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IMPROVING SUPPLY CHAIN MANAGEMENT SYSTEMS THROUGH THE EFFECTIVE IMPLEMENTATION OF RFID TECHNOLOGY

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ABSTRACT

Here, we explore the key elements of RFID technology within a comprehensive supply chain strategy that directly enhances the effectiveness and efficiency of supply chain management. We look at the business processes influenced by RFID, the planning and evaluation necessary for successful implementation, and the potential impacts on supply chain performance. The focus is on the business value and strategic benefits of RFID, as well as the challenges and recommendations for adopting the technology, especially when a company extends its supply chain to upstream suppliers and downstream customers, where external integration is crucial for improving capacity planning and efficiency. By examining four major supply chain processes, we highlight the economic opportunities and challenges associated with integrating RFID into an existing supply chain framework. Our focus is on RFID's ability to ensure security, privacy, and integrity in supply chain operations while supporting information sharing with suppliers and customers, fostering alliances, forming strategic partnerships, and securing competitive advantages.

Keywords: Radio Frequency Identification Technology, Supply Chain Management, Electronic Product Code, Retail, Manufacturer, Distribution, Profit

1. INTRODUCTION

Radio Frequency Identification (RFID) and Electronic Product Codes (EPC) offer significant potential for improving the effectiveness and efficiency of supply chain management by addressing various supply chain challenges. EPC involves storing product identification data on tiny chips, no larger than a grain of sand, which are then attached to objects to enable unique identification. RFID technology allows for more accurate, real-time inventory tracking, leading to reduced processing time and labor. The use of RFID/EPC across the supply chain offers a wide range of applications, enabling real-time tracking of moving objects, which provides complete visibility of inventory from the manufacturer's floor to warehouses and retail stores. This visibility presents opportunities for improving and transforming supply chain processes. RFID technology can benefit a diverse range of sectors, from hospitals and patients to retailers, customers, manufacturers, and distributors, driving productivity gains and efficiencies throughout the supply chain. This study aims to answer the following questions: (1) Which supply chain processes are most affected by RFID technology, and where

can this technology generate the greatest business value? (2) Given the interconnected nature of supply chain processes, what capabilities does RFID have in ensuring security, privacy, and process integrity, while facilitating information sharing with suppliers and customers, fostering strategic alliances, and achieving competitive advantage? (3) What are the challenges and recommendations for adopting and implementing RFID technology in the supply chain? We will explore the key components of RFID technology within the context of a comprehensive supply chain strategy that enhances the effectiveness and efficiency of supply chain management. This includes examining which specific business processes within the supply chain are impacted by RFID and identifying where RFID adds the most value. Specifically, we will focus on the business value and strategic advantages of RFID, as well as the challenges and recommendations for adopting and implementing the technology, considering the interdependent nature of supply chain processes.

2. THEORETICAL AND PRACTICAL BACKGROUND

RFID technology holds significant promise for improving supply chain management. The future success of RFID and other mobile services largely depends on businesses' ability to deliver the right products and services to consumers. Beyond supply chains, RFID has the potential to impact areas such as manufacturing, after-sales service, and managing a product's entire life cycle. RFID systems can identify a variety of objects, including manufactured goods, animals, and people. These systems support numerous applications, from asset management and tracking to customer services, access control, and automated payments. Each RFID system is tailored to support specific business processes and can vary greatly in complexity depending on the industry and specific enterprise requirements. Conceptually, RFID systems consist of three subsystems: (1) the RF subsystem, which uses wireless communication for identification and related transactions; (2) the enterprise subsystem, which contains computers running specialized software to process and analyze data from the RF subsystem to support business operations; and (3) the inter-enterprise subsystem, which connects enterprise systems for sharing information across organizational boundaries. RFID systems typically include an RF subsystem made up of tags and readers.

In many cases, this is supported by an enterprise subsystem, which includes middleware, analytical systems, and networking services. In supply chain applications, RFID enables tracking of tagged products throughout their life cycle, from manufacturing to final purchase and sometimes beyond (e.g., product recalls or related services). This necessitates sharing information across organizational boundaries, and hence, RFID systems for supply chains also include an inter-enterprise subsystem. The enterprise subsystem is the computer system and software that utilizes the data stored on RFID tags, integrating the RFID system as a whole. Depending on the industry, the system may have a front-end component to manage readers and antennas, while a middleware component routes this data to servers running core database applications. In manufacturing, for example, enterprise software must integrate RFID data at various stages of production and along the supply chain. Middleware technologies are categorized into three levels: (1) software applications for addressing connectivity and monitoring in specific industries, (2) application managers that connect disparate applications within an enterprise, and (3) device brokers that link applications to devices like shop-floor machines and RFID readers. The Auto-ID Center at MIT developed a software called 'Savant' to manage the massive data generated by RFID readers. In a typical manufacturing scenario, readers capture continuous streams of RFID data, which may include errors such as duplicate or phantom reads. The Savant software filters and manages this data, forwarding only clean information to prevent overwhelming enterprise applications.

