, but they cannot be overwritten.

Another tag classification criterion is *memory size*. Generally speaking, tag memory size can vary from 1 bit to 32 kbits and up. Active tags are able to retain more memory than passive tags. But more data on the tag leads to increased data reading time. One of the most challenging RFID implementation issues is the choice of the right memory capacity to support specified requirements.

Frequency is the leading factor that determines RFID range, resistance to interference and other performance attributes. RFID systems are available in a wide range of frequencies to suit various performance needs and they can be classified based on the band in which they operate. For the moment, there is no global frequency standard for RFID communication, bandwidth availability being regulated by telecommunications authorities in each country. RFID uses a range from 125 kilohertz (low frequency) to 5.3 gigahertz (microwave), generally divided in four distinct categories: Low Frequency (LF), High Frequency (HF), Ultra-High Frequency (UHF) and Microwave systems. Most commercial RFID systems operate at either the UHF band, between 859 and 960 MHz, or HF, at 13.56 MHz. Not all frequencies are available for use throughout the world and this is an important point to consider when planning supply chain applications. Most RFID technology used in warehousing and distribution operates at 13.56 MHz (HF), 860-930MHz (UHF) or the 2.45GHz (microwave) band. For material handling, logistics and supply chain applications RFID systems are concentrated in the UHF band and 13.56MHz.

The *reading range* of RFID systems is given by the maximum distance between the tag and the reader antenna that allows the reading of the information stored on the tag chip. The reading range varies from a few centimeters to tens of meters, depending on the frequency used, the power output, immediate physical environment and the directional sensitivity of the antenna. For read/write tags, the reading range typically exceeds the write range. HF range is limited to the near field only. Thus HF technology is used for short-range applications and can be read from up to about three meters; this means it cannot be used on cases and pallets where warehouses and distribution center logistics require longer range RFID operations. UHF technology provides a reading range of 20 meters or more. The detection range of active tags is relatively large (up to 300 feet), whereas passive tags only operate at smaller distances (a few inches up to 30 feet).

The material composition of the tagged item and the contents of the items to be tagged can have a serious impact on the reading performance. Tag performance generally decreases with size, so it's advisable to use the largest size possible that fits the object. Longer ranges require larger tags, and it's a reality of physics that with longer ranges, the read rates are slower, and more reader power or more sensitive tags are needed. Extra range may be required if the application calls for reading a large number of tags moving very quickly past the antenna.

Given current tags costs, Byrne indicates that only medium to high value products should be tagged (Byrne, 2004). Industry is hoping that tag manufacturers can hit 5 cents per unit, and that is being regarded as a breakthrough level, and Gaughan sets the item/product cost delineation at least $15 (Gaughan, 2005).

RFID technology is emerging as a powerful and proven tool for streamlining production at manufacturing facilities of all sizes. As RFID is integral to the future of supply chain management and items tracking, it is important to examine RFID in detail and to compare its capabilities to an existing industry standard, the barcode.

2.2 RFID vs. barcode

RFID is similar to another AIDC technology, barcode technology. Conceptually, bar coding and RFID are quite similar. In fact, an RFID tag can be attached to a product as a means of identification, in much the same way as a barcode label. The two technologies differ in terms of the technology employed: barcode uses optical technology, while RFID uses radio technology. However, RFID tags have numerous advantages over barcodes.

The major advantage is that RFID has the capacity to store larger amount of information. Barcode is based on WORM (write once read many) technology, which means that once printed, a barcode cannot be modified. But an RFID tag can be read and written with a reader for thousands of times, acting as a portable database. In fact, RFID-enabled supply-chains can generate 10 to 100 times more information than traditional barcode technology.

Another advantage of RFID technology is that information gathering is faster than in the case of barcodes, while the read/write operations can be performed through different materials such us paper, plastic or wood, with the exception of metals.

RFID also allows easy, uninterrupted and upon-request access to the tag data. Unlike the barcode where identification is limited by line-of-sight, RFID technology requires neither a line of sight for identification, nor a straight-line alignment between the tags and readers. This means that packaging never needs to be opened to read a product tag. RFID tags are also sturdier than barcodes, allowing for use in adverse conditions (including exposure to dirt, outdoors, etc.), and tags can be affixed or embedded on the product packaging or inside the item. Barcodes are scanned one at a time, requiring much more time and effort to scan than RFID tags, when a large number of items are to be counted or tracked. The barcode is generally used to identify a product family, not the single item. The RFID tags can track items more precisely than traditional barcodes, and they can be read faster with less human intervention, thus allowing for more rapid product movement. Furthermore, by anti-collision mechanisms, several RFID tags in the field of a writer/reader can be addressed at the same time. For example, if a large amount of pallets are being unloaded into a warehouse, they can simply be crossed through docking doors attached with RFID readers instead of being unpacked and scanned manually.

