Critical Success Factors and Challenges of Implementing RFID in Supply Chain Management

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Radio Frequency Identification, or RFID, is one of the most promising and anticipated technologies in recent years. Implemented properly, RFID can save the firm money now-- and make the company more competitive for years to come. Despite many useful applications, there are major impediments to RFID adoption in supply chain. In this study, we examine supply chain processes where RFID technology creates the most value, identify the opportunities and challenges facing RFID implementation in supply chains, and suggest a possible relationship between RFID system benefits and implementation success factors. We survey RFID applications in supply chains of various industries, and summarize empirical evidence of benefits gained.

Key Words: Supply Chain Management; Radio Frequency Identification (RFID); Universal Product Code (UPS); RFID Technology; RFID Tags, Bar Coding ; CPFR

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I. INTRODUCTION

A strong market for RFID technology has been created with the need for optimization of total cost and accurate asset tracking and monitoring. In the past few years, many companies have embraced RFID in their supply chains and are beginning to enjoy real business benefits from the technology. Companies in different sectors have come to realize that RFID technology does a lot more than just tracking boxes in the supply chain. RFID is slowly reemerging as a valuable way to improve internal efficiencies (Attaran 2006, 2007, 2011b; Hou and Hung, 2006; Reyes and Frazier, 2007). According to a forecast by ABI Research, the global RFID market will exceed $8.25 billion in 2014, enjoying nearly a 14% compound annual growth rate over the next few years (ABI Research, 2010).

Today, supply chains have to rely on technology to deliver a higher level of performance in satisfying consumer needs. The technology for supply chain management (SCM) is still emerging. Of all the emerging technologies in SMC, RFID has the potential to make the biggest impact. RFID can revolutionize the way the supply chain meets customer expectations by offering direct insight into consumers' buying habits and increasing efficiency and accuracy within the supply. The technology could dramatically improve supply chain performance by reducing inventory levels, lead times, stock outs and shrinkage rates. It can also increase throughput, inventory visibility, inventory record accuracy, order accuracy, customer service, quality and collaboration among supply chain members.

Companies face several fundamental challenges when evaluating, planning and implementing RFID in their supply chains. In this study major supply chain processes are used to highlight these challenges and discuss the economic opportunities and strategic values of

RFID implementation. Furthermore, this study attempts to demonstrate a relationship between the critical implementation factors of RFID and the benefits gained. Finally, application of RFID in the supply chains of various industries is examined and the benefits gained are summarized.

Adoption challenges for deploying RFID across supply chains are reviewed in Section II. Section III, examines processes in supply chains that will be affected by RFID technology, discusses real-world success factors in defining and implementing a winning RFID-enabled strategy, and suggests a likely relationship between RFID system benefits and implementation success factors. Section IV reviews real-world application cases, bottom-line business benefits, and successful integration across supply chains. Evolving trends of RFID technology are discussed in Section V. Finally, Section VI provides a summary and conclusions.

II. OBSTACLES TO RAPID ADOPTION

Implementing a successful RFID strategy takes time and effort. Implementing a full-fledged system in a large manufacturing company can cost $10 to $25 million. Considering the initial costs of RFID, there is no return on investment (ROI) for companies that implement the technology if compliance is the only pursuit.

RFID technology faces numerous implementation challenges. The major challenges include technological maturity, global standardization, government regulations, and cost as summarized in Table 1 and described below:

Table 1. RFID Implementation Challenges

Levels	Challenges
Fundamental	• High capital costs • Challenges in finding the ROI • Challenges in finding the "drivers" for adoption
Technical	• Imperfect read-rates • Unproven systems • Problems with assembling low-cost tags • Uncertainty about the role of the middleware • Lack of in-house experts to implement RFID
Security	• Concerns regarding the compromise of data during wireless transmission • Uncertainty around security of data storage and physical security of storage site
Privacy Issues/ Government Regulations	• Privacy concerns and the potential for legislation • Uncertainty around standards

1. **Fundamental** – The business benefits that RFID technology offers will not arrive with a big bang. From a supply-chain, manufacturing, or warehouse standpoint, RFID technology has limited applications. There is also a question regarding the "drivers" for adaptation. There must be incentive for retailers and manufacturers to

adopt the technology. A return on investment (ROI) is not always a straightforward calculation. Ultimately, a desire on the part of buyers and suppliers to collaborate is necessary to promote the use of RFID.

2. **Technical** – Among the technical problems of implementation are imperfect read-rates, unproven systems, and conflicting problems with assembling low-cost tags. RFID is more expensive than bar codes, and problems can occur when using the tags on metal objects. To reduce tag cost the size of the chip needs to be reduced. However, reductions in the size of the chip make assembly of the tags more expensive. Further, technology vendors do not have a clear idea of what RFID middleware should do. Finally, companies often lack in-house experts with the knowledge to implement RFID technology and hiring outside experts can be difficult and expensive.

3. **Security** – RFID is a wireless technology and, as such, poses some potential security concerns to users regarding the compromise of data during wireless transmission, storage of data, and security of storage sites. Some of the security issues have been addressed by RFID vendors by employing varying querying protocols, jamming and other techniques.

4. **Privacy Issues and Government Regulations** – The use of RFID could have profound social implications. Without safeguards in place, RFID technology has the potential to compromise consumer privacy and threaten civil liberties. Consumer groups have expressed concern over the privacy invasion that might result with widespread application of RFID tags. Governments around the world regulate the use of the frequency spectrum. There is virtually no part of this 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 ultimately hinders the use of RFID tags in a global environment.

III. Strategic Values and Challenges for RFID Implementation

Several factors have contributed to the overall growth of the RFID market as described below and summarized in Figure 1

A. Factors Influencing Adoption

Economic slowdown created major stress for many supply chains. Companies are challenged to keep critical products and supplies moving, manage inventory levels effectively, maintain productivity, improve safety and security, meet compliance requirements and keep emergency transportation costs in check. The inefficiency and lack of responsiveness of traditional SCM systems are highlighted by several empirical studies. According to a study by the Grocery Manufacturers Association, errors occur in 36 percent of consumer packaged goods orders which lead to inventory inaccuracy and are acknowledged as a multi-billion dollar problem (Zebra Technologies, 2011). Another recent study conducted by Efficient Foodservice Response identified more than $800 million in savings available to the foodservice supply chain through more extensive use of technologies like RFID (Zebra Technologies, 2011). Data collection by RFID can help prevent errors in order picking and shipping that plague the foodservice industry.