Different applications interact with RFID in various ways, some treat RFID reads like manually keyed data or barcode scans, while others are specifically designed to work with RFID tags. RFID applications span from manufacturing and distributing physical goods like automobiles and components to processes like minting banknotes, oil exploration, shipping, port operations, and pharmaceutical packaging. RFID, a form of automatic identification and data capture (AIDC) technology, uses electric or magnetic fields at radio frequencies for identification, authentication, and location tracking, among other applications. RFID systems are capable of sharing information across organizational boundaries, which is particularly useful in supply chain applications. For example, Reno GmbH, one of Europe's largest shoe companies with over 700 stores across 15 countries, plans to embed RFID chips in shoes sold in stores. While Reno has used RFID to track product shipments from factories to stores, it has not yet used it for tracking individual products inside stores. These RFID chips, designed for shoes produced in Asian factories, aim to reduce theft of boxed products, display shoes, and those customers try on in stores. In Japan, RFID chips have become a de facto standard in the past five years. Millions of people use RFID-enabled credit cards for railway travel and e-money transactions.

Sony's FeliCa chip, integrated into cell phones, allows for credit card purchases in stores. Tokyo's subway and private railway systems are adopting a common travel card based on the FeliCa platform, allowing users to travel on over 100 railway lines and hundreds of bus routes with a single card. Other cities, such as Hong Kong, Singapore, and Shenzhen, also use similar systems. In the U.S., Schiff Nutrition International, a mid-sized company in Salt Lake City, is deploying RFID to continue doing business with Wal-Mart. Wal-Mart set deadlines for suppliers in 2003 to start using RFID tags on shipments. Despite initial concerns about the costs, the project is expected to enhance supply chain efficiency and reduce costs in the long run. IDC estimates that the RFID market for related consulting, implementation, and managed services will grow by 47% in 2004, reaching $2 billion worldwide by 2008. By 2005, over 1.3 billion RFID tags were produced, with the number expected to grow to 33 billion by 2010, driven mainly by supply chain applications. However, for successful RFID deployment, widespread standards and regulations are essential. The transition of barcode standards from proprietary to globally accepted open standards played a pivotal role in the technology's global adoption. Similarly, RFID will need similar standards to become widely accepted. For small and medium-sized enterprises, the high costs of implementing and maintaining RFID systems have been a significant barrier to adoption.

3. ENTERPRISE SYSTEMS

In the 1990s, IBM established company-wide divisions for procurement, logistics, fulfillment, and manufacturing. By 2002, these units were consolidated under the newly created Integrated Supply Chain division, which played a significant role in reducing costs and improving responsiveness within the year. IBM had to balance two key measures of supply chain performance: (1) effectiveness, focusing on flexibility and responsiveness, and (2) efficiency, aiming to reduce costs as much as possible. The effort to optimize the supply chain required IBM to seek opportunities to strike a balance between these two factors across four areas: (a) the data collected at various points in the supply chain, (b) the business processes involved, (c) the information systems used, and (d) the organizations executing these business practices. To effectively measure both effectiveness and efficiency, businesses need to have a clear understanding of key supply chain processes and performance metrics for each. Industries like fast-moving consumer goods, manufacturing, consumer electronics, and apparel are still in the early stages of adopting new technologies such as EPC and RFID. These technologies will enhance companies' ability to accurately track the location and status of physical objects throughout the supply chain. Wal-Mart, for example, has faced slower-than-expected implementation of RFID due to supply chain infrastructure challenges and the high costs of deployment.

To better understand supply chain management and RFID technology, this study explores supply chain infrastructure, especially as it pertains to RFID's enterprise and inter-enterprise subsystems. Supply chain technologies primarily aim to improve operational and transactional efficiencies in sourcing, manufacturing, and distribution, both within a company and across its broader supply chain. According to the Supply-Chain Council, supply chain management encompasses all efforts involved in producing and delivering a product or service, including managing supply and demand, sourcing materials, manufacturing, warehousing, inventory tracking, order management, distribution, and customer delivery. Keen and Mackintosh argue that RFID technologies form part of a "universal infrastructure" for mobile commerce. They introduce the idea of "process freedom," which allows value to be added throughout the entire supply chain by enabling the mobility of critical elements such as business activities, people, information, and documents. This technology has the potential to greatly reduce human labor in certain workflows and make information accessible to all participants in the value chain. However, supply chain management must address complex interdependencies and be open to reengineering processes to create an "extended enterprise" that stretches beyond the factory, incorporating material and service suppliers, wholesalers, distributors, retailers, customers, and supply chain consultants. For supply chain participants, core competencies must enable them to deliver value in the form of reduced costs, improved quality, enhanced flexibility, faster speed, and better information for decision-making. RFID technology, for example, can facilitate the integration of supply and demand chains or value chains, driving revenue and innovation while gaining a competitive advantage.

