

# Journal of International Technology and Information Management

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Volume 15 | Issue 4

Article 7

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2006

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### Recommended Citation

Attaran, Mohsen (2006) "The Coming Age of RFID Revolution," *Journal of International Technology and Information Management*: Vol. 15: Iss. 4, Article 7.

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## **The Coming Age of RFID Revolution**

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### **ABSTRACT**

*Radio Frequency Identification, or RFID, has been around for decades and is being used in manufacturing to complement established barcodes for the past 25 years. Recently, many companies are embracing RFID as a competitive weapon that can improve their efficiencies, and provide significant business benefits. Despite many useful applications, the technology's potential has yet to be fully realized. The aim of this paper is to provide an overview of contemporary RFID systems, highlight its promises as well as its pitfalls, identify the implementation challenges and key business drivers, survey its application in various industries, and speculate about where this technology is headed.*

### **INTRODUCTION**

Radio Frequency Identification (RFID) is an e-tagging technology that can be used to provide electronic identity to any object using radio waves. Tags can contain a large amount of data, allowing suppliers, manufacturers, and retailers to track and manage products more efficiently. RFID is not a new technology; it was first used in World War II to identify friendly aircraft. However, the application of RFID to the supply chain is new. For a nominal price, an RFID tag could be attached to the product in the initial stages of manufacturing and then follow the product down the supply chain all the way to a retail setting, and finally into the hands of the consumer. There, it could again be scanned while in a box or crate, saving labor. In a retail setting, the tag could serve as the price tag. Moreover, consumers could count on the tag for warranty information after purchase.

This desire to cut supply chain costs has pushed Radio Frequency Identification (RFID) technology into the forefront. Mandate from powerhouses such as Wal-Mart, Metro Group, Target Cop., and the U.S. Department of Defense that requires suppliers to begin using RFID technology in supply chain operations, has pushed RFID technology to climb from relative obscurity to become one of today's most discussed retail technologies.

Customer demand for the RFID technology is building fast. Suppliers are racing, and a flood of RFID applications is about to flood the industrial and consumer landscape. Many industries including pharmaceuticals, government, health care, and homeland security are quietly embracing the technology. Given the current implementation pace, the objective of this paper is to go beyond the hype and explore basic issues related to RFID technology, including its promises as well as its pitfalls. Section II discusses the evolution of RFID, and addresses its capabilities, Section III highlights the implementation challenges and key business drivers. Section IV elaborates on RFID's application in various industries. Section V discusses case examples of success. Finally, Section VI summarizes the paper.

### **THE EVOLUTION OF RFID**

The term *paperless factory* refers to the flow of product through a system without the accompanying paperwork. The computer was the initial major impetus making this possible, and the next major development was the introduction of technology that provides automatic identification of parts. This technology has dramatically improved material handling into, through, and out of all types of operations. Several different forms of automatic identification of parts are in use. Bar coding is the most used and recognized form and allows computer technology to quickly and accurately collect and effectively manage data. Bar coding has become very important for all industries, including both manufacturing and services, because it greatly simplifies inventory and production control. The bar code system involves three components: the bar code symbol, the symbol reader, and the printing process.

The service sector has been using bar code technology since the mid-1970s. Bar codes appear on almost every purchase, from soft drinks to automobiles. The code itself is made up of a series of wide and narrow parallel lines and spaces and can store as many as twenty to thirty characters per inch of coded information. That is enough space to store the Universal Product Code (UPC) for the item, which tells the computer to respond with the correct price for the item. Over the course of the last 20 years, UPC has become the dominant product-tracking standard for the consumer packaged goods industry. UPC was created by U.S. manufacturers to negate the lure of much cheaper offshore manufacturing labor and championed by industry retailing giants. UPC coding has paid off with improved product tracking over multiple retailers, reduced labor costs, and faster product replenishment.

