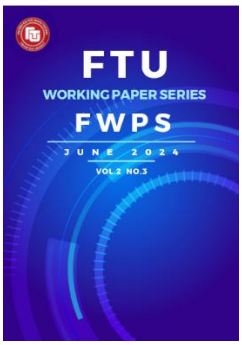

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ỨNG DỤNG CÔNG NGHỆ RFID TRONG QUẢN LÝ CHUỖI CUNG ỨNG THỜI TRANG VÀ ĐỀ XUẤT CHO DOANH NGHIỆP VIỆT NAM

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Tóm tắt

Ngành công nghiệp thời trang Việt Nam đang trên đà phát triển mạnh mẽ, đóng góp 5,6 tỷ USD vào GDP năm 2023 (Manono, 2020) và dự kiến đạt 2,06 tỷ USD vào năm 2024 (Statista, 2024) đóng vai trò quan trọng trong nền kinh tế, đồng thời phải đối mặt với nhiều thách thức như: hiệu quả chuỗi cung ứng thấp, hàng giả tràn lan và nhu cầu minh bạch trong quản lý hàng hóa ngày càng cao. Công nghệ RFID (Radio Frequency Identification) với khả năng theo dõi thời gian thực, quản lý kho hàng và xác minh sản phẩm hiệu quả được xem là giải pháp tiềm năng cho các vấn đề trên. Việc ứng dụng RFID trong ngành thời trang quốc tế đã mang lại nhiều lợi ích như: giảm thiểu sai sót, tăng tốc độ xử lý hàng hóa, chống hàng giả và nâng cao độ tin cậy cho thương hiệu. Nghiên cứu này tập trung vào việc tích hợp và ứng dụng công nghệ RFID vào chuỗi cung ứng của các doanh nghiệp thời trang trên thế giới nhằm từ đó đánh giá vai trò của RFID trong việc đề xuất giải pháp nâng cao hiệu quả hoạt động, giảm chi phí và tối ưu hóa hiệu suất tổng thể cho các doanh nghiệp Việt Nam. Nghiên cứu sử dụng phương pháp phân tích dữ liệu thực tế từ các doanh nghiệp

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áp dụng RFID. Kết quả nghiên cứu được kỳ vọng sẽ cung cấp thông tin và khuyến nghị thiết thực cho các doanh nghiệp thời trang Việt Nam trong việc ứng dụng RFID để nâng cao năng lực cạnh tranh và phát triển bền vững.

Từ khóa: RFID, Thời trang, Việt Nam, Chuỗi cung ứng, Công nghiệp 4.0, Quản lý kho hàng, Tích hợp công nghệ.

APPLICATION OF RFID TECHNOLOGY IN FASHION SUPPLY CHAIN MANAGEMENT AND RECOMMENDATIONS FOR VIETNAMESE ENTERPRISES

Abstract

The Vietnamese fashion industry is experiencing remarkable growth, contributing 5.6 billion USD to the GDP in 2023 (Manono, 2020), and is projected to reach 2.06 billion USD by 2024 (Statista, 2024). While playing a significant role in the national economy, the industry faces numerous challenges, including low supply chain efficiency, rampant counterfeiting, and increasing demand for transparency in product management. RFID (Radio Frequency Identification) technology offers real-time tracking, warehouse management, and efficient product verification—a potential solution for the fashion industry. Its international application has reduced errors, accelerated processing, combated counterfeiting, and enhanced brand reliability. This study assesses RFID integration in the supply chain of Vietnamese fashion enterprises. Utilizing real-world data analysis, the research aims to provide practical insights for Vietnamese fashion businesses, enhancing competitiveness and sustainable development through RFID adoption.

Keywords: RFID, Fashion Industry, Vietnam, Supply Chain, Industry 4.0, Inventory Management, Technological Integration.

1. Introduction

1.1. Overview of supply chain management in fashion industry

The supply chain in the fashion industry refers to the complex network of businesses and services that bring clothing and accessories (shoes, belts, purses, jewelry, and more) from concept to customer. A strong fashion supply chain helps reduce production, inventory, and logistics costs while increasing customer satisfaction.

Supply chain management in different countries

Supply chain management (SCM) in the fashion industry varies across different countries based on factors such as manufacturing capabilities, labor costs, infrastructure, regulatory environment, and market demand. Here's an overview of SCM in the fashion industry in some other key countries:

China: China has long been a dominant player in the global fashion supply chain, with a vast manufacturing base which gives this country the position of the world’s largest manufacturing hub for 12 years (ENGLISH.GOV.CN, 2024) and a well-developed infrastructure for production and distribution, as of 2022, the length of China’s highways exceeded 177.000 kilometers (Statista, 2024). Many international fashion brands source their products from China due to its large pool of skilled labor, economies of scale, and efficient logistics networks. However, rising labor costs, environmental concerns, and trade tensions have led some companies to diversify their sourcing

strategies and explore alternative manufacturing destinations.

Bangladesh: Bangladesh is one of the world's largest garment exporters (Vietnam Credit, 2021), known for its competitive labor costs and fast fashion production. However, challenges such as worker safety, labor rights, and infrastructure limitations have garnered international attention and prompted efforts to improve working conditions and sustainability practices in the industry.

Italy: Italy is renowned for its luxury fashion brands, high-quality craftsmanship, and innovative design such as Gucci, Prada, Fendi, Versace,.... The country has a strong tradition of textile manufacturing, with specialized clusters of production located in regions such as Tuscany, Lombardy, and Veneto. Italian fashion houses emphasize craftsmanship, creativity, and heritage, positioning themselves at the high end of the market. Italy's fashion industry benefits from a skilled workforce, close collaboration between designers and manufacturers, and a focus on sustainability and ethical production practices.