Despite unexpected events and a slowdown in the economy, companies continue to initiate supply chain improvement initiatives based on the growing recognition that excellent supply chain performance has strategic value that can lead to:

- Rapid financial payback, often within months;

- Improvements in productivity and profits;

- Improvements in customer positioning and product quality;

- Improvements in safety and security;

- Meeting compliance requirements;

- Enhancements in long-term relationships with suppliers

FIGURE 1. Factors Influencing RFID Adoption

There are tremendous cost savings that RFID technology can bring to supply chain operations. According to experts, it is not compliance driving RFID technology; it is the overall savings opportunity. For example, retailers using RFID technology 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 logistical delays by up to 5% (Krivda, 2004).

Another factor influencing adoption is mandates from powerhouses such as Wal-Mart, Target, and others that require the use of RFID-enabled tags for their largest suppliers. In addition, recent technological advances in RFID and a strong industry-wide commitment to standards and investment point to a bright future.

Experts believe the 2009 food-poisoning incidents in the U.S. and the 2010 outbreak of e-coli in Germany highlight the importance of RFID traceability in the food industry. Moreover, RFID technology can provide an efficient, accurate way to comply with regulations such as the Bioterrorism Act and the EU Food Law, which require businesses to collect, process, and store vast amounts of information. These regulations also require timely and accurate information exchange between trading partners. RFID helps organizations throughout the food supply chain gain traceability for compliance and business improvement. Advantages including ease of use, the ability to track individual products packed in crates and to scan items from significant distances help RFID to emerge as the long-term technology of choice in both the pharmaceutical and food industries.

B. RFID Reported Benefits

A number of companies are actively involved in testing and adopting RFID technology in their SCM. The benefits of RFID technology in the supply chain are fairly compelling. Organizations who take the time to understand the technology's capabilities and limitations can increase their inventory visibility while streamlining their operations. In addition,

Table 2. RFID Reported and Recommended Business Benefits in Supply Chain Management

Reported Benefits/ Success Variables	Recommended Benefits/Success Variables
1. Enhanced visibility into what customer will need 2. Enhanced visibility along the supply chain 3. Accurate and timely asset tracking 4. Smart product recycling 5. Streamline or better manage a business process within the company 6. Improved productivity by generating the fastest and lowest cost method of acquiring the data 7. Improved velocity by responding to demand signals faster 8. Reliable and accurate order forecasts 9. Reduction in inventory costs including stock-out and holding costs 10. Eliminate duplicate costs 11. Push growth opportunities 12. Improved technology return on investment 13. Improved accuracy by reducing the opportunity for human error 14. Improved competitiveness in the information. 15. Increased productivity and dramatically reduced operating costs 16. Improved product quality and reliability including traceability 17. Improved supply chain management by better tracking transportation and warehousing channels 18. Improved Counterfeiting identification, theft prediction, and faster recalls 19. Enhanced long-term relationships with suppliers 20. Reduced opportunity for human errors	I. Enhanced visibility along the supply chain II. Speedy and accurate information retrieval III. Accurate asset tracking IV. Better-quality information V. Better decisions VI. Improved productivity VII. Reduced operating costs VIII. Improved business process IX. Improved quality & reliability X. Improved competitive position

RFID has the ability to provide far more information than bar-coding. This information can be used to improve inventory management at the retail store and along the supply chain.

Several studies have investigated important benefits that businesses are able to obtain by embracing RFID technology in their supply chain management (Attaran 2007; Hou and Hung, 2006; Kern, 2004; Patton, 2005; Prater, Frazier, and Reyes, 2005; Reyes, Frazier, Prater, and Cannon 2007; Smith, 2005; Wasserman, 2007). Supply chain cost that includes receiving, inventory, shrinkage, distribution, logistical delays, and out-of-stock merchandise is often cited as a major factor influencing RFID adoption. These benefits are listed in column one of Table 2.

Out of these twenty benefits, we have chosen and identified ten major RFID benefits or success variables and listed them in column 2 of Table 2. The ten success variables are used later in Table 3 to summarize strategic values gained from implementation of RFID in supply chain management processes, in Table 4 against implementation success factors, and in Table 5 against reported RFID benefits.

Table 3. Supply Chain Management Processes and RFID Benefits

Supply Chain Management Processes	RFID Benefits/Success Variables
I. Demand Management	• Speedy and accurate information retrieval • Better decisions
II. Order Fulfillment	• Enhanced visibility along the supply chain • Better-quality information
III. Manufacturing Flow	• Accurate asset tracking • Enhanced process automation
IV. Reverse Logistics	• Improved productivity • Improved quality and reliability
V. Supplier Relationship Management	• Reduced operating costs • Improved competitive position

C. RFID Benefits in Supply Chain Management Processes

In general, RFID technology could generate business value at three levels for any SCM:

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 for the right price. And demand-driven, product fulfillment systems can link consumer behavior back into inventory planning, and logistics. (Intel Corporation, 2004a, b).

Sabbaghi and Ganesh 2008, explored the effectiveness and efficiency of RFID applications and identified four key processes where RFID creates the most value in the management of the supply chain. Considering the ever increasing value of sharing historical data and forecasts among supply chain partners, a fifth process,

"Supplier Relationship Management," has been added to this list. These five processes along with the benefits gained from RFID technology implementation are discussed below:

I. Demand Management - One of the challenges in demand planning is a lack of accurate, timely, and reliable data. RFID can produce accurate and timely information related to the inventory of work-in-process, in-transit, and finished goods. Timely data regarding market demand provides support for accurate forecasts and assists in the development of better strategies in production, distribution and marketing. An accurate forecast provides the input to match supply with demand and produce profitable aggregate planning.

II. Order Fulfillment – RFID enables automation of processes such as picking, shelving, and cross-docking. These operations are consolidated and the costly logistics mistake of not dispatching the right item to the right customer at the right time is reduced with the use of RFID. RFID technology provides enhanced visibility along supply chains enabling suppliers to accurately determine the location of a pallet and to track its journey through the supply chain.