Research and development in bar coding technology has led to the development of the new two-dimensional code which contains a stack of as many as 90 one-dimensional bar codes, each just three-hundredths of an inch high. This new bar code allows the user to maintain a large block of information about each product – manufacturer, cost, price, order size, weight, etc. High-speed laser scanners read the new bar code quickly and retrieve the information for continual monitoring.

Bar coding has become very important for all industries, including both manufacturing and services. However some situations have environmental conditions, such as temperature, dirt, or hazardous contamination, that make optically scanning the bar codes on a label ineffective. In those cases a different technology, called Radio Frequency Identification (RFID), is often preferred. RFID does not require the tag or label to be seen to read its stored data. RFID uses radio waves to capture data from tags, rather than optically scanning the bar codes on a label. RFID tags can provide vast amount of additional information when it is compared to bar codes. Bar codes provide between 12 and 15 information characters, while most RFID chips use a 94-character protocol. RFID tags can store information about the production, cost, location, date, etc.

RFID technology originated in the 1940s, when the U.S. government used transponders to distinguish friendly aircraft from enemy aircraft. Through the 1970s, the federal government primarily used the systems for tracking livestock and nuclear material. Radio tags have been used commercially in so called “closed loop” systems for delivering packages, handling luggage, tracking food in supermarkets and monitoring highway tolls in 80s and 90s. In 1997, Mobil installed an RFID system called “Speedpass” that let you wave the tag in front of the pump to record your transaction and debit your credit card. In 1980, the Bay Area Rapid Transit (BART) installed an RFID system to provide equal access to the system for disabled individuals. Under the new system disabled people were issued an ID tag at no charge. To operate the system, the disabled person holds the tag close to the reader to activate station elevators (Hackanson, 1991).

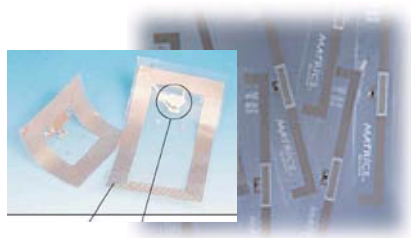
RFID systems have three primary components: the tag or transponder, the reader, and the application software and a host computer system.

## The Tag

RFID tags, or transponders, are made up of the microchips that are embedded in the product, pallet, or case that store and transmit information about the specific unit. Tags are made of a hard copper coil consisting of an integrated circuit (IC) attached to an antenna then packaged into a housing appropriate for the application. RFID tags are very rugged and come in several form and sizes (Figure 1). Some can be as small as a grain of rice or one-third millimeter. Data is stored in the IC and transmitted through the antenna to a reader. RFID tags are broken down into two categories:

1. **Passive RFID Tags** – Passive tags do not have their own power supply but use the radiated energy from RFID readers to transmit information. They have a smaller memory capacity and they can transmit information over short distances (typically 10 feet or less). Passive tags (Figure 1) are more popular, less expensive, with virtually unlimited life. Cost estimates range from \$.05 per tag to a projected \$.25 per tag. There is speculation that future development might bring the cost of passive tags down to \$.01 or less (Homs, 2004).

**Figure 1. Passive RFID Tags.**



Source: RFID Exchange.

2. **Active RFID Tags** –Active tags are self-powered by a battery and act as miniature computers and transmitters that receive, store, and transmit information about a product to the RFID reader (Figure 2). They have a larger memory capacity and they can transmit information over the greatest distances (100 + feet). The Tag’s life span is limited, unless there is a way to recharge the battery. Active tags are less popular and more expensive. Cost estimates range from \$4 to \$20 per tag.

**Figure 2. Active RFID Tags**



Source: RFID Exchange.

Tags can be read-only where stored data, during the manufacturing process, can be read but not changed, or a read-write where stored data can be altered or re-written. Read-write chips are more expensive than read-only chips. Another type of chips available on RFID tags is called a “WORM” chip (Write Once-Read Many). It can be written once and then becomes read-only afterwards.