United States: The United States has a diverse fashion industry, encompassing a range of segments from fast fashion to luxury brands. While domestic production has declined in recent decades due to outsourcing, there has been a resurgence of interest in local manufacturing and sustainable sourcing practices. American fashion companies prioritize innovation, technology adoption, and supply chain transparency. E-commerce has also transformed the retail landscape, with many brands leveraging online platforms for sales and distribution.

Overall, SCM in the fashion industry varies across different countries, reflecting the unique strengths, challenges, and opportunities of each market. Companies must carefully consider factors such as cost, quality, lead times, and sustainability when making sourcing and supply chain management decisions.

Supply chain management in Vietnam

According to Vietnam Credit (2021), Vietnam is among the top five exporting countries of textiles and garments globally, has surpassed Bangladesh in the global apparel market and has become the world's second largest exporter of ready-made garments. In 2023, the export value of textiles and garments in Vietnam was estimated to reach approximately 40.3 billion U.S. dollars. Therefore, textiles and garments are among the leading export products by export value from Vietnam (Statista, 2024). However, environmental issues are now the biggest concern relating to the manufacturing of textiles and garments. The concept of a sustainable supply chain is new to many supply chain players in the country. Many of Vietnam’s fashion and textile industries are working to achieve the triple bottom line (social, environmental, and financial) of sustainability. Therefore, lean manufacturing, which aims at reducing process waste for efficiency and productivity, is being adopted in the fashion and textile industry. Lean can help to lower the manufacturing cost in the rising labor and material cost markets. One of the ways to enhance lean manufacturing can be listed is RFID technology, since RFID can provide real-time data information and accurately track inventory in real-time.

1.2. RFID technology in fashion industry

1.2.1. Definition of RFID technology

RFID (Radio-Frequency Identification) is a technology that uses electromagnetic fields to automatically identify and track tags attached to objects. These tags contain electronically stored

information, which can be read from a distance using an RFID reader or scanner. The RFID system consists of three main components: the RFID tag, the RFID reader, and the backend database or system.

- **RFID Tag:** This is the physical component attached to or embedded in an object that needs to be identified. RFID tags can come in various forms, such as labels, stickers, cards, or embedded chips. They contain a microchip that stores unique identification data and an antenna to transmit this data to an RFID reader.

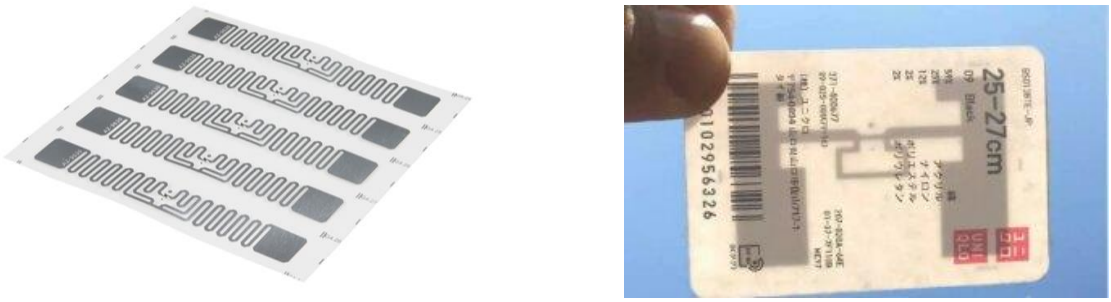

Figure 1: Normal RFID tag and RFID tag of Uniqlo

Source: sparkfun.com, huayuansh.com

- **RFID Reader:** The RFID reader is a device that emits radio waves and receives signals back from the RFID tags within its range. It sends out electromagnetic waves through its antenna, which power the RFID tags and elicit a response containing the tag's information. The reader then decodes this information and sends it to a computer system for processing.

Figure 2: RFID Reader

Source: cytrontech.vn

- **Backend System:** The data collected by RFID readers is typically sent to a backend system or database for storage, analysis, and further processing. This system can track the movement and location of tagged objects, monitor inventory levels, authenticate products, and perform various other functions depending on the application.

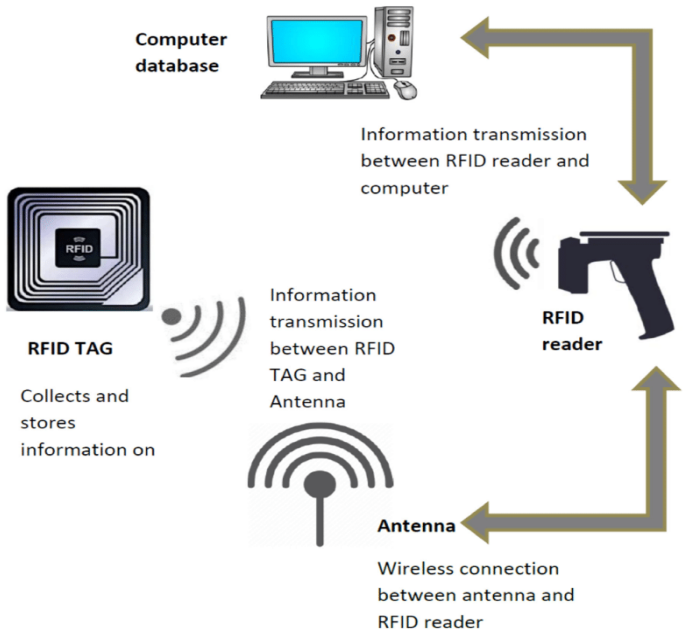

Figure 3: How backend system works

Source: researchgate.net

RFID technology is widely used in various industries for applications such as inventory management, supply chain tracking, access control, asset tracking, payment systems, and electronic toll collection. Its advantages include automation, efficiency, accuracy, and the ability to identify and track objects without direct line-of-sight or physical contact.