Barcode presents some privacy and security issues. Although the data encoded on the barcode could be encrypted, there is no protection to prevent the barcode data from being copied and decrypted using commercial tools. Thus barcodes may be duplicated and attached to products. RFID tags allow more sophisticated forms of data protection and encryption than barcode. Each RFID tag has its own unique identity code or serial number from the manufacturer embedded on the tag. This number may never be modified making the tags counterfeit proof.

Barcodes are cheaper than RFID tags; a barcode label costs fractions of a penny instead of RFID tags cost that vary from 20 cents to a couple of dollars (for specialized tags). But, as time passes, it is estimated that RFID tags costs will decrease due to an increase in demands and lower costs from suppliers. On the other hand, barcode costs would are likely to remain the same because companies have already invested enough in the technology and its corresponding equipment.

Table 1 summarizes these aspects and provides a brief comparison between RFID and barcodes technologies (Vempati, 2004; ***b, 2007).

Characteristic	**RFID**	**Barcode**
Reads Per Second	40-200	1-2
Read Range	Up to 25 feet for passive RFID and up to 100's of feet or more for active RFID	Several inches
Read/Write	Yes	No
Anti-collision capabilities (simultaneously read capabilities)	Yes	No
Cost	More (>$.20)	Less (pennies)
Reusability	More	Less
Human Intervention	Less	More
Line of Site Required	No	Yes
Read Speed	Milliseconds	> second
Dirt Influence	No effect	Very high
Security	More	Less
Reader Interoperability	Limited, but growing	Yes

Table 1. RFID versus Barcodes

Speaking in enterprise terms, it is evident that the usage of RFID tags in a supply chain system enjoys considerable benefits (***c, 2007): high efficiency in collecting, managing, distributing and storing information on inventory, business processes, and security controls; increased productivity; products are processed at high speeds, so the time allotted to product scanning is considerably reduced; the time involved in product handling is reduced; inventory activities are simplified and data accuracy increases. Thus, various studies have proved that all inventory procedures may be performed faster than those involving barcodes (Davis & Luehlfing, 2004). Moreover, if one user gets near the products holding a mobile reading system, the handheld device will immediately collect and store data; product management is improved thanks to the re-programmable memory which also allows instant product location; customer services are considerably improved; RFID will allow receiving authorities to verify the security and authentication of shipped items.

RFID technology is not likely to replace barcodes in the near future. In fact, since barcode and RFID technology exchange data in different ways, nowadays the two technologies complete each other in real applications. They are both valuable in different situations, and can often be used together effectively for many purposes. In such a hybrid solution, a tag may be linked with a preprinted barcode.

But the differences in data exchange between the RFID and barcodes can help the user to decide where each technology can be most effective. The implementation of RFID technology will focus initially on pallets and crates containing products. Only when passive RFID tag prices are sufficiently low and adoption is more widespread, will the barcode be under threat in the retail industry. However, in the coming years, RFID tags and barcodes will still coexist.

2.3 ISO standards

The International Organization for Standardization (ISO) has developed RFID standards for automatic identification and item management that tried to solve the compatibility problems. This standard, known as the ISO 18000 series, deals with the air interface protocol (the way tags and readers communicate) for systems likely to be used to track goods in the supply chain. They cover the major frequencies used in RFID systems around the world. There are seven parts:

18000–1: Generic parameters for air interfaces for globally accepted frequencies

18000 - Part 2: Parameters for Air Interface Communications below 135 KHz (ISO standard for Low Frequency)

18000 - Part 3: Parameters for Air Interface Communications at 13.56 MHz (ISO standard for High Frequency)

18000 - Part 4: Parameters for Air Interface Communications at 2.45 GHz (ISO standard for Microwave Frequency)

18000 - Part 5: Parameters for Air Interface Communications at 5.8 GHz

18000 - Part 6: Parameters for Air Interface Communications at 860 – 930 MHz (ISO standard for UHF Frequency)

18000 – Part 7: Parameters for Air Interface Communications at 433.92 MHz.

ISO has also created standards that define how data is structured on the tag. For example, ISO 11784 and 11785 describe the structure and the information content of the codes stored in the tag for RF identification of animals.

