Application Analysis of RFID in Supply Chain Management

Xueqin Su*

School of Business Management, University at Buffalo of New York State, Buffalo, 14260, United State

* Corresponding Author Email: xueqinsu@buffalo.edu

Abstract. With the increase in global trade and the intensification of market competition, the importance of supply chain management is becoming more and more obvious. Radio Frequency Identification (RFID) technology emerged as the times required, bringing a new solution to supply chain management. This article will discuss the application analysis of RFID in supply chain management. The article mainly analyzes the environmental benefits of RFID technology; RFID application analysis based on the clothing industry and the application of RFID technology in inventory management of companies. The results of the study pointed out that although there are still some difficulties in the application of RFID technology, RFID technology has indeed effectively improved the efficiency of the supply chain. Moreover, the development trend of RFID is getting better and better, and the RFID technology has gradually lowered the application threshold standard as more people invest in research. RFID ultimately brings more benefits to enterprises and society. Therefore, this paper proposes to increase investment in the application of RFID technology in the supply chain. This article aims to provide decision-making guidance and reference significance for enterprises using RFID technology.

Keywords: RFID Technology, Supply Chain Management, Inventory Management, Input, Sustainability.

1. Introduction

Supply chain management refers to a series of activities that plan, organize, implement, and control all aspects of logistics, production, inventory, and sales during the entire process of products from raw material production to final delivery to customers. With the increase in global trade and the intensification of market competition, the importance of supply chain management is becoming more and more obvious. Faced with a more complex and extensive supply chain network, enterprises need to find effective ways to improve efficiency, reduce costs, reduce inventory, and improve customer satisfaction. However, there are some challenges with traditional approaches to supply chain management. For example, manually recording and tracking the movement of materials throughout the supply chain is prone to errors and delays, leading to inventory deviations and inaccurate material positioning. Additionally, a lack of real-time data and visibility makes it difficult for businesses to react to changes in the supply chain, resulting in reduced efficiency and poor customer service.

In this context, Radio Frequency Identification (RFID) technology emerged as the times require, bringing a new solution to supply chain management. The introduction of RFID has brought revolutionary changes to supply chain management. It is based on radio frequency identification technology, by storing information in RFID tags, and exchanging data with readers through wireless communication. This enables enterprises to realize real-time tracking and monitoring of materials, products, and assets, thereby solving many bottleneck problems in traditional supply chain management. The application of RFID technology enables enterprises to track the location, status and quantity of materials and products more accurately, simplifying inventory management and asset tracking processes. At the same time, RFID provides higher supply chain visibility, enabling enterprises to monitor logistics operations in real-time and respond quickly to any problems in the supply chain. This not only improves the efficiency and flexibility of the supply chain but also enhances the company's ability to control product quality and authenticity traceability, further strengthening its brand reputation.

To sum up, the introduction of RFID technology has brought great improvements to modern supply chain management. It provides enterprises with smarter and more efficient logistics operations, helps enterprises adapt to market changes, improves customer satisfaction, and maintains competitive advantages. This paper mainly studies the environmental benefits, RFID application analysis based on the clothing industry, and the application analysis of inventory management of RFID technology in supply chain management.

2. Case Description

RFID technology is widely used in supply chain management as an automatic identification and tracking technology. It is a technique that employs radio waves to track and identify objects wirelessly. RFID tags, usually referred to as transponders or labels, RFID readers, and a backend database or system for storing and processing data are the three basic parts of an RFID system [1].

An integrated circuit (IC) and an antenna make up RFID tags, which are tiny electrical gadgets. An electronic product code (EPC), which is linked to a particular item, is a unique identification that is present on the IC. Using radio waves, the antenna enables communication between the tag and RFID scanners. An RFID tag can be of two major types: While passive RFID receives power from the reading antenna, whose electromagnetic wave induces a current in the RFID tag's antenna, active RFID, which is an active RFID tag, has its own power source, typically a battery [2].