1.2.2. Types of RFID systems

Depending on the frequency band they operate at we find different systems: low frequency (LF), high frequency (HF / NFC) and ultra-high frequency (UHF). There are also two broad categories of systems which are passive RFID and active RFID.

- Low frequency: The LF band covers frequencies between 30KHz to 300KHz. Typical LF RFID systems work with 125 KHz or 134 Khz. This frequency provides a short reading range, about 10 cm, and the reading speed is slow. It is very resistant to external interference. Typical applications of LF are access control and animal control.

- High frequency: The ranges of the HF frequencies go from 3 to 30 MHz. Most RFID HF systems work with 13.56 MHz, with reading ranges between 10 cm and 1m. Interferences moderately affect HF systems. HF systems are commonly used for ticketing, payments and data transfer applications.

- Ultra-high frequency: UHF systems cover frequency ranges from 300Mhz to 3Ghz. RAIN RFID systems comply with the standard UHF Gen2 standard that uses frequencies 860 to 960 MHz. There are differences in variation between regions, most of them operate between 900 and 915 Mhz. UHF RFID reading systems can reach more than 12 meters, have very fast data transmission and are very sensitive to interference. Therefore, most RFID projects currently use UHF.

1.2.3. Principles of an RFID system

RFID is a "wireless communication technology", so its signals are transmitted without contact. A complete RFID system consists of three parts; electronic tags, readers (card readers), and application databases (back-end computers). Through wireless communication technology, the electronic tag transmits the data to the reader. The reader then transmits the data to the database, where it is processed and stored. Electronic tags and readers "identify" the electronic ID tag, and let the computer manage the corresponding information.

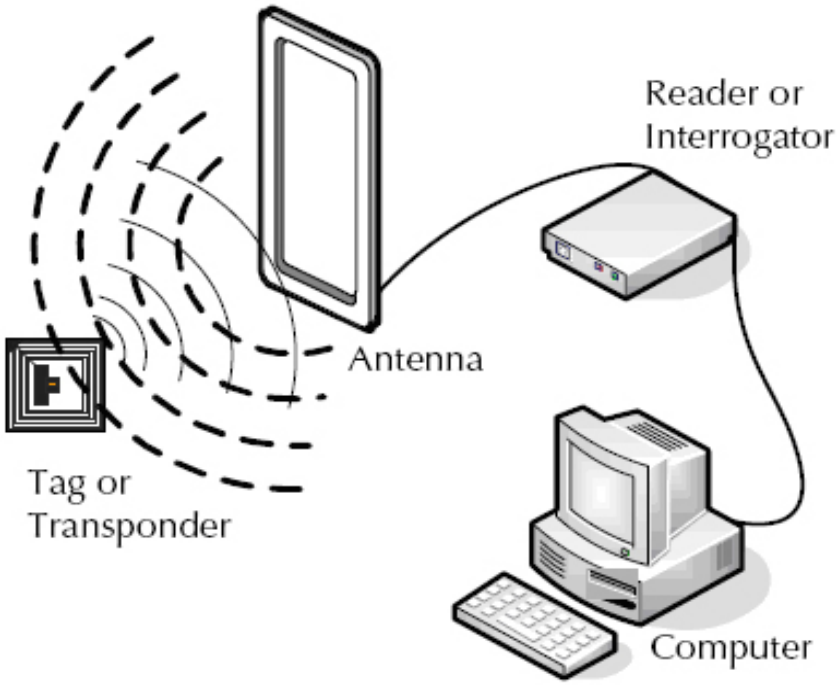

Figure 4: Principles of an RFID system

Source: epc-rfid.info

2. Literature Review

2.1. RFID Technology in Fashion Supply Chain Management

The application of RFID technology in the fashion supply chain has been extensively explored in existing reports, highlighting its potential to revolutionize various aspects of supply chain management. Fashion Supply Chain Management Using Radio Frequency Identification (RFID) Technologies looks at the application of RFID technologies in such areas as order allocation, garment manufacturing, product tracking, distribution and retail. (W.K. Wong and Z.X. Guo, 2014). "The value of radio frequency identification (RFID) technology is critical for the clothing and textiles supply chain, because the fashion business is characterized by a wide assortment of seasonal items with short life-cycles, high levels of impulse-purchasing and complicated distribution and logistics operations" (A. Lui and C.K.Y. Lo, 2014). Rajkishore Nayak et al. (2015) also shared the same idea: "A range of problems unique to the fashion industry can be solved by installing the RFID system in various processes involved in the fashion supply chain. Fashion industry can be divided into four sectors such as manufacturing, overseas transportation, distribution and retailing. In manufacturing, RFID can be used to avoid product and component mixing, and mixing of

different accessories. In overseas transportation, RFID can be used to track and trace the consignment before and after Free on Board, if the product is outsourced. RFID primarily can solve the issue of sorting and tracking the product very quickly, thus reducing the lead time during distribution (Moon and Ngai, 2008).” Despite these advantages, challenges persist, creating difficulties for widespread adoption across the fashion supply chain. “Although the technology existed for several years, the technological challenges and cost issues are the major hurdles for the widespread use of RFID.” (Rajkishore Nayak, Amanpreet Singh, Rajiv Padhye & Lijing Wang, 2015). “The main barrier identified to the deployment of RFID is the problem of interoperability. The costs associated with the technology are the main disadvantage pointed out by the companies.” (Susana Garrido Azevedo, Helena Carvalho et al. 2012). In the future, RFID systems cannot completely replace barcode technology, because of higher cost, but the accuracy, speed and the return on investment is high in RFID systems. It is clear that RFID technology has a very bright future ahead in the fashion and textile industry. (Mazharul Islam Kiron, 2021). Future research directions may focus on addressing remaining challenges, and assessing the long-term impact of RFID adoption on sustainability and profitability within the fashion industry.