### **The Reader**

RFID readers, sometimes called the interrogators, are radio frequency transmitter and receiver, controlled by a microprocessor or digital signal processor that communicates with the tags. Readers, using an attached antenna, capture data from tags then pass the data to a computer for processing. In passive systems, readers transmit an energy field, “wake up” the tag, and provide the power for the tag to operate. In active systems, a battery in the tag is used to boost the effective operating range of the tag (Figure 3).

**Figure 3: Long Range Reader.**



Source: RFID Exchange.

Readers may have multiple antennas and can have an effective range of a few centimeters to a few meters depending on the frequency of operation and the type of tags. Readers come in a wide range of sizes, offer different features and start at \$500. They can be affixed in a stationary position, integrated into a mobile computer that is used for scanning bar codes, or even embedded in electronic equipment such as label printers.

The information exchanged between RFID tags and readers is comprehensive, including everything from numeric data that summarizes the contents of a carton to the manufacturing details of complex goods such as pharmaceutical products.

Different versions of RFID tags operate at different radio frequencies: high frequency (850-950 MHz and 2.4-5 GHz), intermediate frequency (10-15 MHz) and low frequency (100-500kHz). Low-frequency tags are used for applications which require shorter read ranges, such as security access and asset management. High-frequency tags transmit data faster and can be read from farther away. High-frequency systems are used for applications which require longer read ranges, such as toll-collection and railroad car tracking (Homs, 2004).

### **Application Software and A Host Computer System**

Data collected from tags is then passed through cable or wireless to host computer systems in the same manner that data scanned from bar code labels is captured and passed to computer systems for interpretation, storage, and action. The host computer could be any device, such as a laptop computer, an electronic scale head, a mobile or a hand-held computer, that is capable of communicating with a reader and accepting the information from it. The openness and flexibility of the technology infrastructure, especially the mobile computers and wireless LANs that will be used to collect and communicate RFID data affect the ease with which RFID can be integrated into current operations. One way to maintain flexibility is to use mobile computers with card slots that can be used to add RFID capability without sacrificing other functions. Application software, considered by many to be the heart and soul of a comprehensive RFID system, allows users to actually tie electronic identity to production and management information message the data and share the information with others.

### **IMPLEMENTATION ISSUES**

With mandates from retail powerhouses that require near-term RFID use for their largest suppliers, the future of RFID is fast arriving. In addition, recent technology advances and a strong industry-wide commitment to standards and investment point to a bright future.

An important promise of RFID technology is to cut costs and deliver a wealth of information that helps firms more effectively understand, predict, and respond to customer demand. RFID is not a solution. It is an enabler that allows firms to change their supply chain processes for the better. RFID technology faces implementation challenges. Implementing full-fledged systems in a large manufacturer can cost \$13 million to \$23 million.

Considering the sheer cost of RFID implementation, there is no ROI for the technology if you only pursue compliance. The early adopters of the technology have encountered many issues while running field trials and starting deployments. The rest of this section will identify these challenges:

## Challenges

Although RFID has enormous potential for reducing the total cost of supply chain, there are also a number of reasons at the fundamental and technical levels for its delayed acceptance:

1. **Fundamental** – The business benefits that RFID technology promises will not arrive with a big bang. There must be incentive for retailers and manufacturers to adopt the technology. Similarly, there is the question of the “drivers” for adaptation. In a recent AMR Research survey of 500 companies, a majority of survey respondents cite significant challenges finding the Return on Investment (ROI) to justify their RFID spending. Twenty eight percent cite it specifically as their biggest obstacle with regard to RFID adoption (Reilly, 2005). A return on investment (ROI) is not always a straightforward calculation. What promotes a desire on part of buyers and suppliers to collaborate using RFID? From a supply-chain, manufacturing, or warehouse standpoint, RFID technology still has limited applications. Uncertainty around standards (a lack of standards maturity), high capital costs, including expenses related to project management and network integration, will also need to be addressed before retailers can adopt and benefit from the technology.
2. **Technical** – Among the technical problems are imperfect read-rates, unproven systems, lack of standards for the data structures to be used, and conflicting problems with assembling low-cost tags. RFID is still more expensive than bar codes, and there are problems using the tags on metal objects. To reduce tag cost is to reduce the size of the chip. However, reductions in the size of the chip make assembly more expensive. Another related problem is that RFID creates massive volume of data that are difficult to manage. The challenge for IT experts is to develop cost-effective ways to manage RFID data and integrate it into their back-end systems (Winans, 2005).
3. **Government Regulations** – Governments around the world regulate the use of the frequency spectrum. There is virtually no part of the spectrum that is available everywhere in the world for use by RFID. This means that a RFID tag may not work in all countries. This might hinder the use of RFID tags in a global environment.
4. **Privacy Issues** – Consumer groups have expressed concern over the potential privacy invasion that might result with widespread application of RFID tags. In November 2004, fifteen privacy and consumer organizations called for manufacturers to voluntarily hold off on their plans to equip consumer goods with RFID tags. Consumer groups worried that the tags will be used to track people instead of being used to track boots, jeans and books (Garfinkel, 2004).

## Opportunities

Despite the above challenges, the future of RFID technology will hold exciting opportunities for almost every business. It is expected that over the next 10 years, retailers will continue to use barcodes and gradually introduce RFID tagging. When the price of tags becomes economical enough, it is expected that RFID will take off in other venues.

In the technical front, several companies are collaborating to develop an active tag that can transmit signals up to 600 feet. These active tags have numerous applications in the retail industry and will move fast into the people-tracking realm. According to Intel Corporation, RFID technology will generate business value at three levels (Intel Corporation, 2004):

**Immediate:** RFID readers can read multiple tags simultaneously, without requiring line of sight or human involvement. This can cut checkout, inventory control, and loss-prevention costs.

**Short-Term:** RFID can improve supply chain performance through asset tracking, product origin tracing, and product recall.

**Long-Term:** Collaborative use of RFID information can help supply chain partners put the right item in the right place at the right time. And demand-driven, product fulfillment systems can link consumer behavior back into inventory planning and logistics

According to IBM Business Consulting Services, the potential business value of any RFID project falls in three categories (Robbins, 2005):

1. Increased Revenue (2-6%) through increased market intelligence, increased market share, and increased volume.
2. Increased Operating Income (5%) through reduced cost of goods sold and reduced operating costs.
3. Increased Capital Efficiency (5-30%) through increased fixed capital turnover and increased working capital turnover.

Another possible way to use RFID technology to generate value across the enterprise is “closed-loop RFID”. In this approach, RFID technology is used across the enterprise on projects designed to enhance internal corporate applications rather than supply chain operations that share data with other business partners along the supply chains. “Closed-loop RFID,” can help streamline a business process, enhance visibility into what customers need, and improve productivity by generating the fastest, lowest cost method of acquiring the data within the boundaries of a company.

### Key Business Drivers for Implementing RFID

Many companies have benefited from implementing RFID technology in their organizations. Supply chain cost that includes receiving, inventory, shrinkage, distribution, logistics delays, and out-of-stock merchandise is often cited as a major factor influencing RFID adoption. According to experts, it is not the compliance driving RFID technology; it is the overall saving opportunities. For example, using RFID technology, retailers can reduce the costs of receiving, inventory, and shrinkage by 11% to 18%, they can decrease the occurrence of out-of-stock merchandise by 9% to 14%, and they can cut logistics delays by up to 5% (Krivda, 2004). In a recent “Managing Automation” survey of 275 manufacturing companies, the majority of manufacturers polled point to both mandates and process improvements as the reasons for implementing RFID. Despite high implementation costs, the majority of manufacturers polled are moving ahead with their implementation plans (McBeath, 2005).