RFID readers are devices that transmit radio frequency signals and receive responses from the RFID tags within their range. The readers can read and write data to the RFID tags, extracting the unique identifiers and other information stored on the tags. When an RFID tag comes within the range of an RFID reader, it receives power wirelessly from the reader's signal and responds by transmitting its stored data back to the reader. This data can include the unique identifier, product details, manufacturing information, or other relevant information associated with the item. The backend database or system collects and processes the data received from the RFID readers. This information can be used for various purposes, such as inventory management, supply chain tracking, authentication, asset tracking, or access control.

RFID technology offers several advantages over traditional manual methods of identification and tracking. It enables quick and accurate data capture, improves efficiency in various processes, reduces human error, enhances visibility in supply chains, and provides real-time information on item location and status [1]. RFID has found applications in various industries, including retail, logistics, manufacturing, healthcare, agriculture, and more. It is used for inventory management, supply chain optimization, asset tracking, anti-counterfeiting measures, access control, and improving customer experiences.

3. Environmental Benefits of RFID Technology in Supply Chain Management

It is becoming more crucial to check the environmental box because any supply chain management system's primary goals are to balance cost, service, and environmental impact. The relevance and significance of supply chain systems in this field are becoming increasingly clear to businesses globally. For instance, to increase productivity and lower its carbon footprint, Nike teamed with supply chain software vendor Llama Soft in 2012 and extensively invested in a software platform and larger infrastructure [3]. RFID technology offers several environmental benefits when applied to supply chain management. Here are some of the environmental advantages of RFID.

3.1. Reduced Paper Usage

RFID technology eliminates or significantly reduces the need for paper-based documentation, such as printed shipping labels, receipts, and inventory records. By transitioning to electronic data capture and storage, RFID reduces paper consumption and contributes to the conservation of natural resources.

This helps in minimizing deforestation, energy consumption, and greenhouse gas emissions associated with paper production.

3.2. Reduced Food Waste

In the case of perishable goods, RFID technology can play a crucial role in reducing food waste. By implementing RFID tags and sensors, companies can monitor the temperature, humidity, and other environmental conditions of food items during transportation and storage. This real-time monitoring helps ensure that optimal conditions are maintained, minimizing spoilage, and reducing the amount of food waste generated.

3.3. Sustainable Packaging and Recycling

RFID technology enables better packaging management, allowing companies to optimize packaging materials and reduce waste. By tracking individual items, companies can reduce excess packaging and utilize sustainable packaging materials. Additionally, RFID helps in efficient waste sorting and recycling, as it can assist in identifying and segregating items with specific recycling requirements.

3.4. Green Supply Chain Practices

By adopting RFID technology, companies can implement and enforce environmentally friendly practices throughout the supply chain. This includes optimizing energy consumption, reducing water usage, promoting sustainable sourcing and production, and implementing eco-friendly disposal and recycling practices. RFID provides the data and visibility needed to monitor and drive sustainable initiatives.

3.5. Optimize Inventory Control to Reduce Waste

RFID's capacity to deliver data in close to real-time can help eliminate common industrial wastes including defective materials, waiting, overproduction, movement, inventory, complexity, and expense when utilized in lean manufacturing/production or just-in-time operations. Waste and shrinkage refer to the loss of inventory due to damage, theft, expiration, misplacement, or human error. RFID inventory control can help prevent these losses by providing real-time visibility and accuracy of inventory status and location. RFID tags can also store information about product conditions, expiration dates, and quality, which helps optimize inventory turns and avoid damage, saving money, resources, and space, and minimizing environmental impact. For example: Improving transportation efficiency can reduce carbon emissions [4]. The technology could be used to reduce unnecessary trucking. And, RFID inventory control can help optimize delivery routes and scheduling, reducing fuel consumption and the carbon footprint of vehicles.