III. Manufacturing Flow Management – RFID streamlines assembly line operations by enhancing process automation resulting in a reduction in cycle times and an increase in production throughput. Tracking capabilities, enabled by RFID, improve the velocity and visibility of products along the supply chain. Furthermore, RFID technology can be useful to manufacturers with just–in-time (JIT) assembly lines.
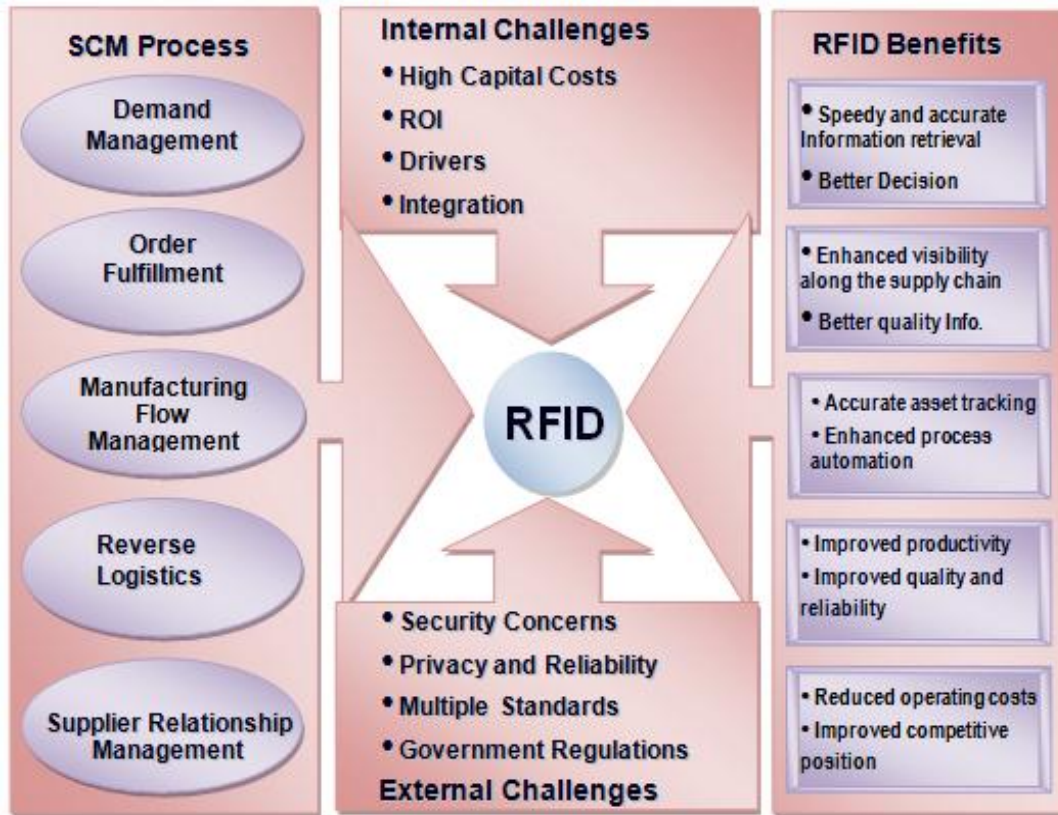
IV. Reverse Logistics and Return/Recalls Management – RFID can facilitate the return of defective products and product recall, also known as reverse logistics. RFID technology facilitates return management by matching a product to a particular sale. Enhanced traceability and tracking capabilities, enabled by RFID, allows manufacturers to eliminate fraudulent products being returned to retailers. Moreover, RFID makes lot-level traceability available throughout the supply chain limiting the logistics of handling costs and administrative burden, so recalls can be resolved and unaffected products can be redistributed quickly. The enhanced traceability also limits liability exposure and prevents lawsuits from unaffected individuals. Enhancement of the reverse logistics process will ultimately lead to sustained competitive advantage and will permit firms to actively monitor productivity improvements.

V. Supplier Relationship Management – Collaboration among supply chain partners and good relationships with suppliers are essential for a supply chain to be competitive. Collaborative Planning, Forecasting and Replenishment (CPFR) is an initiative that facilitates the reengineering of the replenishment between trading partners. CPFR was developed and evolved from an industry wide, efficient consumer response concept. An important promise of CPFR is that the accuracy of a forecast (demand, order, sales) will improve by having the customer and supplier participate in the forecast. While the CPFR process does not fundamentally depend upon technology, it does advocate using common tools and processes to improve supply-chain planning through accurate and timely information flow. A specialized technology such as RFID is able to integrate with the CPFR process providing more scalability. The major purpose of RFID deployment is identification, authentication, and automatic data acquisition. The processes affected by the implementation of RFID provide enhanced visibility along the supply chain and facilitate the sharing of historical data and forecasts among supply chain partners. Therefore, RFID is positively related to CPFR adoption.

Table 3 summarizes strategic values and benefits gained from implementation of RFID in the five key supply chain management processes. Figure 2 displays SCM processes and RFID

FIGURE 2. RFID Benefits and Challenges in Supply Chain Management

benefits, along with internal and external implementation challenges.

D. RFID Implementation Success Factors

Several studies have identified factors that contribute to the success or failure of a large system development project. For example, Vatanasombut and Gary (1999) identified 51 success factors that contribute to the success/failure of data warehousing projects. Sammon and Finnegan (2000) recommend ten-commandments of data warehousing success. DeLone and McLean have reviewed the definitions and classified six major categories of an information systems success and the corresponding measures. A multidimensional measuring model was used to distinguish between the different success categories (DeLone & McLean 1992, 2003). Other researchers have provided lists of critical success factors (Watson and Haley, 1997; Wixon and Watson, 2001).

Based on these studies and the review of other RFID papers (Attaran, 2011a; Angeles, 2005; Reyes, Frazier, and Prater, 2007; Visich, Li, Khumawala, and Reyes 2009; Waters and Rahman, 2007) ten critical implementation factors have been chosen to represent the prominent influences of RFID adoption by companies:

1. Clearly defined business needs/benefits

2. Top management involvement

3. Proper planning/scoping

4. Measurable business benefits (ROI)

5. Adequate funding

6. Partnership with competent technology providers

7. Integrating RFID into a company's existing IT architecture

8. Determining which practices should be incorporated into their RFID systems

9. Project management (teamwork)

10. Proper staff training and participation

In the next section (Part E), these ten critical implementation factors are examined alongside RFID success variables in an attempt to find possible interactions between the two.