Some of the most important benefits that businesses are able to get by embracing RFID technology are summarized in Table 1.

**Table 1. Key Business Drivers.**

Key Drivers	Made Possible By:
<b>Revenue Growth</b>	<ul style="list-style-type: none"> <li>◆ Enhanced visibility into what customer will need</li> <li>◆ Enhanced visibility along the supply chain</li> <li>◆ Increased order fill rate</li> <li>◆ Decreased retailers out-of-stocks</li> <li>◆ Improved velocity by responding to demand signals faster</li> <li>◆ Improved productivity by generating the fastest and lowest cost method of acquiring the data</li> <li>◆ Reliable and accurate order forecasts</li> </ul>
<b>Lower Costs</b>	<ul style="list-style-type: none"> <li>◆ Improved supply chain management by better tracking transportation and warehousing channels</li> </ul>

	<ul style="list-style-type: none"> <li>◆ Increased labor productivity by automating manual data collection tasks</li> <li>◆ Improved product quality and reliability including traceability</li> <li>◆ Reduced inventory costs including stock-out and holding costs</li> <li>◆ Improved accuracy by reducing the opportunity for human error</li> <li>◆ Improved Counterfeiting identification, theft prediction, and faster recalls</li> </ul>
<b>Reduced Invested Capital</b>	<ul style="list-style-type: none"> <li>◆ Reduced inventory through better on-hand data</li> <li>◆ Smart product recycling</li> </ul>
<b>Better Utilization of Fixed Assets</b>	<ul style="list-style-type: none"> <li>◆ Accurate and timely asset tracking</li> <li>◆ Improved technology return on investment</li> </ul>

**APPLICATIONS IN DIFFERENT INDUSTRIES**

Data generated by RFID technology can improve supply chain efficiencies across industries such as retail, manufacturing, distribution, healthcare, and government. RFID is gaining broad appeal in various industries. According to Venture Development Corp., global shipments of RFID systems (hardware, software, and services) reached nearly \$965 million in 2002 and are expected to touch nearly \$2.7 billion by 2007 (Bindra, 2004). Similarly, according to a study by Allied Business Intelligence Inc., the RFID market will jump from \$1.4 billion annually in 2003 to as much as \$3.8 billion in 2008.

RFID technology is used in a range of applications, including access control to buildings, document tracking, toxic waste monitoring, duty evasion, livestock tracking and identification, vehicle security, pay-at-the-pump gasoline sales, product authentication, retail, sports timing, supply chain, ticketing, and wireless payment. More specifically, it has useful applications in the following industry:

1. **Supply Chain Management** – Supply chain automation is the key early driver for developments and implementation of the technology. RFID is being used today for tracking of assets in offices, labs, warehouses, pallets and containers in the supply chain. RFID technology enables suppliers to accurately determine the location of a pallet, to track its journey through the supply chain, and to make instantaneous routing decisions. For example, RFID tags are embedded in the fleet of trucks. At the service center, the tag automatically determines what loading/unloading activities are needed and assigns an appropriate crew to service the truck. RFID tags continually gather information as products move from shelves to the check out counter. The ability to write to the tag allows the addition of information such as the contents of the crate, sell-by date and manufacturer. Retailers can link this type of information to the store’s inventory management systems to ensure that goods are moved to the shelves and reduce spoilage and out-of-stocks. The technology not only helps the retailer to reduce labor and manual costs, it also curbs shoplifting and boosts store productivity.
2. **Manufacturing Sector** – This sector has been finding different ways to derive value out of this technology such as tracking of parts during manufacture, and tracking of assembled items. For example, to ensure accuracy, parts are individually tagged and tracked throughout the manufacturing process while on the production line. This would certainly help manufacturers with their carefully scheduled Just-In-Time (JIT) assembly lines. Tags containing equipment specifications can be attached to enable easy upgrading. Similarly, tags can be used to keep track of usage, availability, location, and maintenance of material handling equipment. Furthermore, RFID facilitates real-time inventory by automated registration of items in a warehouse or storeroom. Dell Computers uses thousands of RFID tagged totes and trays throughout its factories. Tags are used to track work-in-process inventory, to provide a clear view of production activity, and to speed production processes.
3. **Livestock and Food Production** – Increased government regulation about food traceability in the U.S. and mandate from the European Union (EU) for tightened traceability requirements beginning in