4. RFID Application Analysis Based on the Clothing Industry

4.1. Basic Applications and Advantages of RFID Technology in the Clothing Industry

RFID can be applied to different scene designs in different industries, among which the garment industry is a typical industry suitable for RFID application analysis because the garment industry usually involves a large-scale supply chain network, including raw material production, manufacturing, distribution, retail, and other links. In this complicated process, problems such as inventory management, goods circulation, and anti-theft are prone to arise. RFID technology can effectively solve the problems of supply chain complexity, inventory management, anti-theft, brand protection, and customer experience faced by the industry, and help promote the development of the industry in a more intelligent, efficient, and sustainable direction [5]. RFID technology has several applications in the clothing industry, revolutionizing various processes from production to retail. Here are some basic applications of RFID technology in the clothing industry:

1) Tag Attachment and Reading:

RFID tags are attached to individual clothing items during the manufacturing or packaging process. These tags contain unique identifiers that can be read by RFID readers. Tag attachment can be done using various methods such as sewing, heat-sealing, or adhesive backing. RFID readers can quickly and accurately identify and read the tags, enabling seamless tracking and management of individual garments.

2) Logistics Tracking:

RFID technology enables efficient logistics tracking in the clothing industry. Throughout the supply chain, RFID tags on garments can be read at various checkpoints, such as distribution centers, warehouses, and retail stores. This provides real-time visibility into the movement of garments, allowing companies to track and manage inventory, monitor shipment progress, and optimize logistics processes.

3) Inventory Management:

RFID simplifies inventory management by providing accurate and automated tracking. With RFID tags attached to garments, companies can conduct inventory counts more efficiently and accurately. The time and effort needed for manual inventory checks are considerably reduced by the speedy multiple-item scanning capabilities of RFID scanners. This ensures inventory accuracy, minimizes stockouts, and enables efficient restocking.

4) Anti-Theft and Counterfeiting:

RFID technology helps in reducing theft and counterfeiting in the clothing industry. RFID tags can be used as electronic article surveillance (EAS) tags, triggering alarms when garments with active RFID tags pass through exit points without proper authorization. This enhances security and reduces shoplifting incidents. Also, RFID tags can be used to authenticate genuine products, helping to combat counterfeiting by distinguishing between genuine and counterfeit items.

5) Self-checkout: RFID self-service cash register is a self-checkout system that uses RFID technology to enable customers to complete shopping settlements more conveniently. In the clothing industry and retail industries, RFID self-service cash register system is gradually being introduced to improve the shopping experience and speed up checkout, reduce personnel dependence, improve the shopping experience, avoid pricey errors, data collection, and analysis.

6) Customer Experience and Personalization:

RFID technology can enhance the customer experience in the clothing industry. RFID-enabled smart mirrors or fitting rooms can recognize tagged garments and display relevant information such as size availability, color options, and product recommendations. Customers can make purchases in a personalized and interactive environment that helps them make informed choices.

These are some of the basic applications of RFID technology in the clothing industry. The adoption of RFID in this sector offers numerous benefits, including improved inventory accuracy, enhanced logistics efficiency, reduced theft and counterfeiting, and enhanced customer experiences. However, there are differences between theory and practice. For example, merchants use the first five points very frequently, and merchants use the sixth point very rarely. This is based on necessity and customer demand. The input cost of RFID is expensive. So far, businesses are still more willing to spend limited human resources, human training, and investment budgets on more necessary sectors.