E. RFID System Benefits vs. Implementation Success Factors

Table 4 attempts to find an interaction between RFID critical implementation factors and system success variables. No formal hypotheses are developed; simply, the objective is to suggest a possible relationship among the two variables. Table 4 provides guidelines for practitioners to plan and implement an RFID project. Since different organizations have different objectives, Table 4 can be used to identify exact factors that need attention. For example, an important objective of companies relatively new to RFID technology is to improve visibility along the supply chain. In this case, according to Table 4, it is recommended to concentrate on six factors: "clearly defined business needs," "top management support," etc. On the other hand, for advanced companies interested in using RFID technology for competitive advantage, it is recommended to concentrate on three variables: "measurable business benefits," "clearly defined business needs," and "proper development technology."

IV. Case Examples of Success

Numerous case studies provide ample evidence of early successes that companies in North America and Europe have had in implementing RFID technology. The presence of this evidence has led to RFID technology gaining a broader appeal. Data generated with the use of RFID improves supply chain efficiencies across industries such as retail, manufacturing, distribution, healthcare, and government. According to The Institute of Electrical and Electronics Engineers, the estimated value of the entire RFID market will grow to over $25 billion by 2017 (Srivastava, 2010).

RFID enables trading partners to collaborate more effectively, plan more accurately, and respond more rapidly up and down the value chain. RFID technology can help retailers reduce the costs of receiving, inventory, and shrinkage. It can also cut logistics delays, reduce the cost of checking inventory, and decrease the occurrence of out-of-stock merchandise (Krivda, 2004).

RFID can be used for automated data collection to augment ERP systems (Gupta, 2000). In addition, this technology can also facilitate inter-organizational e-commerce initiatives, such as continuous replenishment or vendor-managed inventories. It is already being used in a variety of settings, including access control to buildings, animal tracking, asset management, document tracking and library management, health care, payment processing, vehicle security, pay-at-the-pump gasoline sales, product authentication, retail, sports timing, tracking baggage and package wireless payment (Attaran, 2011b, 2009; Juban and Wyld, 2004; Kern, 2004; Reyes and Frazier, 2007). RFID technology can also reduce material-handling costs by improving pallet throughput and warehouse data accuracy through the deployment of sensor-based RFID forklift systems.

RFID technology could be an extremely powerful tool for improving efficiencies, especially when used as an infrastructure for many applications. A few companies, such as Airbus, have already adopted this infrastructure approach, and have been successful. Airbus, a consortium of several European aerospace companies, started testing RFID in the 1990s, but like many corporate giants, the company didn't have a coordinated plan. In 2006, the company made a conscious decision to implement

Table 4. RFID System Benefits and Implementation Success Factors

RFID Success/Benefits	Implementation Success Factors
I. Enhanced visibility along the supply chain	♦ Clearly defined business needs/ benefits ♦ Top management support ♦ User involvement/participation ♦ Practical implementation schedule ♦ Proper development technology ♦ Adequate funding
II- Speedy Information Retrieval	♦ Proper development technology ♦ User involvement/participation ♦ Project management (teamwork) ♦ Proper Integration with existing IT
III. Accurate Asset Tracking	♦ Proper planning/scoping ♦ Project management (teamwork) ♦ Proper Integration with existing IT
IV. Improved Information Accuracy	♦ Proper planning/scoping ♦ Practical implementation schedule ♦ Proper Integration with existing IT
V. Better Decisions	♦ Clearly defined business needs/benefits ♦ Measurable business benefits (ROI) ♦ Project management
VI. Improved Productivity	♦ Measurable business benefits (ROI) ♦ User involvement/participation ♦ Adequate IT staff and consultants
VII. Reduced Operating Costs	♦ Measurable business benefits (ROI) ♦ Adequate funding ♦ Clearly defined business needs/ benefits
VIII. Improved Business Process	♦ Proper development technology ♦ Proper planning/scoping ♦ Measurable business benefits
IX. Improved Quality	♦ Top management support ♦ Measurable business benefits (ROI) ♦ Proper planning/scoping
X. Improved Competitive Position	♦ Clearly defined business needs/benefits ♦ Measurable business benefits (ROI) ♦ Proper development technology

RFID technology in three phases. In phase one, Airbus decided to streamline its supply-chain tracking capabilities, and warehouse logistics and distribution processes. By using RFID-enhanced shipping labels, Airbus fully automated data entry across its warehouse and logistics processes. The RFID process enabled a100 percent inventory accuracy and a 75 percent reduction in handling time that in turn helped reduce cycle times and inventory levels. The second phase of the RFID program was designed to help improve the process in manufacturing, assembly, and global transport. In this phase, RFID-based technology pilots were aimed at evaluating the use of RFID for tracking work orders and improving the handling of tools throughout the manufacturing process. In the third phase of the RFID program, Airbus was looking at in-service processes and support operations that could be enabled by RFID (Wasserman, 2007). Table 5 summarizes reported benefits of RFID technology in supply chain management for each system success variables.

RFID has useful applications in the following industries:

1. Shipping and Distribution – In this industry, 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. At a major trucking and logistics provider company, RFID tags are embedded it the fleet of 2600 trucks. At the service center, the tag automatically determines what loading/unloading activities are needed and assigns an appropriate crew to service the truck (Intermec, 2004).

2. Tracking Baggage and Packages – In December 2008, Lisbon's international airport installed an RFID system to monitor baggage within the facility from the time the passenger gives a bag to the clerk to the moment it is placed in the belly of a plane. All transfer bags received at Lisbon airport are tagged with RFID tags on arrival and tracked only via RFID. Bar coded tagging, with only 80 to 90 percent accuracy rates, has been eliminated completely from the airport's system for transfer baggage. Milan's Malpensa Airport, Italy's busiest with 24 million passengers passing through it each year, is the second airport in Europe, and the third worldwide, to implement comprehensive RFID baggage tracking across the entire baggage handling system from baggage check-in onwards. Air Transport Association (IATA) says that RFID baggage handling systems are correct nearly 99 percent of the time (RFIDNews, 2009).