There are also standards that deal with supply chain applications (i.e. how standards are used in different domains):

- ISO 17358 - Application Requirements, including Hierarchical Data Mapping
- ISO 17363 - Freight Containers
- ISO 17364 - Returnable Transport Items
- ISO 17365 - Transport Units
- ISO 17366 - Product Packaging
- ISO 17367 - Product Tagging (DoD)
- ISO 10374.2 - RFID Freight Container Identification

The usage of RFID to track items in open supply chains is relatively new and fewer standards have been finalized. For example, ISO has proposed standards for tracking 40-foot shipping containers, pallets, transport units, cases and unique items. These are at various stages in the approval process (***a, 2008).

2.4 RFID privacy & security

RFID data must be used in compliance with clear regulations concerning IT security as well as consumer and data protection (Heintz, 2005). A primary RFID security concern is the illicit tracking of RFID tags. Unauthorized readout of the RFID tag memory content has raised privacy concerns from both retailers and consumers. The issue of consumer privacy in RFID applications has received a great deal of attention from consumer groups and has garnered high visibility through the media. Therefore, it is necessary to provide counter measures which enhance consumer privacy and eliminate the concerns when consumer-sensitive data like pharmaceuticals are involved. In fact, RFID technology, when combined with a secure tag and data infrastructure, can assure both package authenticity and pedigree while creating new revenue opportunities.

A method of defense against unauthorized readers uses cryptography to prevent tag cloning. Thus, some tags use a form of "rolling code" scheme, wherein the tag identifier information changes after each scan, thus reducing the usefulness of observed responses. Nevertheless, cryptographically-enabled tags typically have dramatically higher cost and power requirements than simpler equivalents, and as a result, deployment of these tags is much more limited (***d, ****).

2.5 RFID applications

The RFID technology has been available for decades, but given the current significant lowering of tag costs, it is expected that their usage will be considerably increased. RFID allows the identification, location, tracking and monitoring of individual physical entities such as people, individual products or palleted goods. RFID may be viewed as a means of explicitly labeling objects to facilitate their "perception" by computing devices; thus, real-time information about these objects can be easily obtained from the factory, through shipping and warehousing, to the retail location (Finkenzeller, 2003). In fact, the RFID term is often used to describe the entire system of supply chain management using RFID, from the physical tags to the processing of information on electronic databases.

Almost all industries have used automatic identification (Auto-ID) in many applications: access and security systems, item tracking systems, inventory management and simplified checkout at retail stores. For example, automatic identification technology offers the potential to achieve inventory accuracy and thus reduce supply chain costs as well as the out-of-stock level. The relatively new technology, RFID upgrades the Auto-ID capabilities and enhances implementation in various industries with significantly hard and soft savings. Employed in a wide range of applications, RFID technology has become an indispensable asset.

RFID technology will benefit lots of industries and applications are constantly being developed and refined as the technology advances. The potential applications of RFID technology in supply chain are vast and refer to any organisation engaged in the production, movement or sale of physical goods. This includes retailers, distributors, logistics service providers, manufacturers and their entire supplier base, hospitals and pharmaceuticals companies, and the entire food chain. For example, the logistical tracking of goods will increase efficiency and will make available accessible supply chain transport and route information to everyone involved from the producers to the consumers. RFID tags in car sub-assemblies will make safety checks and recalls faster and easier. Tags in sub-sea structures like oil and gas pipelines will make maintenance and repair simpler. Hospitals will be able to maximise their return on assets by tracking the whereabouts of expensive and life-saving equipment at all times. The pharmaceutical industry will be able to reduce or even eliminate counterfeiting by giving each unit of dosage a unique EPC number. This will allow pharmaceutical data to be properly recorded. In fact the location of certain drugs will be made accessible to all supply chain partners; they will know the exact location of any drug and historical locations, the time spent for to transport it from one place to another, as well as the environmental storage conditions from its production to its usage.

Perhaps the most significant sign of transition to RFID was Wal-Mart's announcement in June 2003 of its intention to have top suppliers begin using RFID tags on pallets and cases by January 2005. In USA, the Department of Defense, Target, Best Buy, Albertson's, and others followed with their own RFID initiatives.

In retail industry, it is imperative that perishable products remain within a fixed temperature range across the entire supply chain. Temperature levels can be monitored in real-time by a temperature sensor connected as an additional device on an RFID tag attached, for example, to a shipping container, an individual product or a vehicle. In the not too distant future RFID tags will offer seamless product temperature records from point of manufacture to the time of purchase (Smith, 2005).

RFID, with its expected advantages, has currently been a major trend in many industries. Ranging from commercial to military uses, RFID technology is a modern resource which has not exhausted yet its applicability potential.