The primary purpose of deploying RFID technology is for identification, authentication, location tracking, or automatic data acquisition (ADA). While authentication applications generally involve individuals, such as smart cards used for automatic payments, most supply chain applications focus on tracking objects like products, cases, and pallets. The data collected in ADA applications feeds into enterprise systems such as supply chain management, customer relationship management, and enterprise resource planning systems. RFID technology also aligns with the concept of ubiquitous computing, where tags attached to various items automatically communicate and coordinate with other

networked devices. The effectiveness of these applications depends largely on the type of RFID tags used, with some offering longer read ranges or more data storage capabilities, at varying costs. As RFID technology becomes more affordable and its applications more economical, it offers significant productivity gains over traditional methods. For example, Ford uses RFID for real-time logistics and visibility. Similarly, RFID is evolving in its application, much like e-commerce initially automated existing workflows. The true value of RFID will emerge as businesses utilize the intelligence of the technology to enhance collaboration with suppliers and innovate new applications. Neubauer and colleagues suggest that businesses should not view RFID merely as a replacement for barcodes but should instead redesign their business processes to leverage RFID's capabilities for maximum return on investment. RFID can create a seamless supply chain where cargoes are tagged for easier customs clearance, and security is enhanced by tracking containers and monitoring for tampering. RFID also facilitates information sharing with customers and suppliers, fostering innovation and strategic alliances. Ultimately, RFID can enable the creation of an integrated supply and demand chain that drives revenue, innovation, and competitive advantage, rather than simply reducing costs.

4. STANDARDIZATION

A key aspect of RFID application in the supply chain is the standardization of encoding information on RFID tags, similar to how barcodes are used in the Universal Product Code (UPC) system. These standards simplify electronic transactions between companies' ERP (Enterprise Resource Planning) systems when goods are shipped. They define how middleware processes data from RFID readers as items enter a warehouse and pass this data to enterprise applications. The current version of the EPC Tag Data Standard specifies the format for encoding and reading data from RFID tags, which contains product information similar to UPC codes, including company and product identifiers. Both EPCglobal and the International Organization for Standardization (ISO) have adopted RFID standards. The leading industry standards for RFID are the EPCglobal specifications, which manage the encoding of data on RFID tags. This organization, which also manages the UPC barcode standards, sets the protocols for encoding basic product information into RFID chips. EPCglobal, a nonprofit organization founded in 2003 by the MIT Auto-ID Center in collaboration with other research universities, supports the EPC network as the global standard for identifying items in the supply chain. EPCglobal establishes the standards for how data is transferred from RFID readers to applications and between applications in the supply chain. ISO, a network of national standards institutes from 157 countries, also has RFID standards.

ISO's role bridges the public and private sectors, as many of its members are government-affiliated, while others stem from private sector industry partnerships. The ISO 18000 series covers both active and passive RFID technologies, and various other ISO standards (such as ISO 15418, 15434, 15459, 24721, 15961, and 15962) address the data content of RFID systems. The ISO 18046 and ISO 18047 series outline performance and conformance standards for both types of RFID technologies. Data synchronization is another critical component of RFID in the supply chain. Companies need detailed data about their products and supply chains, and the ability to share this information with trading partners to streamline business transactions and product movement. Two major information networks have been developed: the Global Data Synchronization Network (GDSN) and the EPCglobal Network. The GDSN ensures accurate static information about products and commercial entities among trading partners for collaborative trading. The EPCglobal Network provides real-time data about the movement of individual items through the supply chain. Both networks offer unique benefits, and for companies aiming to adopt a fully collaborative business model, combining the EPCglobal Network and the GDSN provides a comprehensive, integrated approach to electronic collaboration, enhancing the optimization of global trading relationships.

5. SUPPLY CHAIN DYNAMICS

RFID can be applied in various supply chain management processes, including demand management, order fulfillment, manufacturing flow management, and returns management. This section explores these four areas in detail. One major challenge in demand planning is the lack of reliable data, but adopting RFID can provide accurate information regarding inventory at different stages, finished goods, work-in-progres, and in-transit, along with reliable due dates. RFID data can eliminate inaccuracies caused by human error or missing information. Consumer demand for lower prices and higher quality drives companies to make their supply chains more efficient. Having timely, item-level data on market demand helps in developing better strategies for production, marketing, and distribution. Accurate forecasting enables

better alignment of supply with demand through aggregate planning, which can be improved by RFID data, avoiding the need for costly buffer stocks during demand planning. Order fulfillment is a crucial process for meeting customer needs and enhancing supply chain efficiency. RFID enables process automation in tasks like picking, shelving, cross-docking, and consolidation, while reducing costly logistical errors such as sending the wrong item to a destination or failing to dispatch the right item on time. These improvements help reduce operational costs. RFID technology also helps suppliers track the exact location of pallets, monitor their journey through the supply chain, and make real-time routing decisions.