2.2. Research Gap and Proposed Research

From the above discussions, it can be shown that most early publications focus on the importance and sustainable benefits of applying RFID technology to the performance of the fashion and textile supply chain in general. However, research specifically focused on RFID implementation within Vietnam's fashion supply chain remains relatively limited, given that the adoption of RFID in Vietnamese fashion enterprises is still in its early stage.

Our study will analyze case studies of global fashion giants, therefore propose recommendations for Vietnamese businesses application of RFID technology in Vietnam's fashion supply chain management. This approach will enable us to examine the current state of RFID implementation in the Vietnamese textile and clothing industry; meanwhile, identify challenges and opportunities associated with RFID adoption in this specific context. From there, practical recommendations will be proposed with the intention of assessing the long-term impact of RFID adoption on sustainability and profitability within the Vietnamese fashion supply chain management. This research aims to contribute valuable insights to the existing body of knowledge and provide practical guidance for businesses considering RFID adoption.

3. Assessment of RFID technology in fashion supply chain management

3.1. Purpose

The main purpose of applying RFID technology in the fashion industry is to improve supply chain management. In this industry, products often go through multiple steps, from manufacturing in overseas factories, through transportation and distribution, to reaching the end consumers. RFID technology provides the ability to accurately track the location of these products throughout their journey, from factory to store shelves. This helps enhance traceability of product origin, efficient inventory management, and minimizing loss of goods.

3.2. Benefits

Managing inventory efficiently

RFID technology offers the capability to automatically track the quantity and location of products in real-time. Unlike traditional barcode systems that require line-of-sight scanning, RFID tags can be read remotely and simultaneously, enabling faster and more accurate inventory management. This real-time visibility into inventory levels allows businesses to optimize stock levels, reduce stockouts, and minimize excess inventory, leading to improved supply chain efficiency and cost savings.

Minimizing Loss of Goods

By providing accurate and continuous tracking of product movements, RFID helps prevent loss of goods during transportation and storage. With RFID tags attached to individual items or packaging, businesses can monitor the movement of products throughout the supply chain, from manufacturing facilities to distribution centers and retail stores. Any unauthorized removal or tampering with tagged items can be quickly detected, reducing the risk of theft, shrinkage, or misplaced items.

Tracing product origin

RFID technology enables the traceability of products throughout the entire supply chain, allowing businesses and consumers to trace the origin and journey of each item. By embedding unique identification codes in RFID tags, companies can record key information such as manufacturing date, batch number, production location, and distribution history. This transparency in the supply chain not only helps verify the authenticity and quality of products but also ensures compliance with regulatory standards and sustainability initiatives. Additionally, in case of product recalls or quality issues, RFID enables faster and more precise identification of affected items, minimizing the impact on consumers and brand reputation.

Enhancing Shopping Experience

With the proliferation of mobile devices and RFID-enabled technologies, customers can now access product information and interactive experiences directly through their smartphones or specialized RFID readers. By simply scanning RFID tags or labels, shoppers can retrieve detailed product descriptions, pricing, availability, and related promotions, enhancing their overall shopping experience. Additionally, RFID-enabled fitting rooms and smart mirrors allow customers to virtually try on clothing items, view product recommendations, and access personalized styling advice, further enriching their retail experience and driving sales conversion.

3.4. Challenges

Security and Privacy

While RFID technology offers numerous advantages, such as real-time tracking and inventory management, it also presents security and privacy concerns. RFID tags transmit data wirelessly, making them susceptible to interception by unauthorized parties. This raises concerns about the confidentiality and integrity of sensitive information, such as product details, customer data, and supply chain logistics. To mitigate these risks, robust security measures must be implemented, including encryption protocols, access controls, and secure data transmission channels. Additionally, privacy regulations must be adhered to, ensuring that consumer rights regarding the collection and use of personal information are respected.

For example , sensitive product information from 10,000 RFID-tagged items, including designs, materials, and pricing, is compromised. This breach not only damages the company's reputation but also results in financial losses estimated at $500,000 for legal fees, regulatory fines, and customer compensation.

Costs and Initial investment

One of the primary challenges of adopting RFID technology in the fashion supply chain is the substantial upfront investment required. The costs associated with implementing an RFID system include purchasing RFID tags, readers, antennas, software, and infrastructure, as well as installation, integration, and training expenses. Additionally, ongoing maintenance and support costs must be factored in. Before committing to RFID deployment, companies need to conduct a thorough cost-benefit analysis to evaluate the potential return on investment (ROI) and determine the feasibility of implementation. While RFID technology offers long-term benefits such as improved efficiency, reduced labor costs, and enhanced visibility, the initial financial outlay can be a barrier for some organizations.

For instance, A fashion manufacturer considers implementing RFID technology in its supply chain, with an estimated initial investment of $1 million. This includes purchasing 50,000 RFID tags at $1 each, 100 RFID readers at $5,000 each, and RFID software integration costs of $200,000.

Acceptance from Employees and Partners

Another challenge in adopting RFID technology is gaining acceptance from employees and external partners involved in the supply chain. Resistance to change, fear of job displacement, and lack of familiarity with RFID systems can hinder adoption and implementation efforts. To address this challenge, companies need to invest in comprehensive training and change management programs to educate employees about the benefits of RFID technology and alleviate concerns about job security. Furthermore, collaboration and communication with supply chain partners are essential to ensure alignment and cooperation in implementing RFID solutions. By fostering a culture of innovation and collaboration, companies can overcome resistance and facilitate the successful adoption of RFID technology across the fashion supply chain.