3. Retail Industry – RFID technology offers a very significant advantage over bar-coding. Wal-Mart's initiative and move in using the technology was heralded as the most important technology development for retailers since the bar code. RFID tags continually gather information as products move from shelves to the checkout counter. The technology not only helps the retailer to reduce labor and manual costs, it also curbs shoplifting and boosts store productivity (Gogoi, 2005). The tags already help Wal-Mart with reordering, stocking, and keeping track of purchases. According to an estimate, Wal-Mart can save $6.7 billion in labor costs alone from RFID implementation (Rockwell Automation, 2004). The Gillette Company placed RFID tags on all of the cases and pallets of its new Fusion razor that were shipped to 400 retailers with RFID readers in their storage facilities in 2006. When the data collected by the RFID reader showed the products had reached a store's storage facility but were not placed on shelves for sale in a timely manner, Gillette personnel would call and request that the product be moved out quickly. This strategy forced Fusion razors to be placed on store shelves 90 percent faster than before. Gillette expected a 25 percent return on its RFID investment by 2016 (Rothfeder, 2008). Finally, Walgreens, The largest U.S. drugstore chain has completed installation of an RFID tracking system to track product displays at nearly all of its 5,000 stores.

Table 5. RFID Reported Business Benefits in Supply Chain Management

RFID Success/Benefits	Reported Benefits
I. Enhanced visibility along the supply chain	• Saving of more than $300,000 due to reliable and accurate order forecasts
II. Speedy Information Retrieval	• Up to 90% faster order fulfillment
III. Accurate Asset Tracking	• Asset tracking accuracy improvement of up to 100%
IV. Improved Information Accuracy	• Inventory accuracy improvement of 80 to 100%
V. Better Decisions	• Most popular displays were placed on the sales floor at the proper time and location, thereby boosting sales by as much as 400 %
VI. Improved Productivity	• Realizing full ROI within months
VII. Reduced operating costs	• 75 percent reduction in handling time that in turn helped reduce cycle times and inventory levels • Improved Equipment Utility Rate with saving of more than $150,000 • Reduced Labor costs by 40 %
VIII. Improved Business Process	• Yearly saving of more than $500,000 due to better process management • Cut logistical delays by up to 5% • Reduced the costs of receiving, inventory, and shrinkage by 11% to 18%
IX. Improved Quality	• 100% accurate patient identification in the operating room.
X. Improved Competitive Position	• Sales boost of more than 300% due to better demand management

The project began in 2007 and has enabled the drugstore chain and its suppliers (such as Revlon) to manage the promotional displays more effectively, thereby increasing sales of the promoted products. The data gathered by the RFID system enabled Revlon to ensure that the most popular displays were placed on the sales floor at the proper time and location, thereby boosting sales by as much as 400 percent (Swedberg, 2009).

4. Supply Chain –IBM recently surveyed nearly 400 supply chain executives at companies located in 25 countries and serving 29 separate industries. The study revealed that supply chain visibility is still a major issue. The technology best poised to improve supply chain visibility is RFID that can collect and deliver real-time data regarding every facet of an interconnected supply chain (Bacheldor, 2009c). There are many success stories of effective implementation of RFID technology in this sector. For example, the U.S. Army is using a Global Sentinel Unit (GSU), which is mounted onto a truck and acts like RFID tags and communicates via satellite and cellular communications to ensure troops in Iraq receive their necessary supplies. More accurate visibility, helps the military keep supplies from running out, and prevents overstocking (Bacheldor, 2009a).

5. Manufacturing Sector – This sector has been finding different ways to derive value out of this technology. For example, manufacturers are using RFID product tracking mechanisms to ensure accuracy. Parts can be individually tagged and tracked throughout the manufacturing process while on the production line. Parts received from the production plant can be tracked throughout the assembly process. 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. At some of the Land Rover Group Ltd. factories, RFID tags are used to keep track of vehicles as they leave the assembly line for testing and refinement. The technology reduced the labor costs involved in looking for "lost" vehicles, decreased inventory carrying expenses, and assured faster order-to-cash cycles. Furthermore, Land Rover realized a full return on investment within nine months. (Rothfeder, 2008)

6. Apparel Industry – In this industry, RFID technology addresses critical challenges of how to gain greater control of merchandise flow. The technology helps apparel industry to improve turnover and increase the brand profitability. RFID enables apparel manufacturers and retailers to realize fewer operational errors throughout the supply chain, to accurately determine what stock is in the store, and to enjoy automatic replenishment that include stolen items. Some of the most important benefits that the apparel industry is able to gain by embracing RFID technology include, enhanced visibility into customer needs, accurate and timely asset tracking, reduction in inventory costs including stock-out and holding costs, and improved product quality and reliability including traceability. At a major vertically integrated clothing manufacturer and retailer, RFID tags were embedded in garments to achieve item-level visibility within several of its nearly 280 stores. At each store, the tags are read as a means of recording the receiving of those goods, tracking inventory within each store and identifying items purchased. The primary objective of the RFID system was to provide improved inventory accuracy and better-stocked sales floors. Employees kept the sales floor fully stocked, and the weekly process of taking in store inventories was accomplished with just two people in two hours - down from four workers eight hours before. Moreover, a better-stocked sales floor helped boost sales. A Scandinavian women's clothing designer began tagging all of its garments for supply chain tracking in 2007. The

clothing is manufactured at factories in Eastern Europe and China. With RFID readers at the company's distribution center in Finland, the company has been able to reduce errors and cut man-hours spent checking garments to ensure the correct products are being sent to the proper locations. The most recent phase of the deployment has been to bring RFID into the stores themselves and create a smart store. The system assists staff members in improving inventory management and security. The store's employees use the system for daily inventory checks, to obtain real-time data regarding which item is on the shelves and automatic notices when it is time to replenish. Additionally, RFID sensors are employed in store's dressing rooms and on its shelves to provide customers with better, more personalized service. When an item is carried into the fitting room, an RFID reader sends the item information to the store's back-end ERP system. Information and images related to the item appear on the LCD screen in the dressing room. In that way, users could, for example, visualize a garment with other accessories or clothing (Swedberg, 2008).