2.6 Integrating RFID technology into supply chain

An important application of RFID technology is supply chain management, where RFID helps close information gaps by enabling real-time supply chain visibility. By placing RFID tag on a product, users can track the product throughout the supply chain- from the manufacturer all the way to the customer.

In most cases the RFID tag can be written and rewritten so that the information in the tag doesn't remain static. For instance, at first, the tag may only contain manufacturing information; later on, additional information from the distributor may be added. RFID can enable the vision of real-time, multidimensional coordination for all the players in the supply chain (Grackin, 2004).

In fact, RFID is considered the most intelligent technology for managing and collecting product data or tracking it as it moves through the supply chain.

Today, companies looking to adopt RFID have to deal with three key challenges:

1. *RFID Hardware* - Selecting tags, readers, and antennas; placing RFID tags on the products; placing and configuring readers and antennas in the stores, warehouses, and other locations.
2. *Software Infrastructure* - Capturing and managing data from the RFID readers, integrating the data into different levels of enterprise information systems, and sharing data with trading partners for business collaboration.
3. *Evolving business processes* - Supporting finer granularity, more real-time product data, automating supply chain execution, and developing new business processes for exploiting RFID technology.

The non-line of sight capability of RFID makes it a perfect supply chain technology (Gibson & Bonsor, 2005). Passive tags operating under the ultra high frequency (UHF) band are common to supply chain applications because tag costs are low and the read range and rate is adequate (Tajima, 2007). In the case of supply chain management (SCM), RFID is not just about the identification of an individual pallet, case or item but about the relationships between objects, between organizations, between space and time. RFID is about process level change that can streamline business-to-business (B2B) operations and bring about major changes to organizational policies, culture, performance and structure (Lefebvre et al., 2007).

2.7 Electronic Product Code (EPC)

The use of RFID in supply-chain application is based on EPC. The EPC was conceived as a means to uniquely identify all physical entities. In fact EPC is a numbering scheme that provides unique identification for physical objects, assemblies, components and systems. Information is not stored in the code, but serves only as a reference to on-line – or Internet-based – information (Brock, 2007).

EPC ID numbers assigned to an entity are used with RFID tags in the same way that UPC (Universal Product Code) numbers are used with barcodes. In fact, the EPC is considered the electronic equivalent of the UPC barcode and a possible successor to the barcode. An RFID tag stores a single EPC number in its memory, just as a barcode holds a UPC number. Barcodes have been in use for over 30 years and have become an integral part of product identification. Product identification is performed differently by RFID tags and conventional barcodes. A UPC refers to an object class or generic category of products. For example, when a barcode gets scanned at a store checkout counter, it will return product information such as product name and price; the same information is valid for every product in the same category. An EPC refers to a specific instance of product, allowing the unique identification of any tagged item. Thus, an EPC makes it possible to automatically track individual items, for example, products from the manufacturing line that reach the shelves.

The current version of the specification comprises encodings for EPCs of 96 to 202 bits length. But EPC codes are typically 96 bits in length (24 four-bit characters) divided into four fixed length components (header, Domain Manager Number, Object Class Number and Serial Number), each part containing specific information.

The first section consists of an 8-bit *header* indicating the number, type and length of subsequent data sections. Practically this header provides a real extensibility for future, unanticipated data requirements.

The second section of EPC code identifies the company or entity responsible for maintaining the subsequent codes. This entity is known as the *EPC manager*. Its responsibility is to maintain both object type codes and serial numbers in their domain. The EPC manager section covers a 28-bit section, encoding a maximum of 228 = 268,435,456 companies.

The next section of the EPC code, called the *object class*, occupies the next 24-bits. The object class number is used to identify a class of product, meaning a group of products sharing similar characteristics. When applied to retail products, the object class is often considered the skew or stock keeping unit (SKU), lot number or any other object-grouping scheme considered by the EPC manager. For each organization is allowed more than 16 million object types, so this section could encode all the current UPC SKUs and many other object classes. This allows expanding beyond retail applications into general supply chain.

The final section of the EPC code encodes a unique object identification number that serves to identify a particular item belonging to the specified object class. It is the managing entity responsibility to assign unique serial number for every instance within each object class. For

all objects of a similar type, the *EPC serial number* provides 36-bits, or 236 = 68,719,476,736, unique identifiers. Together with the product code, this provides 1.1×10^{18} unique item numbers for each company – currently beyond the range of all manufactured products.
In January 2008, 1347 companies from different industries were EPCglobal subscribers (Schmitt & Michahelles, 2008).