RFID portals in key points of a distribution center can read tags and automatically update inventory as tagged cases and pallets enter. This helps match incoming merchandise with the correct purchase orders and easily identify discrepancies. By automating manual tasks like inventory checks, RFID enhances process efficiency. In manufacturing, RFID can streamline assembly line operations, reducing cycle times and increasing production throughput. Enhanced automation and tracking capabilities from RFID improve product velocity and visibility within the supply chain. This aids manufacturers, especially in just-in-time (JIT) production. Procter & Gamble (P&G) believes that RFID can help track the exact location of every item in the manufacturing and supply chain, leading to savings of up to $1 billion in working capital and $200 million in inventory carrying costs. According to Lee and Ozer, a bottom-up approach, starting with the operational characteristics of processes, is an effective way to evaluate RFID's value. In reverse logistics, RFID helps streamline product returns, such as tracking product recalls or defective items. RFID technology, through its smart Electronic Security Marker (ESM), can also aid return management by verifying whether the item being returned was sold by the retailer. An ESM links a specific product to a sale and its subsequent return. Manufacturers can reduce fraudulent returns by tagging high-end products and components with RFID tags. Customer returns, rather than depleting inventory, can be added to it. In this context, RFID provides visibility into negative demand, or returned items, further improving supply chain management.

6. CONCLUDING WITH CERTAIN IMPLICATIONS

There are several challenges regarding the future of RFID in supply chain processes. These issues primarily involve the complexity of implementing processes, integration, interdependencies, and security concerns. Further research is needed to improve the range of RFID signals and address interference issues. Additionally, solution providers and consultants must figure out how new smart labels, barcodes, and RFID equipment can integrate with customers' existing business practices. A key challenge for companies adopting RFID technology is properly integrating it with other information systems, both internally and externally within their supply chains, and redesigning their business processes to create a strategic advantage. For instance, RFID generates large amounts of data compared to barcode technology, requiring new data warehousing systems to effectively process and mine the data at an economical storage cost. Companies extending their supply chains upstream to suppliers and downstream to customers need improved external integration for better capacity planning and efficiency. Security, privacy, and system integrity play an important role in the type of supply chain application. Since RFID is a wireless technology, it raises potential security concerns, such as eavesdropping and traffic analysis between the tags and readers. Security risks may involve data being compromised during wireless transmission, data storage, and physical security of storage sites. Supply chain applications are particularly vulnerable to security threats because external parties may have access to RFID tags or related databases. For example, the world's three largest seaport operators have collaborated to implement RFID-based automated tracking, detection, and security for containers entering U.S. ports. Theft prevention is another advantage of RFID. However, while wireless access is beneficial, it can also create security risks if not properly controlled. RFID vendors have tackled some of these concerns by encrypting data transfers, blocking transmissions with jamming, using different querying protocols, and employing blocker tags.

Several privacy-protection schemes have been proposed for RFID, including methods that add memory or lightweight circuits to the tags, with each method balancing the cost of the tag against the level of privacy protection. EPCglobal has addressed consumer privacy concerns by requiring RFID tags to have a kill command, disabling the tag's functionality after a product is purchased. While this provides privacy protection at minimal cost, there's always the potential for human error. Privacy concerns with RFID tags are significant, and solutions generally follow two main approaches: normal-tags, which protect privacy without modifying existing tags, and smart-tags, which include components such as rewritable memory, basic logic circuits, and encryption units for stronger privacy. Another challenge in adopting RFID technology is the existence of multiple, sometimes conflicting standards that could hinder the deployment of the technology and limit its expected benefits. For example, while EPCglobal has developed RFID

specifications for the U.S., ISO has set standards addressing air interface parameters for RFID communication at different operating frequencies. Companies with global supply chains may have to choose between standards and develop applications that work with one but not the other. This conflict between ISO and EPCglobal standards for RFID deployment raises concerns about interoperability. If different countries adopt divergent RFID technologies, it could undermine the compatibility of RFID systems and software applications for tracking goods across supply chains. In global supply chains, this situation could lead countries to mandate certain standards to protect domestic markets and achieve short-term economic gains, rather than focusing on technical needs. To enable RFID technology in global supply chains, it's crucial to address international interoperability of tags and readers, as well as international spectrum allocation for technology operability. Ensuring that international regulatory processes remain transparent and non-discriminatory in supporting RFID standards is essential, as this would help ensure the standards are based on technical merit and support global interoperability. This will allow RFID technology to achieve its potential for economies of scale in the global supply chain.

CONFLICT OF INTERESTS

None.

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