- 2005 has pushed RFID technology into food sourcing. RFID can help these traceability requirements and a reasonable cost. The technology should also reduce recall costs by increasing the ability of the manufacturers to identify and recall only the affected items (Homs, 2003). Similarly, RFID technology is used to secure identification of cattle by means of implanted tags for tracking and linking the animal to food, and location. Few states are testing RFID tags as one way to help protect elk herds from contagious disease by allowing agriculture officials to better track animal movements.
4. **Health Care and Medical** – RFID technology can be used in health-care industries to improve quality and reliability. RFID is being used today for linking a patient with key drugs, personnel giving the drugs, and biometric measurements. RFID tags, embedded in wristbands, are used to identify patients and update their status automatically. RFID tags are also used to match blood samples to patients. Medical Centers are using RFID technology to track and manage assets, such as medical devices, and wheelchairs. Medications and dosages are tagged so doctors and nurses can ensure that the right medicine is given in the right amount at the right time to the right patient (Krivda, 2004).
  5. **People Tracking** – RFID seems to be moving quietly into the people-tracking realm. RFID is being used today for security tracking for entrance management, contact management at events, post-natal ward baby tracking in hospitals, tracking patients in hospitals, tracking guests in entertainment and sporting/amusement parks, and for law enforcement applications. For example, RFID tags could be inserted into outerwear from vests to jackets to belts and leg-wraps for hikers, bikers, skiers, as well as law enforcement, government, and military personnel. It is being considered in the case of body recovery for identification purposes. If clothing were separated from the individual, the RFID clothing tag would give law enforcement information as to whom it belonged (Sullivan, 2005). The Department of Homeland Security is planning to test passports embedded with RFID chips at several airports. RFID chips have already been embedded in I-94 forms to help reach the goals of expediting safe entrance into the United States. RFID tags sewn into the hems of pajamas can be valuable tool for monitoring children. RFID Readers installed at various points throughout a house, will be able to scan the tags within a 30-foot radius, and will trigger an alarm when boundaries are breached. Similarly, RFID technology is already being used to track passenger progress through airports. The result is a reduction in the number of passengers arriving late at the gate.
  6. **Parcel and Parts Monitoring** – This sector is another emerging application area for RFID technology. RFID tags enable improved items tracking during the sorting and delivery processes in the postal environment. The technology allows multiple postal items be read as they pass through the RFID reader. Shipper mandates from Wal-Mart and other giant retailers helped convince DHL to adopt RFID technology in a wider way. DHL announced recently that it would place RFID tags on all of the more than 1 billion packages it ships annually by 2015 (Hoffman, 2005). The Navy on the other hand uses RFID tags for weapon management with a range of less than 6 inches to protect sensitive data. Weaponry data collected by RFID tags reveal anything from materials to capabilities and mission details (Aitoro, 2005). The Department of Defense is requiring suppliers to deploy RFID tags on cases and pallets they deliver to the department by January 2005. The department will use the technology to track packaged meals, chemical and biological warfare suits, as well as on supplies moving from military distribution centers to tactical forces (Bachelder, 2003).
  7. **Self-Policing**– The drug industry uses RFID technology to self-police in the fight against thieves and counterfeiters. For example, Pfizer is planning to put the radio tags on bottles of its widely counterfeited Viagra drug by the end of 2005. With RFID tags, pharmacists will be able to identify counterfeit drugs and law enforcement officers also will be able to quickly check whether bottles they recover have been reported stolen. The U.S. Food and Drug Administration is requiring the drug industry to deploy RFID labels by 2007 (Patton, 2005). Radio tags can also be implanted in the major metal parts of the bike or engineered into the engine castings of vehicles, allowing police to prosecute and identify the stolen items and obtain convictions. RFID tags incorporated into the garment at the manufacturing plant can be valuable tool for brand owners. The tag's unique identification number certifies the garment as authentic and enables control of counterfeits. Las Vegas Casinos are using radio tags on betting chips to deter counterfeiting card-counting and other bad behavior. Casino