2.8 Benefits

The RFID technology will bring benefits to a wide range of industries, but one of the main domains of RFID adoption has been the supply chain for retail sector. RFID technology can help improve efficiency and visibility; it will cut management costs, influence considerably the production of higher quality goods and enhance the utilization of products; it will also reduce shrinkage and counterfeiting, and increase sales by reducing out-of-stocks.
For example, RFID technology has the potential to:

- reduce the time taken to re-order shipments;
- minimize warehouse discrepancies by validating the accuracy of deliveries and shipments;
- reduce product shrinkage and theft;
- improved tracking of pallets, cases and individual products;
- provide better planning and optimization of inventory and reusable products;
- allow more efficient use of labor by automation data handling and reading multiple products;
- monitor expiration dates of an organization's complete inventory list;
- automate supplier receiving and billing procedures;
- reduce manual entry errors (e.g. data typing mistakes);
- allow more efficient transport and distribution;
- allow information sharing to better collaboration between partners;
- increase visibility and lead to better decision making capabilities.

The main benefit of RFID integrating in supply chain process is to allow the constantly monitoring and improving the whole system by using all the available data.
But to maximize competitive advantage in a supply chain context, RFID needs to be used by multiple companies to do all sorts of things, creating widespread advantages for all supply chain participants (Coltman et al., 2008). RFID is expected to be worth billions of dollars in new investments. According to IDTechEx, a leading market research and advisory firm, the RFID market will increase from US$4.96 billion in 2007 to US$26.88 billion in 2017 (Das & Haropp, 2007).

2.9 Obstacles

The path to RFID technology integration in supply chain is not without some obstacles and they can be enumerated briefly:

- tags, infrastructure and implementation costs are still high;
- unclear cost/benefit sharing models;
- the integration in existing systems;
- readers can't always read all the cases on a pallet;
- technology incompatibilities: inability for a single reader to read tags from multiple frequencies;
- standards are in a state of flux;

- some of RFID standards are not globally accepted; different standards coexist in parallel and there are a lot of them incompatible one with other;
- tag reliability can be impacted by humidity, liquid or metals;
- radio interference can upset even the best-laid plans: in close proximity to one another, tags may seriously affect performance. Antenna placement and orientation can also negatively impact the RFID solution;
- end-users lack real RFID knowledge.

3. RFID@B2B

3.1 Business to Business (B2B)

Twenty-first century technology has revolutionized the way companies do business with each other and with their customers. The Internet has connected companies around the world and changed the global economy as a whole. Indeed, the Internet has emerged as a most cost-effective means of driving supply chain integration. A new concept has been devised: e-business - as the marriage between the Internet and supply chain integration (Johnson & Whang, 2002). Following today's economic globalization, e-business has become a necessity for companies to remain competitive. As one major component of e-business, business to business (B2B or B-to-B) includes all applications intended to enable or improve relationships within firms and between two or more companies (***e, ****). In fact, B2B is commonly used to describe any electronic business transaction occurring between two separate business entities. This includes the exchange of both products and service. Examples of exchanged products and services might include the selling of raw material inputs from one firm to another, the sale of capital equipment, the purchasing of commercial insurance or the contracting of one firm with another for the procurement of accounting services. B2B is all about product and materials procurement and the supply chain is the vehicle through which business-to-business is ultimately achieved. In fact, a B2B infrastructure links buyers, suppliers and logistics service providers into a global trading network. One of the new concepts that will further define traditional B2B Internet commerce is RFID (Gerhards, 2006).

3.2 Integrating RFID technologies in B2B applications for enterprise supply chain

In the case of B2B, RFID is supposed to benefit not only the identification of individual pallets, cases or items, but also the relationships between/among objects, between/among organizations, between space and time. RFID is about process level change that can streamline business-to-business operations and bring about major changes to organizational policies, culture, performance and structure (Lefebvre et al., 2006). In fact, according to S.F. Wamba et al. (Wamba et al., 2007), RFID technology and the EPC are enablers of intelligent B2B e-commerce supply chain management.

Our research team has developed an RFID_B2B integrated system which combines the advantages of B2B with those of RFID technology and which presents itself as a viable solution for the problems raised by globalization. The software system deals with business relations between corporations, big companies and groups of companies, in order to optimize the flow of materials among them and the supply chain management inside every company. To identify both parts and finite products, our system uses passive 13.56 MHz tags. Unique IDs are used to control and trace every part of a finite product. The RFID_B2B system could be tailored to the diverse needs of the companies and the different roles of employees in each company. If this system is embraced by the entire supply chain management, final consumers will be able to follow the entire production chain of a finite product. And this is possible if the traceability information is memorized on each tag attached to some part of the final product.