4. Case studies of implementing RFID technology in fashion supply chain management

4.1. Case study of Uniqlo

4.1.1 Overview of Uniqlo , the implementation of RFID technology in managing supply chain

Uniqlo, a major group company of Fast Retailing Co., Ltd., is Japan's largest apparel retailer with sales amounting to US $16 billion (Fashionunited.com, 2024). It ranks third globally, following ZARA and H&M (Satoshi, 2017). The company embarked on a supply-chain transformation journey, leveraging digitalization to enhance its operations.

In the 2000s, Uniqlo began expanding into new cities and became a more sustainable brand, now operating nearly 2,400 stores worldwide (Statista, 2024). The company sought to use RAIN RFID to refine its supply chain operations, starting with unifying the entire clothes-making process, from planning and design to production, distribution, and retail.

To be specific, the brand began adding RFID tags to every product manufactured and shipped.

To track products as they move through the supply chain, RFID readers have been deployed in warehouses, distribution centers and stores-allowing real-time information to be collected and displayed about their location, destination, product availability and even qualities like color and size. At every step, RFID helps retailers like Uniqlo manage inventory from production to distribution to the sales floor, allowing managers to predict inventory needs, maximize the most popular items, and Use real-time inventory data to help employees and customers.

At the present, Uniqlo's RFID reform is in full swing. Featured applications may refer to Fast Retailing's various brand stores in Yokohama, including smart devices such as RFID hang tags, RFID fitting mirrors, RFID shopping carts, and RFID self-checkout. Uniqlo RFID tags are embedded with UHF RFID tags. Based on the size difference, Uniqlo uses a variety of UHF RFID tags. In order to attract customers' attention to RFID, Uniqlo also made a small reminder on the RFID tag. Needless to say, this did arouse the curiosity of customers, and even caused a big discussion among Uniqlo fans.

Uniqlo RFID Hang Tag

Compared with bar codes that require manual operation, RFID tags can automatically read information wirelessly, further saving more labor and inventory costs. RFID tags can also collect specific information such as volume, model and color in a timely and accurate manner, specific information such as volume, model and color in a timely and accurate manner.

Slim UHF Tag *Omnidirectional RFID Label* *Good directional RFID label*

Figure 5: Uniqlo RFID Hang Tag

Source: huayuansh.com

RFID smart shopping guide

By leveraging RAIN RFID technology, Uniqlo enhances customer trust, preference, and overall shopping experience while maintaining an efficient supply chain. Just standing in front of the screen and swiping gently will help customers to choose clothes, try on clothes, and recommend a variety of collocations. If the store is small and cannot display all the products, at this time, the cloud shelf can present a large number of commodities that are not placed for the customer to choose. Moreover, clients can select the product and scan the code with one click to place the order, and the fastest delivery will be in their hands.

Figure 6: RFID smart shopping guide in a Uniqlo store

Source: huayuansh.com

Meanwhile, customers can put their hands on the head to view the buyer's comments, thereby helping themselves to judge the cost-effectiveness of the clothes. After the customer selected the clothes of interest, they can put the RFID tag on the RFID device of the shopping cart, and then the device will immediately display the product color, inventory status, and other sizes. For a large chain store like Uniqlo, this technology has greatly reduced the cost burden of shopping guides that the company has to pay for the staff.

Uniqlo's RFID Storage Management

Under the trend of fast fashion, whether fashion can really "fast up", the efficiency of logistics warehousing operations is very critical. Especially for chain companies, once the efficiency of the logistics system drops, the operation of the entire company will be exposed to risks. Inventory backlog is a common problem in the retail industry. Ordinary stores are solving this problem by means of discounted sales. Using RFID information technology (forecasting demand), you can use data analysis to provide products that consumers really need, from the source to solve this problem.

RFID tags can automatically transfer information indefinitely, saving labor costs in inventory management, and more accurately obtain specific information about commodities such as transaction volume, model, color, size, etc., so that the inventory system can be updated in real time.

For example, if a certain item is sold out, you can quickly make a decision to replenish or reproduce it. The time required for electronic label inspection products is only 10% of the current commonly used inventory management system in the industry (HUAYUAN, 2021). Uniqlo's initial introduction of RFID tags is also considering this. At present, Uniqlo has applied RFID to its warehouse management.

According to related reports, Uniqlo attached RFID tags to all products and combined with automated material handling equipment. After establishing an automated warehouse, the number of warehouse personnel was reduced from about 100 to 10, saving 90% of labor costs (Martinroll,

2021). At the same time, Uniqlo's production efficiency has increased by 80 times, shipment productivity has increased by 19 times, storage efficiency has increased by 3 times, personnel training costs have been reduced by 80%, and the accuracy of RFID automatic detection has been 100% (Martinroll, 2021).

In the Double 11 shopping carnival in 2018, Uniqlo achieved sales of $ 1 billion in one minute (Ventures, C., 2018). And relying on its excellent automated inventory system, Uniqlo enables customers to pick up goods in offline stores within 24 hours.