4.2. Challenge of Application of RFID Technology in the Clothing Industry

4.2.1 Analysis of High Input Cost Based on RFID

RFID technology has also encountered challenges and bottlenecks in the clothing industry. The input cost of RFID is relatively high, and not every enterprise could bear the input cost. Currently, lowest price tags are as low as 7.2 cents per piece for orders of 10 million copies or more. The normal cost of an RFID tag is between 30 and 40 cents if the demand quantity is low, whereas the cost of a barcode is only 4 cents [6]. The input cost depends on many factors, including the scale of operations, the complexity of the supply chain, the application scope, and the selected RFID system. Here are some key areas where investment is typically required:

1) RFID Tags:

The cost of RFID tags is an essential component of the investment. The number of tags needed will depend on factors such as the size of the clothing inventory, the level of item-level tracking desired, and the frequency of tag replacement. The cost of RFID tags can vary depending on factors such as the type (passive or active), the read range, the desired features (e.g., durability, washability), and the volume of tags required.

2) RFID Readers and Infrastructure:

Investment is needed for RFID readers, antennas, and the supporting infrastructure. The number and placement of RFID readers will depend on factors such as the size of the facility, the desired coverage area, and the complexity of the supply chain. The cost includes the purchase of RFID readers, antennas, cabling, network infrastructure, and any necessary installation and setup.

3) Software and Integration:

Investment is required for RFID software and integration with existing systems. This includes the selection, customization, or development of suitable software for data capture, processing, and integration with inventory management, warehouse management, point-of-sale, or other relevant systems. The cost can vary based on the complexity of integration requirements, customization needs, and ongoing support.

4) Training and Change Management:

Investment is needed for training employees on RFID technology and the associated processes. This includes educating staff on RFID operations, data handling, system usage, and any changes to existing workflows. To enable the easy implementation and acceptance of the RFID technology throughout the organization, change management initiatives may be required.

5) Pilot Projects and Testing:

Conducting pilot projects or small-scale deployments before full-scale implementation is advisable. This allows for testing the RFID system in a controlled environment, identifying any issues or challenges, and refining processes. Costs can include equipment, personnel, evaluation, and adjustments based on pilot results.

6) Maintenance and Support:

Investment is required for ongoing maintenance and support of the RFID system. This includes regular maintenance, troubleshooting, software updates, and technical support to ensure the system operates effectively and remains optimized over time.

4.2.2 Technical Challenges in RFID Applications

It is difficult to initialize the application of RFID, which is mainly reflected in the following aspects:

1) Technical complexity: RFID technology is more complex than traditional bar code systems. The initial introduction of RFID technology may require the involvement of relevant technical teams to ensure proper configuration and operation of the equipment.

2) Data Integration: Integrating RFID technology into existing supply chain management systems may require some data integration work. This involves ensuring compatibility and smooth data exchange of RFID systems with existing systems.

3) Adjustments during transition: During the initial operation, some operational adjustments and problems may occur. This requires the team to follow up and solve it in time to ensure that RFID technology can be smoothly integrated into the business process of the clothing industry.

4) Technology

Due to its reliance on the radio frequency theory, the RFID can be affected by other radio signals, metals, liquids, etc. The frequency of the tag and the usage environment both affect the amount of interference, which could lead to inaccurate reading. When using RFID readers to read price tags on items purchased at checkout counters, for instance, radio waves from other products may cause interference. Due to their creation in various countries, the products may also come in a variety of packaging [6].

5) A lack of uniformity

Since radio frequency identification is still in its infancy, there are still numerous obstacles to overcome. There are numerous RFID variants that use various frequencies and call for various scanners and software. Therefore, a frequency or set of frequencies must be chosen by consensus in order for distributors, retailers, and manufacturers to work together [6].

5. Application of RFID in Inventory Management of Companies

5.1. Analysis of Advantages

Based on the above analysis, it can be concluded that Inventory tracking is the most successful use case for RFID technology. With accurate production-location data in hand, companies can streamline inventory management, accelerate picking and packing and ensure on-time delivery. Some of the key benefits of RFID in inventory tracking include:

1. Improved Inventory Accuracy: Unlike traditional barcode systems that require line-of-sight scanning, RFID can read multiple items simultaneously, even when they are stacked or hidden. This leads to higher inventory accuracy, as manual counting errors are minimized, and the inventory count is more reliable [7].