The RFID_B2B system architecture is flexible and easily extensible. The research team chooses to design a layered architecture arranged in such a way that the lower layers support and enable the upper layers. This architecture has some advantages: divide the complex system into several more manageable components, allow different groups to work on different layers concurrently etc. The RFID_B2B system is structured on three levels: the corporation level, the local level and data collection level at the material control departments (Figure 1).

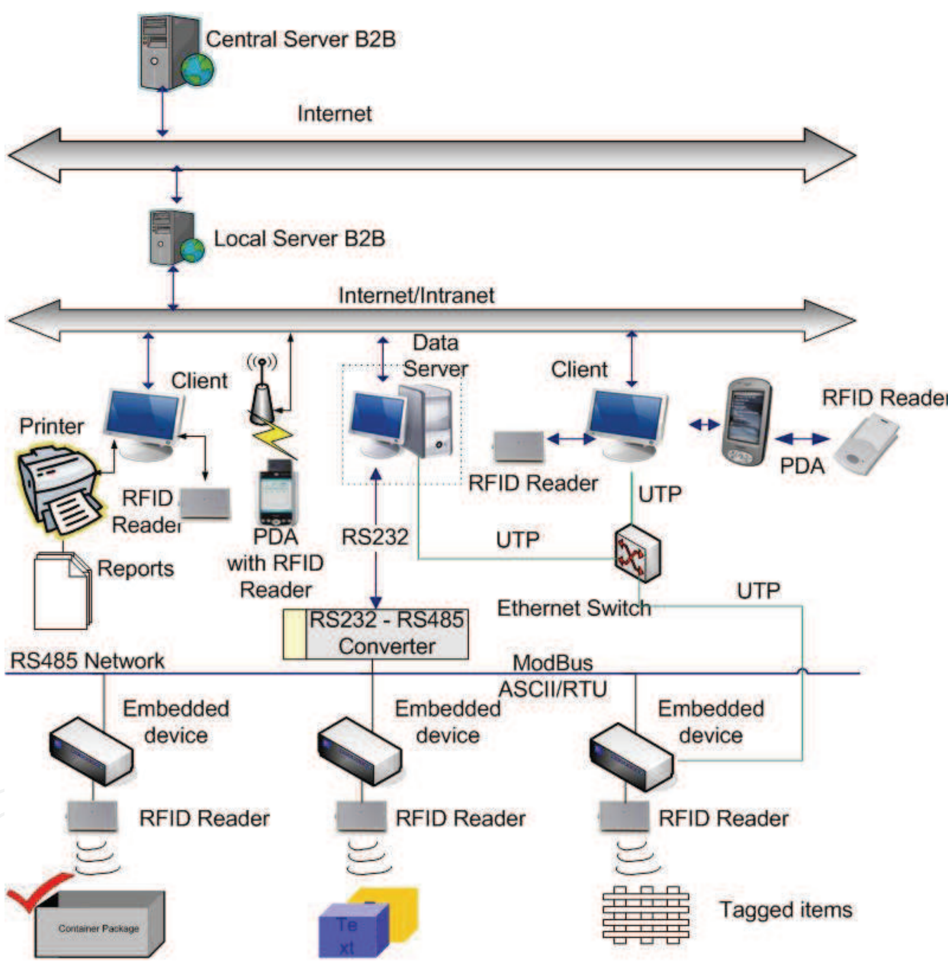

Fig. 1. The RFID_B2B system architecture

At the platform's *corporation level,* the following achievements have been made:

- services are offered to ensure the support for concluding contracts, along with the agreements, the conventions at the board level of the corporations, the firm groups or the representatives of the firm groups;
- informational management of the group/corporation enterprises, ensuring supervision of the material flows (with effects on the establishing of supply and sales strategies), as well as of the good functioning of the internal network of the group/ corporation;

- supply of reports regarding the current activities within the group/ corporation, including alarm in case of generation of specified events.

The following are provided at the *local level* or at the enterprise level:

- proper administration of the received, sent, defective, repaired, returned entities at the enterprise level;
- access to the company servers network, as well as communication management along the supply- sales main chain, providing the opportunity to manage and access the information referring to the route followed by materials, assemblies and finite products;
- coordination of the materials/assemblies flow in order to ensure adequate distribution to corresponding departments, as well as to deliver the order to the gates in departments;
- documents delivery for controlling the production, materials, finite products, assemblies, including those in the service department.

Different applications of RFID are implemented in the *data collection level* in order to write and read the data from the tags attached to the materials, assemblies and finite products. At this level, the communication is wired or wireless.