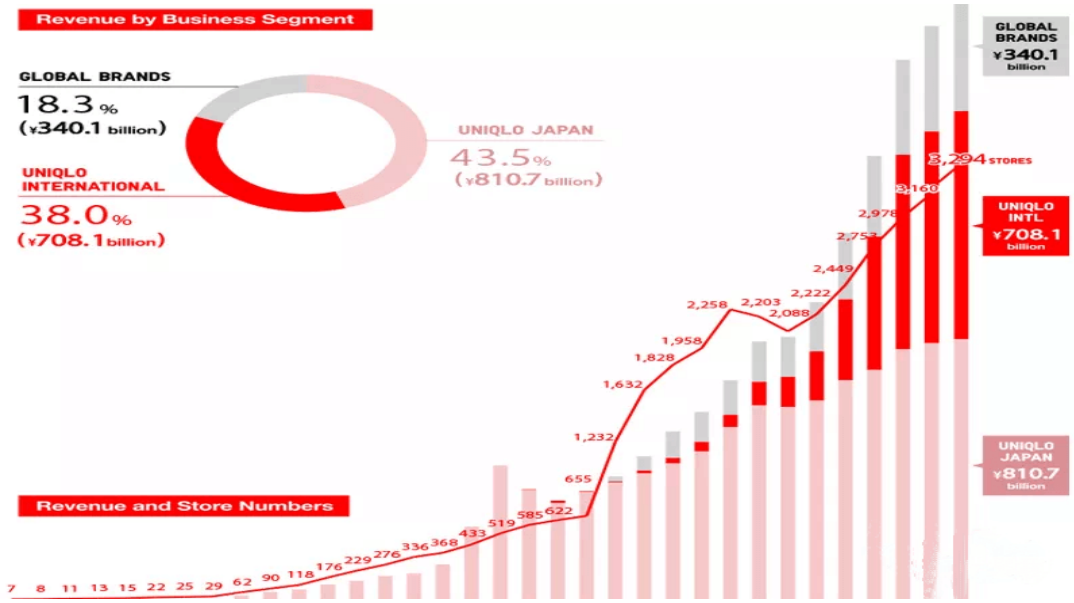

Figure 7: Fast Retailing Sales & Milestones

Source: fastretailing.com

4.1.2 The benefits of RFID technology in Uniqlo's supply chain management.

Supply chain automation

Uniqlo's factory-to-store strategy calls for an automated warehouse that streamlines production, packaging and shipping. As highlighted in the Huayuan RFID industry report, Uniqlo's RAIN RFID solution tripled inventory storage efficiency, helped save 90% on labor costs, increased productivity of all employees and achieved nearly 100% accuracy when reading tagged inventory (HUAYUAN, 2021).

Inventory management

Uniqlo embeds RFID chips in its price tags during manufacturing. These chips allow the brand to track individual items from factories and warehouses to stores. RAIN RFID readers are placed at warehouses, distribution centers, and stores. These readers provide real-time insights into product location, destination, availability, color, and size. By using RAIN RFID, Uniqlo can predict inventory needs, maximize popular items, and improve visibility for omnichannel fulfillment.

RFID inventory management allows the company to offer quick turnaround times-customers can order clothing online and receive it in store within 24 hours. For example, with real-time inventory visibility at all steps in its supply chain, Uniqlo can direct shipments to stores that are short on their most popular items and predict reporting demand for products that consumers really want. The implementation has led to a 25-30% increase in inventory accuracy and an 80%

improvement in shipping and picking accuracy (Ashley Burkle, 2023). This means Uniqlo can better track its stock levels, reducing discrepancies, ensuring items are where they should be, smoother logistics, fewer errors, and faster order fulfillment.

The RAIN RFID also helps with reduction in Out-of-Stocks, by accurately monitoring inventory, Uniqlo has achieved an up to 50% reduction in out-of-stocks (Ashley Burkle, 2023). This translates to fewer disappointed customers who can't find their desired items on the shelves.

Automatic payment

Uniqlo has implemented a new generation of RFID readers in its checkout machines. Shoppers can now simply drop their purchased items into bins at automated checkout stations. These stations read the RFID tags on the products, eliminating the need for manual scanning by hand. In another word, when customers are done shopping at Uniqlo, they can order an entire basket or bag of tagged items on an RFID-enabled self-checkout kiosk. The kiosk automatically reads all tagged products and quickly calculates the total. The customer then pays for the product, with virtually no steps involved.

This approach has improved customer experience and brand reputation while reducing lost revenue opportunities, eliminated the need for manual scanning by hand and refined sales data that can drive smart selling.

4.2. Case study of ZARA

4.2.1 Overview of ZARA, the implementation of RFID technology in managing supply chain

ZARA is a global fashion retailer operating close to 3,000 stores in 96 countries (Inditex.com, 2023), has become a prime example of an impressive supply chain model. The brand's objective is to bring customers closer to high-end fashion design but at an affordable price (Inditex.com, 2018). In order to achieve this goal, RFID technology was introduced in its stores in 2014. These chips allow the company to quickly take inventory by detecting radio signals from the RFID tags. When an item is sold, the stockroom is immediately notified so that the item can be replaced. Since the implementation of this technology, sales have boosted between 2% and 30%, and now the fashion brand is capable of monitoring its inventory with an accuracy level that exceeds 95%, where previously with traditional methods they were only able to get a 60% level of precision. (Bjork, 2014).

ZARA first implemented RFID technology in 2014 (Marc Bain, 2023). The first application of RFID was in the brand's flagship store in Soho where it was possible to pay for purchases directly in the fitting room. An innovation in terms of customer experience that allows the customer to skip the checkout and thus make the customer journey more fluid. The RFID chips are embedded in the security tags attached to clothing items. These tags are removed when a product is purchased and can be reused. This system allows ZARA to efficiently manage inventory by detecting radio signals from the RFID tags. The adoption of RFID has significantly contributed to ZARA's success in the fast fashion industry, enabling clear visibility of products, efficient distribution, accurate stock replenishment, and enhanced customer experience.

RFID in inventory management

As a reminder, RFID technology is implemented by inserting a chip into a product that stores its data. It can be read remotely, making it possible to follow the route of the garment and its

location. It saves a lot of time, especially for those brands that have to manage a large stock of clothes due to the constant renewal of collections.

For example, ZARA has inserted this technology into its EAS (Electronic article surveillance) hard tags with the information of each product. In addition, each point of sale has its own mini data center to optimize processing speed. This is known as "edge computing", which advocates simplified use of data by users.