executives envision RFID transforming the way they operate table games. The casinos are installing RFID readers and PCs at game tables. Dealers can take a quick inventory of chips that have been wagered. In addition to monitoring wagers, the technology would let dealers or cashiers see when the value of the chips in front of them does not match the scanners' tally. The casino industry is also planning to use the technology to help casinos monitor how much players bet and how long or often they play for incentive programs. For example, Hard Rock Hotel plans to use its RFID system to monitor gamblers to reward good customers with free rooms, meals, or other perks based on how much and how often they wager. RFID is giving the casino a more accurate and efficient tool to rate players and allows casino to be more aggressive (Gilbert, 2005).

8. **Library and Air Transport** – Inventory control has been a time consuming operation for libraries. RFID technology can be used in libraries to automate the issue and return of books, CDs, and other materials and to give real-time visibility for inventory. The tags provide a much higher degree of accuracy in inventory management and can reduce the need for personnel. Similarly, RFID can be used for baggage handling in the air transport environment. RFID tags offer the additional re-write functionality allowing information to be changed at different points in the airline system.

### CASE EXAMPLES OF SUCESS

The following are examples of some companies that capitalized on RFID technology advantages and have made great strides by applying this technology:

**Delta Airlines:** Mishandled baggage is a key component of the airlines' service quality algorithm. In an Airline Quality Rating report published in 2004, Delta fell to last among the twelve major U.S. airlines. Delta Airlines has seen the performance of its current bar code-based system stop improving. Scanners were successfully reading bar-coded labels only 85 percent of the time. Delta's top management has decided to tackle its "bag problem", looking to RFID technology. In the fall of 2003, the airlines implemented a pilot test of an RFID tracking system for checked luggage on flights between Jacksonville, Florida and its main hub in Atlanta, Georgia. On a test on 40,000 bags, RFID tagged bags were correctly scanned between 96.7% and 99.8% of the time, a sorting accuracy rate far superior to Delta's present bar code-based system. In 2004, Delta also implemented another pilot RFID baggage-tracking system and found similar improvements in sortation accuracy. Delta spends nearly \$100 million each year to return "lost" bags to their rightful owners and provide compensation to passengers whose luggage is never found. Delta plans to use passive tags, which will cost the airline approximately 5 cents a unit by the time the system is fully implemented in 2007. Delta estimates that the full implementation cost of its RFID-based tracking system for its 81 airport locations will ultimately fall somewhere between \$15 and \$25 million. The airline estimates it will recoup this cost in far less than a single year. RFID will also improve customer relationships allowing the airline to take proactive customer service steps on baggage problems (IDTechEx 2006).