The integrated system comprises the following elements:

- an IBM-PC compatible computer which runs an OPC (OLE for Process Control) server with two main components: communication and data acquisition;
- an IBM-PC compatible computer which runs an OPC dedicated client; in fact one and the same computer may be used to run both the server and the dedicated client;
- a network comprising several low-resource embedded devices that have attached low-cost RFID readers; these device processes the local data and are capable of connecting and controlling other devices;
- PDA devices with attached RFID readers;
- an IBM-PC compatible computer which runs the local B2B server (Giza & Cerlinca, 2007);
- an IBM-PC compatible computer which runs the central B2B server (Giza & Cerlinca, 2007).

3.3 Improving supply chain management with RFID mobility solution

Enterprise supply chain systems can offer access to desired tasks (for example, inventory management, demand projections, production planning) from handheld computers, such as Pocket PCs.

Inefficient manual data-handling process in supply-chain management is a common problem with serious repercussions that affected the whole supply-chain, product traceability etc. There are needed solutions that could automate data handling.

Integrating a mobile solution in an RFID-based supply chain system is the answer (Cerlinca et al., 2008). Handheld computers can perform many of the tasks that are commonly executed on a desktop computer or standard laptop. In fact, these devices can be used to extend the capability and reach of an existing information infrastructure by enabling workers to collect, access and analyze desired data at any time from anywhere. Thus, the RFID labeled product can be read and tracked through the entire supply chain with handheld mobile devices (for example, PDA-Personal Digital Assistant) endowed with RFID readers. The collected data is stored on the mobile device using a mobile database software technology. This data is transferred between the mobile device database and PC database whenever it's necessary. For security reasons, the data stored in the handheld device memory can be transferred to a PC, for instance, when the handheld device is placed in a docking station. But, for integration in our complex enterprise application, encrypted data can be securely transferred across any kind of Internet-connected network. The users can also set up a virtual private network. These solutions are less expansive than mobile communications infrastructure.

The visual space on the handheld screen is far too small; the low display resolution and small display screen have inhibited information to be displayed completely and clearly. But the windows of RFID-based mobile application can be adapted to display a plurality of RFID tag information.

With an efficient RFID-based supply chain solution with integrated mobile support, the companies can reduce errors and cut costs. Implementing a mobile solution helps companies improve efficiency, extending the power of enterprise computing to new processes, people and places. Employees are more productive and businesses are more competitive.

3.4 RFID_B2B system benefits

The presented system offers a high degree of flexibility and helps companies of all sizes enable their customers to do business on demand — when they want, where they want and how they want. Other system benefits are:

- Assures realtime inventories so the users can always receive accurate, up-to-date inventory information;
- Offers the possibilities to share meaningful data with supply chain partners;
- Permits strengthening customer and partner relationships with collaboration;
- Speeds and simplifies the deployment and management of e-commerce sites;
- Maximizes performance, scalability and adaptability of partners systems;
- Provides rich, ready capabilities for products catalog and content management;
- Permits a greater visibility through realtime product updates, availability and pricing information;
- Offers personalization capabilities.

3.5 Future improvements

With the growing number of B2B sites available through Internet, a useful addition to the RFID_B2B system would be an intelligent software agent for information gathering. The agent will be able to perform semantic query optimization and to offer data mining facilities. It will dynamically plan for alternative information source when a source or a B2B site goes down. This agent will organize the results and display them in an easily interpreted manner to the user. To face the new global market and to provide an effective collaborative relationship between trading partners, an environment to support the semantic integration could help. Another useful feature would be a special section that enhances the management of production planning to ensure good deliveries and productive efficiencies.

Transition to B4B (Business for Business) – next evolution in B2B communication (Jones, 2007) is the following aspect that might be taken into account as future direction for system development.

The Internet, electronic business and RFID technology are changing the history of supply chains, and modifying the way that consumers select, purchase, and use products and services of partners. The result will be the surfacing of new business-to-business supply chains that are consumer-focused rather than product-focused.

4. Conclusion

This chapter helps to improve readers understanding of the RFID and EPC potential for business processes. RFID technology is classified as a wireless AIDC technology that uses digital data encoded into a radio tag embedding a microchip with an antenna. The data stored on the tag is collected by a reader using radio waves. There are a large variety of RFID tags designs; they also have many different functional characteristics such as power source, carrier frequency, read range, data storage capacity, operational life, cost etc.

RFID has immediate benefits over barcodes. Thus RFID tags are an improvement over barcodes because the tags have read and write capabilities. The data stored on RFID tags can be changed, updated and locked. RFID technology offers a better way to track items with minimal human intervention, for stocking and marketing purposes. Benefits come in the form of inventory, shrinkage and labor reduction on the one hand, and sales increasing due to reducing out-of-stock and getting real-time demand information on the other hand.