7. Agriculture, Cattle 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 have pushed RFID technology into food sourcing. Experts believe the recent food-poisoning incidents, along with improvements in RFID technology, make 2009 "the year for traceability." Recent outbreaks of E.coli and salmonella poisoning will expedite government mandates requiring that food products be tracked throughout their life cycles. RFID technology is well positioned to benefit from this mandate. RFID can help these traceability requirements at 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. The technology is proving more useful and is playing a broader strategic role in this industry. For

example, the silicon-free RFID tag is helping the food industry to avoid the next catastrophe. RFID technology is used to secure identification of cattle by means of implanted tags for tracking and linking the animal to food and to location. RFID can help these traceability requirements at a reasonable cost. The technology could be used to improve food safety and reduce recall costs by increasing the ability of the manufacturers to identify and recall only the affected items. RFID technology could trace the history of every ingredient in a package of food and enable investigators to prevent widespread illness when contaminated food ends up on consumers' dinner tables. RFID improves the management of products, increases the visibility of stock, and enables physical tracking of pallets and cartons as they move from one site to the next. Other advantages include improved management of products, improved productivity, on-shelf replenishment and tracking promotions as well as improving logistics efficiency. RFID technology also improves security and allows manufacturers to ensure the integrity of the ingredients being used and prevent counterfeiting. Lastly, RFID technology can improve quality and safety in the food industry. Most perishable products are highly affected by temperature. Each year a retail store can lose $400 000 due to bad temperature management. RFID temperature tags open a new era in Cold Chain Management.

8. Health Care – RFID technology is increasingly being used in health-care industries to improve quality and reliability of health-care service delivery. RFID is being used today for linking a patient with key drugs, personnel giving the drugs, and biometric measurements (Mehrjerdi, 2011a). RFID tags are used to identify and track individuals in health-care contexts. Examples are: employee identification cards, patient identification cards, ankle and wrist identification bracelets, and implantable RFID chips. 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, wheelchairs, and surgical equipments. Moreover, the technology is used to monitor specimens and laboratory results, verify the authenticity of pharmaceuticals, and track movement of medical waste containers. 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. Finally, RFID technology is being effectively used to help improve patient registration at hospitals and reduce the wait times. Leading health-care providers are effectively using RFID technology to achieve real benefits. At the U.S. Navy RFID tags, embedded in wristbands, are used to identify patients and update their status automatically. RFID technology can be used in health-care industries to improve quality and reliability. A British firm is using RFID tags to match blood samples to patients. Jacobi Medical Center is 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). At a major hospital in Taiwan, wristbands with embedded RFID chips are given to patients. The system automates data gathering and cuts down on previous human error resulting from manual data entry. The new system has enabled the hospital to realize 100% accurate patient identification in the operating room. Lastly, the RFID wristbands offer better patient privacy, improved accuracy, and improved efficiency. A large health-care provider in Oklahoma City used RFID technology for tagging hernia meshes at its acute-care facility. The technology enabled the facility to reduce shrinkage and ensure high-value items are not expired before use. The company estimated an ROI of more than $300,000. Another U.S. health-care provider has implemented an RFID temper resistant infant tracking security system that alerts hospital staff if an infant's ID tag is

tempered with. It also alerts the staff when a patient ID tag approaches an exit, by automatically locking a shut door. St. John's Children's Hospital located in Springfield deploys 100 RFID-enabled, tamper-proof bracelets and a network of readers to secure three floors of its six-story facility and to protect children. If a bracelet is cut, or if an individual attempts to remove it, or someone attempts to take an infant or child wearing a bracelet through a protected point of exit, the system sounds an audible alarm at the nurses' stations, and contacts the staff's cell phones Other hospitals such as Wisconsin's Waukesha Memorial Hospital and Kansas City's Shawnee Mission Medical Center have deployed the similar RFID-enabled, tamper-proof bracelets system throughout their women's and children's wing as well (Bacheldor, 2009b).

9. Pharmaceutical – The drug industry uses RFID technology to self-polices in the fight against thieves and counterfeiters. For example, Purdue Pharma, the manufacturer of the popular painkiller OXYContin, is using RFID tags to track shipment of its theft-prone drug. Pfizer was 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 (Patton, 2005).

10. Government – This sector is another emerging application area for RFID. Government agencies are using RFID technology for supply chain management, inventory, security, and military strategies. The Army uses tags on supply containers for detecting shock and variances in temperature. These tags have a range set of up to a mile to enhance supply management capabilities. 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 (Bacheldor, 2003).

11. Gaming Industry – This industry has been finding other ways to derive value out of RFID technology. For example, the Wynn Las Vegas Casino is 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 casino is 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 keep tabs on 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).

We reviewed case examples of some companies, across different industries, which gained significant benefits from RFID implementation (Aitoro,2005; Bacheldor, 2003, 2009a, 2009b, 2009c; Gilbert, 2005; Intermec,2004; Mehrjerdi, 2011a, 2011b; RFIDNews, 2009; Rockwell Automation, 2004; Sullivan, 2005; Swedberg,2008, 2009). Appendix summarizes the results and provides an overview of the RFID benefits gained in each supply chain management processes.

V. A Look Ahead

RFID technology is maturing and continues to see tremendous innovation. These technological innovations are discussed below and summarized in Figure 3. Today, RFID systems have further extended capabilities by becoming more expansive and less expensive. RFID tags based on paper, plastic, and nontoxic RFID ink are being developed by several companies (McGlaun, 2010). Other companies are collaborating to develop active tags that transmit signals up to 600 feet. These active tags have numerous applications in the retail industry and have the ability to move fast into the people-tracking realm. Over the next 10 years, it is expected that retailers will continue to use barcodes and gradually introduce RFID tagging. When the prices of tags become economical, RFID is expected to take off in other venues. Tags could be placed on supermarket products, if the cost per tag was only a penny or two; everything in the shopping cart, except produce, could be read at once.

Current RFID readers use less power and operate faster, at farther distances, and with more ability to handle interference (Attaran, 2009). Moreover, experts have predicted the average price for readers will be reduced to less than $500 by 2012. Lower costs drive adoption of the product (Attaran, 2006).

In addition, using silicon biometrics technology, "unclonable" tags are designed for use in anti-counterfeiting and other related applications. This process prevents counterfeiting of high value, high interest items such as luxury goods, pharmaceutical products, secure IDs and access card embedding (Biyong, 2008).

Another possible way 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 application, 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 data within the boundaries of a company.

Handheld, forklift-mounted and mobile cart readers are changing the paradigm for RFID, opening up new applications. RFID mobility can cut the time it takes to do inventory to a fraction of what it would normally take by bringing readers to the tags instead of passing tags through stationary readers installed at the warehouse doors.