**METRO Group** – The company is the world's third-largest retailer, operating department stores, hypermarkets and grocery stores in 30 countries, throughout Europe and in Asia. In November 2004, METRO Group passed from pilot to production phase with its pallet tracking RFID applications in its own daily supply chain operations. METRO is running multiple RFID applications, including a system to identify garments on hangars that can sort up to 8,000 items per hour. More than 40 fixed-position, handheld and innovative forklift-mounted RFID readers are now in use. In January 2005, METRO Group celebrated its "First 100 Days of RFID" by announcing it had identified more than 50,000 pallets and was enjoying tag read rates well above 90 percent from its RFID readers. METRO reports trucks are being checked in and unloaded 15 to 20 minutes faster since the RFID systems have been in place. As anticipated, the timesavings raise worker productivity. In addition, incomplete shipments are detected immediately, which has improved inventory accuracy and is a major reason why METRO has reduced out-of-stocks at its stores by 11 percent. Moreover, the goods receipt process in warehouses and stores have accelerated markedly. Less time was lost at delivery, handling was more efficient and out-of-stock situations were avoided. The other benefits RFID produced included a 14 percent reduction in warehouse labor, an 11 percent improvement in stock availability, and an 18 percent reduction in lost goods (Intermec 2006).

**Paramount Farms** - The company is the world's largest supplier of almonds and pistachio nuts, growing and processes about 60 percent of the U.S. pistachio crop. Half of that crop comes from orchards and processing facilities in Lost Hills, California, and the rest comes from a network of nearly 400 grower partners. In its average harvest season, incoming green product totals a half billion pounds over a six-week period. The scope of pistachio receiving operations at harvest is enormous. Paramount receives 400 loads a day, each about 50,000 pounds of gross green weight. That adds up to 20 million pounds per day for receiving, recording, weighing, pre-cleaning, sampling and processing. With this kind of volume, Grower Receiving System is one of the most critical points in Paramount's supply chain. In 2004, the company decided to improve efficiency and productivity by implementing RFID technology that consists of eleven handheld computers, three access points and three RFID tag readers. As each nut-laden trailer arrives at the Paramount scale house, a fixed reader interrogates the trailer's RFID tag, captures each radio-frequency tag's unique identification number and wirelessly transmits it to the central server. The database relays the pre-recorded profile of the identified trailer back to the scale house worker's mobile computer. Now the worker knows the trailer's net weight, license plate number, equipment number and owner name. Scale house workers next use the handheld computers to gather load details including the grower name, ranch, field, product temperature, and harvest method. Next, the trailer's gross weight is automatically retrieved from the truck weigh scale and a weight certification is printed. Paramount's new RFID enabled Grower Receiving System helps the company to achieve many benefits including reduced load-processing time by 60 percent, increased crop receipt data accuracy, and reduced raw material costs. The system also ensures that the volume and quality the company pays for is the volume and quality it receives (Intermec 2006).

## CONCLUSIONS

In today's competitive environment, retailers are increasingly aware that emerging technologies are indispensable in meeting the challenges of increasingly global markets and customers that are more demanding. RFID is one of those technologies with the potential uses limited only by people's imagination. The technology has been used in manufacturing to complement established barcodes for the past 25 years. Barcoding works better in controlled highly engineered environments, while RFID seems to work best in chaotic, randomized business process. RFID can provide immediate and tangible benefits throughout the supply chain. It can also be used for tracking animals, library books, fleet of trucks, medical devices, drugs, weapons, betting chips, container locations, building security and many more. The technology is not standing still. RFID mandates established by major retailers have spurred innovation in every aspect of the technology, including tags, printers, and software. Maturing technology is also helping the next generation of suppliers adopt RFID technology.

According to experts, compliance is not the only dynamic influencing manufacturers to adopt RFID. The other major factor is the need within manufacturing for business process improvements that cut costs, reduce inventory, improve order forecast, improve asset management, and provide high customer satisfaction. ROI is associated with the business process changes RFID technology enables.

Many regard RFID as a technology in its infancy with yet untapped potential. New standards and lower tag prices are encouraging retailers to use RFID not just to collect data, but also to transform this information into actionable business intelligence. However, variety of issues outside the technology itself such as lack of standards, implementation costs and ROI, false promises, and privacy issues are hindering RFID's widespread applications. Manufacturers, however, are aware of these problems and are trying to do something to remedy the mistakes of the past. In the end, though, only those companies with a well-defined implementation plan can achieve the full benefits of RFID.

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