RFID technology represents one of a number of possible solutions to enhance supply chain. It is therefore important to do a cost-benefit analysis to evaluate each alternative solution. The majority of the costs of integrating RFID in supply chain application come from IT, tags, hardware and services. But due to the actual relative high cost of integrating RFID technology, each company needs to evaluate its own business processes to determine where and if RFID can be applied (incorporated) to provide substantial business benefits. Thus, all RFID solutions have to evaluate different performance and cost factors, including the operating environment, on-tag memory storage, and signal transmission restrictions. Each of these issues has significant cost impacts on both tags and readers. The costs of RFID readers have already fallen to a considerable extent. The cost of tags is expected to decrease over time and as quantities increase. Passive tags are undoubtedly less expensive than active tags and most companies are focusing on passive tags. The different studies proves that at a lower quantity the barcode is the cheapest alternative for supply chain, but, as quantity of product increase the optimum choice is RFID. In some applications, RFID and barcodes system will still coexist and this redundancy cost must be considered. However, to realize maximum return on investment (ROI) for RFID integration, the enterprises need to leverage their information architecture strategically.

Any industrial domain may benefit from RFID technology, and the number of applications is on the rise. Thus, RFID technology is applied in a vast area of industrial, commercial and military domains, including manufacturing and logistics, retail, animal tracking, etc. This chapter focuses on how RFID technology can be used to solve problems faced by supply chain. In fact, RFID has the potential to radically change the entire supply chain by improving inventory management, asset visibility, and interoperability in an end-to-end integrated environment. The ability to track, at item level, material flows among partners until they reach the consumer, while maintaining the data accuracy advantages of various types of automatic identification technology (AIT), is the perfect solution to the many issues of enterprises in the past. RFID technology permits the unique identification of each container, pallet, case and item to be manufactured, shipped and sold, thus allowing an increased visibility throughout the supply chain. Thus the RFID has the potential of helping

retailers provide the right product at the right place at the right time, allowing maximizing sales and profits.
The EPC represents a low-cost method of tracking products using RFID technology. The EPC is a short, simple and extensible code designed for the unique identification of individual physical objects such as spare parts and whole products; the identification process may be extended to cover further information related to container, packages, shipments or manufacturers. The EPC can provide up to 268,435,456 companies identifiers, more than 16 million object types and 1.1×10^{18} unique item numbers for each company.
In a global market where change is continuous, companies require tools that allow them to respond quickly to new opportunities. The presented RFID_B2B system can be considered as a viable solution for potential problems raised by globalization process, contributing to a significantly more efficient business process. Thus, the presented system helps small, medium and enterprise organizations to improve productivity and provide better service to their customers by providing a flexible solution for all of a company's B2B needs. Many mobile systems already employed in supply chain management have proved their importance through significant return on investment. Not only can they extend corporate data outwards to mobile devices for viewing and querying, but users can use any mobile device endowed with an RFID reader for data collection. In this way, manual entry data has been eliminated. Moreover, users can read the tags wherever the items are placed, which enables a more flexible storage environment and an efficiency increase of supply chains. The RFID_B2B system is so adaptable that many types of businesses can use it and allows enabling new business opportunities and growth. Using the developed system may help customers sharpen data accuracy, process supply chain transactions faster, and improve supply chain and inventory management. Given slim profit margins, companies are looking for ways to save on costs while remaining globally competitive. RFID@B2B may be their answer.

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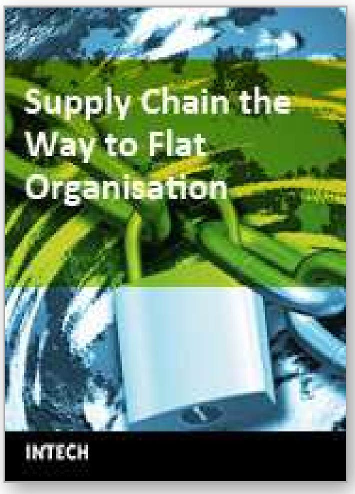

Supply Chain the Way to Flat Organisation
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With the ever-increasing levels of volatility in demand and more and more turbulent market conditions, there is a growing acceptance that individual businesses can no longer compete as stand-alone entities but rather as supply chains. Supply chain management (SCM) has been both an emergent field of practice and an academic domain to help firms satisfy customer needs more responsively with improved quality, reduction cost and higher flexibility. This book discusses some of the latest development and findings addressing a number of key areas of aspect of supply chain management, including the application and development ICT and the RFID technique in SCM, SCM modeling and control, and number of emerging trends and issues.

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