These rigid labels are placed on the garments in the various production sites. These garments then go to the central logistics center in Spain where the tags, supplied by Checkpoints Systems, are encoded. The advantage of this is that the contents of the boxes can be checked without opening them, and the destination of the shipments can be changed at the last moment according to the demands of the shops. The figures speak for themselves: the in-store inventory is completed in 2 hours, compared to 24 hours before this new system. Indeed, all you need is a portable RFID reader to scan the tags. The data is recorded in real time in the inventory software.

RFID in the sales process

This geolocation of products allows the optimization of service and customer satisfaction. Indeed, thanks to RFID coupled with a barcode, the customer can check the availability of a model in real time in the shop or on the website by scanning the label via his smartphone.

In addition, the development of RFID has led to the redesign of checkout. In some shops, such as ZARA in Soho, items can be placed on the counter of the self-checkout machine and are each recognized by their RFID tag containing their data. The items are automatically displayed on the screen with their prices, and all that remains is to proceed with payment. The RFID tags are reusable several tens of thousands of times, so they are sent back to the production sites once their coding is reset to 0.

Online sales are also impacted by RFID. Indeed, it makes it possible to give the availability of products in real time. So, depending on where an order was delivered, products would leave the shops rather than the warehouses. This allowed for great efficiency as products were delivered faster, and the carbon footprint was reduced. In COVID's time, RFID has been very effective, allowing INDITEX to record a 74% increase in online sales in the second quarter of 2020 (S&P Global, 2020).

4.2.2 The benefits of RFID technology in ZARA's supply chain management.

Improved Inventory Accuracy

An RFID system enables real-time inventory tracking, allowing ZARA to quickly and accurately locate items in their warehouses or throughout the supply chain journey. This decreases the risk of stockouts, overstocking, and associated costs. Human error is also reduced when warehouse employees use an RFID reader to track products, helping identify discrepancies and their sources during receiving, storing, or distributing products. In fact, RFID technology ensures inventory accuracy of up to 99% compared to traditional methods (Auburn University RFID Lab, 2023).

Reduced Stockouts and Overstocking

ZARA embeds RFID apparel tags on every single garment within logistics centers. When products arrive at ZARA stores, the RFID system helps logistics workers identify which stock

shipments need replenishment. This ensures efficient distribution of products across stores.

From a study of Auburn University, ZARA experienced a 50% reduction in stockouts after implementing RFID, leading to better customer satisfaction and sales. (Auburn University RFID Lab, 2023).

Efficient Distribution and Stock Replenishment

By using RFID technology, ZARA can quickly identify when specific products are running low in stores. This allows them to refill stock quantities promptly, minimizing any potential out-of-stock situations. The RFID Journal reports that ZARA's RFID implementation resulted in faster stock replenishment, ensuring products are available for customers, the company achieved a 30% improvement in stock replenishment speed (Linkage-retail.com, 2022).

Enhanced Security Controls

When an item with an RFID tag passes through exit doors without being properly checked out, alarms are triggered. This discourages shoplifters and reduces theft incidents. Moreover, RFID enables real-time tracking of items throughout ZARA's supply chain. By knowing the exact location of each product, ZARA can quickly identify discrepancies or missing items. Therefore, this visibility enhances security by preventing unauthorized movement of goods.

Supply chain automation

Utilizing RFID technology helps to improve inventory management by monitoring demand and forecasting supply, minimizing waste and carrying costs, leading to 80% reduction in the time spent on inventory (Margaux POUPIN, 2021). This also offers increased flexibility and responsiveness, allowing companies to quickly respond to changes in demand or supply, improving delivery times and flexibility. This technology also enhances supplier management by monitoring performance and addressing issues promptly, reducing risks. With RFID, the company can predict and respond to disruptions, minimizing downtime and maintaining operational continuity, therefore enhancing customer satisfaction by ensuring timely response to changes in demand or supply. Furthermore, advanced technologies like RFID and real-time data analysis enable informed decision-making, enhancing the overall performance of the supply chain.

5. Application of RFID technology in fashion supply chains in Vietnam

5.1. The situation of applying RFID technology in Vietnam's fashion industry

5.1.1. General status

The current state of implementing RFID technology in Vietnam's fashion sector is still in its infancy stages, primarily adopted by modern and developed industries with international backgrounds. Big brands like Zara, Adidas, H&M, Uniqlo etc. have incorporated RFID into their operations in Vietnam which is aligned with their global standards and practices. Early 2023, Uniqlo Vietnam launched an RFID automated payment kiosk. Customers just need to put their favorite products into the machine and make payment. The entire process of checking and calculating orders is completely automated, shortening payment waiting time. They also recorded that ever since applying RFID, their inventory accuracy has increased by 25-30%, up to 50% off out-of-stock condition and improved shipping and accuracy by up to 80% (trackify.vn, 2023).

Big fashion enterprises are gradually transitioning to RFID for tasks such as inventory management, counterfeit prevention, and shopping experience enhancement. Lesley Suen, senior vice president of SML RFID emphasized that: “SML RFID FactoryCare solutions have been developed to optimize retail operations, maximize retailers’ inventory visibility throughout the entire supply chain and reduce possible errors at source where products are tagged.” (Vinatex, 2020) Meanwhile, the majority of local companies in the fashion and textile sector rely on barcode technology for tracking raw materials and finished products. This might be due to its cost-effectiveness, simplicity, and compatibility with existing systems. In the context of Vietnamese enterprise, comprehensive implementation of RFID across the entire supply chain is ideal; however, it is not a necessary condition for this technology to be effective. Deploying RFID at key stages, such as distribution centers, warehouses and retail stores, can deliver significant benefits without causing major disruption (Xuan Binh, 2023). This might include updates of software, infrastructure and integration of RFID into management systems to improve supply chain efficiency.