2. Enhanced Efficiency: RFID technology automates the inventory management process. When RFID tags are scanned, the inventory data is automatically updated in the system. Companies can optimize inventory management, reduce lead times, and improve operational efficiency [7].

3. Reduced Labor Costs: RFID technology streamlines inventory counting and tracking processes, reducing the need for manual labor and allowing employees to focus on more value-added tasks.

4. Enhanced visibility: RFID tags can be read in real-time, allowing businesses to track their inventory as it moves through the supply chain. They have a chance to make more informed decisions about purchasing and stocking.

5. Minimize supply chain disruption: Manufacturers can also use RFID to work effectively with suppliers and minimize supply chain disruption. RFID technology enables order forecasting. It also makes it easier to track sensitive or high-value materials, automate warehouse processes and maintain a high level of quality. With RFID, you can eliminate orders for out-of-stock items and trace potential product issues faster.

5.2. Case Analysis Based on ZARA

One of the greatest technologies for swiftly and precisely tracking commodities along the value chain is RFID tagging. Nearly 50% of all retailers view out-of-stock as the greatest barrier to success in today's market. RFID tags can reduce stocks by up to 80.3% and bring inventory accuracy up to an impressive 99.9%. Given these figures, retail investment in passive UHF RFID is a no-brainer [8].

A Spanish multinational chain of clothes stores is called ZARA. It focuses on quick fashion and provides apparel, footwear, accessories, cosmetics, and fragrances. ZARA is one of the successful cases of investment in RFID applications. Comparatively, its rivals carry between 2,000 and 4,000 goods, whereas ZARA sells approximately 11,000 unique items annually. Only 15% to 25% of a line's items are designed by ZARA ahead of the season, while more than 50% of its products are created depending on what becomes popular in the middle of a season. This stands in stark contrast to a nearby rival. Most other merchants complete all their design work in advance of a season, which frequently leaves them with extra inventory that they must heavily mark down at the conclusion of the season. [9]. ZARA boasts the lowest year-end inventory levels in the fashion industry through inputting applications of RFID technology, which enables them to boast rapid sales turnover rates. A large part of the success of ZARA's inventory management depends on a large amount of investment in RFID technology, high-quality management, and a wide range of applications [10]. RFID technology enables rapid response to commodity status, which enables the management to formulate products that conform to the trend of the season and put them on the market in time through data analysis, as well as other unique operating strategies.

6. Conclusion

All in all, numerous sectors may enhance inventory management, increase supply chain visibility and accuracy, reduce counterfeit and shoddy products, and improve customer experience using RFID technology. Despite being costly and difficult to get started, RFID technology, which has been on the radar of many manufacturers for decades, has changed a lot. The research and development efforts have paid off, with the average cost of RFID tags dropping by 80% and reader costs by 50% over the past decade. The read accuracy has doubled and the range has been quadrupled, allowing the company to improve results while requiring fewer readers.

Before making any investment decision, it is important to conduct a thorough cost-benefit analysis and assess the specific needs and goals of the industry. Costs can vary widely depending on the size of the operation, the complexity of the supply chain, and the level of RFID implementation required. Working with an experienced RFID solutions provider or consultant can help assess the required investment and optimize the implementation process.

To build a sustainable future for the company and the earth, it is essential for enterprises to implement as many technologies and procedures as they can. Environmentally friendly supply chains not only offer several environmental advantages, but they also offer numerous real economic advantages like increased profitability, improved customer service, resiliency, and increased competitiveness. Therefore, it is recommended that all companies invest in the application of RFID throughout the process, gradually covering the old system, and making the whole society more efficient and integrated. This article aims to provide decision-making guidance and reference significance for enterprises using RFID technology. Due to the cost of RFID technology input and the limitations of technical training for professionals, the potential future research directions for the application of RFID technology in the supply chain may be to simplify procedures, reduce costs, popularize use, and train skills.

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