There has also been a tremendous growth in applications software. Microsoft and other software companies are creating platforms upon which RFID resellers and consultants can create software and applications optimized for RFID. Some innovative companies, working with academic and industry leaders, are using hardware and software to develop powerful integrated RFID solutions. In cooperation with university research labs, companies are developing IT processes and applications to improve efficiency in the retail supply chain, with a particular focus on RFID applications that modernize both store operations and the shopping experience. Figure 3 shows evolving growth of RFID technology.
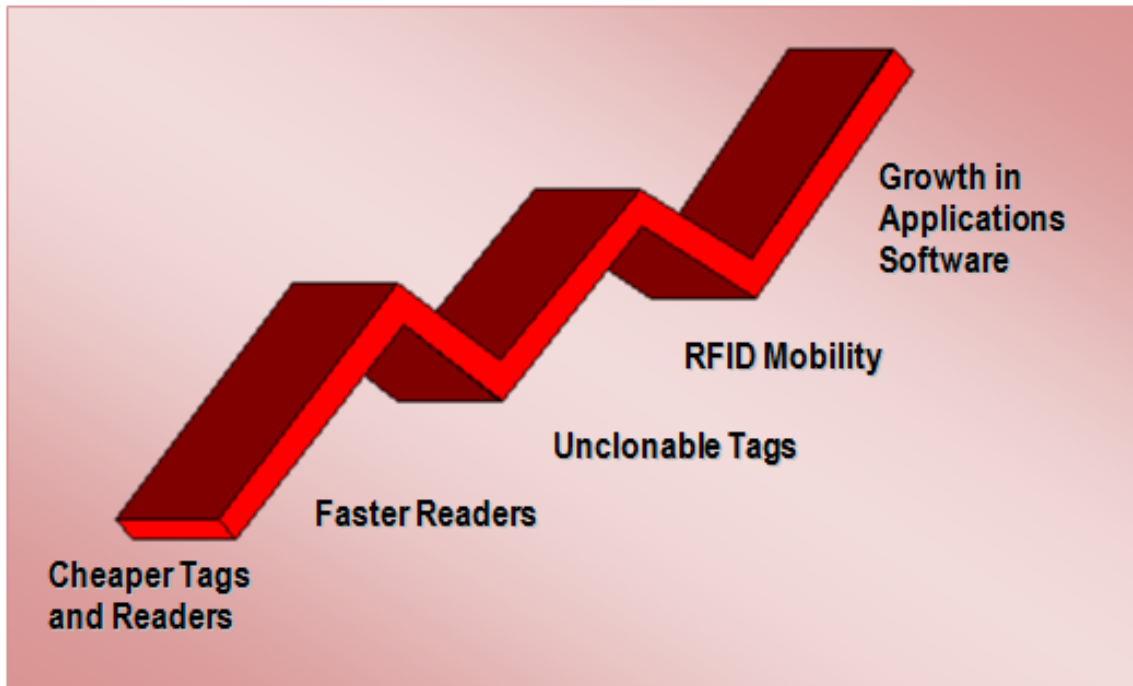

FIGURE 3. RFID Evolving Trends

VI. SUMMARY AND CONCLUSIONS

A. Summary

Despite economic turmoil, companies still need to invest in cutting-edge solutions so their business can compete and grow. RFID is one solution that can save firms money in the short term, while making their supply chains more competitive in the long run. RFID is one of the most promising and anticipated technologies in recent years. An RFID system solution can increase corporate ROI while at the same time improving retail supply chain communication.

Implemented properly, this technology can bring velocity to certain markets by serving more customers faster and increase customer loyalty. RFID has the real potential to increase accuracy and reliability, enhance service and reduce costs.

In tomorrow's supply chain, emphasis will shift from manufacturers and retailers pushing products into the value chain to consumers pulling new or customized items into the supply chain. RFID has the potential to offer direct insight into consumers' buying habits, delivering higher levels of performance in satisfying consumer demands. RFID's insight into consumer buying habits could also change the way retailers operate, and extends the visibility of the supply chain to anticipate end-of-life and recycling potential. The consumer benefits with better service at a better price.

The challenge for IT experts today is determining how to integrate RFID with existing Supply Chain Management (SCM), Customer Relationship Management (CRM), and Enterprise Resource Planning (ERP) applications within the entire system.

While the technology has many benefits to offer, significant stumbling blocks exist. Implementation of RFID involves a variety of issues outside the technology itself: marketing problems, false promises, government regulations, and a lack of standards. Standardization of hardware, software, network protocols and reading devices is important. Industry members, however, have become painfully aware of these problems and are trying to do something to remedy mistakes of the past. If they are able to successfully unify the industry with standards, deliver on future promises, and convince end users of the technology's benefits, then RFID's future looks favorable.

B. Conclusions

In this study, we have examined supply chain processes affected by RFID technology. Using information from published secondary data, we have identified a consolidated list of ten

RFID benefits or success variables that firms are able to gain by embracing RFID in their supply chains. By identifying influencing factors and the benefits gained, this paper presents areas in need of further empirical research in order to understand the significance and strength of each influencing factor.

Moreover, this paper examined the interrelationship between RFID benefits and implementation success factors in supply chains. Since different organizations have different objectives in implementing RFID technology, this study is useful in identifying and prioritizing factors needing attention. In short, results of this study provide a suggested list of critical success factors that can be tailored to suit the needs of individual companies.

Using information from published secondary data, this paper developed a research model for RFID success to facilitate research integration and variable selection in future research. The model is general and allows new factors or success variables, when identified, to be added easily. Further empirical research is needed to examine the strength of interrelationships between RFID system benefits and implementation success factors with the overall intent of shaping the adoption of RFID in supply chains and initiating further developments in this discipline. For example, perceptions of RFID professionals could be examined in a cross sectional survey; and regression analysis could be used on survey data to identify the specific factors that are important to each success variable. The objective is to produce an empirically validated list of factors and report their respective strength of impact on various aspects of RFID success. Since different companies have different objectives or emphases in their supply chain endeavors, the results will be useful in identifying the exact factors that need attention and in providing a basis for prioritizing those factors. The results could also suggest several promising directions for continued research on RFID success.

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Appendix. Supply Chain Management Processes and Successful RFID Implementation

Industry/Processes	Example	RFID Process	Benefits Gained
I- Logistics a) Demand Management b) Order Fulfillment	- VR Group of Finland - Mission Foods - Hush Puppies - Gardeur AG of Germany - Antolini Luigi & Co. of Italy	- Tags embedded in the fleet of 10,000 rail-freight wagons, locomotives and passenger cars - Tracking reusable plastic trays at the warehouse - RFID tags are employed to accurately and precisely manage real-time stock at distribution center - Tags used to track blocks and slabs	- Improved the efficiency of its rail-yard processes, better managed rail-car inventory and maintenance orders, and enabled improved customer service - Prevented loses of thousands of trays per year - Delivered ROI within months - Enabled the company to efficiently fill customer orders and avoid stock-outs - Labor costs were reduced by 40 % and inventory accuracy improved by 80 %
II- Baggage and Package Tracking a) Order Fulfillment	- Lisbon's International Airport - Milan's Malpensa Airport	-Tags used for baggage tracking across the entire baggage handling system	- RFID tagging improved baggage handling systems to 99 %
III- Retail a) Demand Management b) Order Fulfillment c) Returns Management d) Supplier Relationship Management	- Wal-Mart - Gillette Company - Walgreens - Prada's New York Epicenter store	- Tags used on the cases and pallets of Fusion Razor -Tags used to track product displays at nearly 5000 stores - Tags are placed on every item in Prada's NY store.	- Wal-Mart saved $6.7 billion in labor costs alone - Razors are placed on store shelves 90 % faster. Gillett expects a 25 % return on RFID investment - At Walgreens, sales for certain items boosted by as much as 400 %
IV- Packaging a) Order Fulfillment b) Returns Management	-Italian coffee producer Lavazza Ringnes, **t**he Norwegian beverage maker	- Tags—enables just-in-time delivery of reels of printed packaging materials - Tags are used on re-usable containers as they are shipped to retailers, and then returned empty to its distribution center	- The technology has reduced inventory of packaging, as well as the space required to store it, and provided the company with real-time visibility of stock levels - Reduced time spent loading and unloading
V- Manufacturing a) Manufacturing Flow Management b) Demand Management	- Land Rover Group Ltd. - Airbus - Kayser-Roth of Burlington, N.C. - Wells' Dairy ice cream manufacturing facility in Le Mars, Iowa - John Deere	- Tags are used to keep track of vehicles as they leave the assembly line for testing and refinement - RFID-enhanced shipping labels are used - Tags are affixed on individual ice cream buckets throughout the production process - Battery-powered tags were attached to kit carts	- Reduced labor costs involved in looking for "lost" vehicles - Enabled a100 % inventory accuracy and a 75 % reduction in handling time - Assured faster order-to-cash cycles - Realized a full ROI within 9 months - Allowed the firm to track the products and ensured the right products are sent to a customer

Appendix - Continued

Industry/Processes	Example	RFID Process	Benefits Gained
VI - Apparel a) Demand Management b) Order Fulfillment c) Returns Management d) Supplier Relationship Management	- Gerry Weber International - American Apparel - Switzerland's Charles Voegele Group - Portugal's Throttleman - Tomorrow's Mother	- Tags were imbedded in garments - Fashions tracked and managed via RFID - Deployed a smart-shelf system with RFID-enabled product displays	- Better-stocked sales floors - Improved inventory accuracy - Improved on-shelf availability - Taking in store inventories were accomplished with 2 people in 2 hours down from four workers 8 hours
VII - Health Care a) Order Fulfillment b) Demand Management c) Returns Management	- Jacobi Medical Center - St. John's Children's Hospital, Springfield - Wisconsin's Waukesha Memorial Hospital - Kansa City's Shawnee Mission Medical Center -Saint Luck's Hospital of Kansas City - Columbus Air Force Base Hospital - 81st Medical Group Hospital - Albert Einstein Medical Center	-Tags embedded in wristbands - Tags track and manage medical devices and wheelchairs - Medications and dosages are tagged - Tagged hernia meshes at acute-care facility - Tags track pacemakers, coronary stents and defibrillators - RFID-enabled, temper proof bracelets and network of readers are employed to secure the hospital floors and to protect children	- Identified patient and updated their status automatically - Improved asset management - Improved medication management - Realized 100 percent accurate patient identification in the operating room - Reduced the size of its coronary device inventory by half a million dollars. - Reduced shrinkage and ensured high-value items are not expired - Gained an ROI of more than $300,000 - Improved infant tracking security - Boosted revenue with automated billing - Improved Equipment Utility Rate and saved $150,000
VIII - Agriculture, Cattle &Food Production a) Order Fulfillment b) Demand Management c) Returns Management d) Supplier Relationship Management	- LaClare Farms in Chilton - Ste-Lor Oaks Beef of Wisconsin - Levinoff-Colbex-Canadian beef processor - Norway's Nortura	-Silicon-free tags used on package of food - RFID temperature tags used for temperature management - Tags implemented in cattle for linking the animal to food and location	- Reduced recall costs by recalling only the affected items - Improved food traceability - Improved productivity - Improved logistics efficiency - Saved $400,000 each year due to better cold chain management - Quickly identified and tracked any animal products from potentially contaminated or diseased animals

Appendix - Continued

Industry/Processes	Example	RFID Process	Benefits Gained
IX - Pharmaceutical a) Order Fulfillment b) Returns Management c) Supplier Relationship Management	- Purdue Pharma - Pfizer - Glaxo-SmithKline	- Tags are used on bottle of theft-prone drugs to track shipment	- Improved self-policing in the fight against thieves and counterfeiters - Improved validation at every step along the supply chain, significantly increasing patient safety
X - Defense a) Order Fulfillment b) Demand Management c) Returns Management d) Supplier Relationship Management	-U.S. Army - U.S. Navy - Department of Defense	- Tags are mounted onto military trucks in Iraq and communicated via satellite - Tags are used on weapon with a range of less than 6" - DOD is requiring suppliers to deploy tags on cases and pallets they deliver to the Department	- Helped the military keep supplies from running out, and prevented overstocking - Helped the military with better detection of shock and variances in temperature - Improved weapon management - Better tracking of packaged meals, chemicals and biological warfare suits
XI - Library a) Order Fulfillment b) Demand management c) Returns Management	- The Queens Borough Public Library system in NY - The Vatican Library in Rome - The British Library in London - Brighton's city center Jubilee Library in UK	- Tagged millions of books, DVDs and CDs	- Reduced checkout times, boosted visits and added value to the community - Reducing stocktaking time from weeks to half a day - Increased security
XII - Gaming a) Order Fulfillment b) Flow Management	- Wynn Las Vegas - Bellagio - Venetian - Fremont	- Chips with a face-value of $100 or higher are inlaid with RFID	- The house could detect and monitor card counting, dealer mistakes, chip counterfeiting, and chip theft