It also leads to the fact that the comprehensive integration within local fashion enterprises supply chain management is still limited compared to the extensive implementation witnessed in more developed economies. Some businesses still face difficulties in investing in and implementing this technology due to financial and technological knowledge requirements. While there are notable instances of RFID adoption, particularly among large fashion brands with significant resources, the penetration of this technology across the broader spectrum of fashion enterprises in Vietnam is still limited. One significant contributing factor to this incomplete adoption is the lack of financial resources. Many smaller and medium-sized enterprises (SMEs) within the Vietnamese fashion sector often face budgetary constraints that inhibit their ability to invest in the necessary infrastructure and systems required for RFID integration.

For instance, the initial setup costs, including purchasing RFID tags, readers, and software, can be prohibitively high for businesses operating on tighter budgets. Additionally, ongoing maintenance and training costs further worsen the financial burden associated with RFID adoption. Moreover, there exists a notable disparity in technical knowledge and expertise among fashion enterprises in Vietnam. While larger companies with greater financial resources may possess the capability to navigate the intricacies of RFID technology implementation, smaller businesses often lack the requisite technical knowledge. This knowledge gap can hinder the effective deployment of RFID systems, as it requires specialized expertise in areas such as software integration, data management, and troubleshooting. It was found that many SMEs in Vietnam did not understand the RFID technology and its benefits. For the Vietnam SMEs, the major focus is to achieve the profit without extra expenses in technology such as RFID. (Rajkishore Nayak, 2021).

Overall, RFID adoption in Vietnam's fashion and textile industries is on its way to widespread deployment, it remains concentrated among international players and those with global brand partnerships. Local companies, meanwhile, predominantly rely on barcode technology.

5.1.2. The Case of Ava Fashion: Efficiency and Challenges when applying RFID in Supply Chain Management in Vietnam

A specific case of a business in Vietnam that has implemented RFID technology in supply chain management is a well-known fashion brand like "Ava Fashion." Ava Fashion is a renowned

Vietnamese fashion brand known for its high-quality and affordable women's fashion products. To enhance warehouse management efficiency and optimize its supply chain, Ava Fashion decided to deploy RFID technology.

Prior to implementing RFID, Ava Fashion faced challenges with inefficient warehouse management, inventory loss, and difficulties in tracking products from the factory to the send store. However, after implementing RFID technology, they have achieved the following benefits:

- **More efficient warehouse management:** RFID technology helps Ava Fashion accurately track the location of each product in the warehouse, thereby optimizing inventory organization and management.

- **Reduced inventory loss:** By using RFID to control and tag products, Ava Fashion can minimize inventory loss due to employee errors or theft.

- **Enhanced supply chain integrity:** RFID enables Ava Fashion to track the movement of products from manufacturing to the hands of customers, thereby enhancing the integrity of the supply chain and minimizing the risk of loss or damage during transportation.

- **Improved shopping experience for customers:** By utilizing RFID technology to quickly identify product information and enhance inventory management, Ava Fashion provides a smoother and more convenient shopping experience for customers.

With the application of RFID technology in supply chain management, Ava Fashion has enhanced operational efficiency and improved the shopping experience for its customers, while also reducing risks and costs associated with warehouse management and product transportation. Although Ava Fashion has benefited from implementing RFID technology in supply chain management, they may also encounter some challenges during implementation. Ava Fashion may share some similarities with Uniqlo and Zara in applying RFID technology, but there are also significant differences:

- **Initial investment costs:** All three companies (Ava Fashion, Uniqlo, and Zara) face high initial investment costs when deploying RFID technology. This is a common challenge for all businesses, regardless of size.

- **Changes in work processes:** Implementing new technology often involves changing work processes, which is a common challenge. All three companies must ensure that their employees adapt to and use the new technology effectively.

- **Scale and resources:** Uniqlo and Zara are major players in the fashion industry with larger financial resources and workforce compared to Ava Fashion, a smaller business. Therefore, despite common challenges regarding costs and process changes, Uniqlo and Zara may be better equipped to handle them due to their abundant resources.

- **Technical support and training:** Uniqlo and Zara may have larger financial and technical resources to provide training and support to employees in using RFID technology. Meanwhile, Ava Fashion may face greater challenges in providing training and technical support to its employees.

These similarities and differences reflect the diversity in how businesses approach and implement new technologies, depending on their scale, resources, and specific business environments. For small brands like AvaFashion, the cost of adopting RFID technology in the supply chain in the condition of small production scale and not enough high-tech human resources, is a big challenge and relatively risky.

5.2. Recommendation for Vietnamese firms in applying RFID technology in fashion supply chain management

Vietnamese businesses looking to implement RFID technology in their supply chain management within the fashion industry face a unique set of challenges, especially smaller and SMEs. These challenges are primarily rooted in financial constraints and a lack of technical expertise. While larger fashion brands have readily embraced RFID due to their ample resources, the initial setup costs, ongoing maintenance requirements, and specialized knowledge pose substantial barriers for SMEs. Below are recommendations for Vietnamese businesses to solve difficulties in applying this technology to supply chain management:

Taking advantages of Government support

One of the primary obstacles is the cost of technology adoption, which can be significant for small to medium-sized enterprises (SMEs). To overcome financial obstacles, businesses must focus on creating a strong business case for RFID investment that highlights the long-term savings and efficiency gains. Additionally, exploring financial support options, such as government grants, subsidies, or industry association programs, can significantly alleviate the initial financial burden for SMEs. Furthermore, collaborative implementation with other SMEs within the fashion sector presents an opportunity to pool resources and share the costs associated with acquiring, maintaining, and managing RFID technology. This collaborative approach can make RFID adoption more financially viable for smaller businesses.

Investing in training programs to enhance the workforce's technical skills

Another challenge is the need for technical expertise to manage and maintain RFID systems due to the lack of skilled professionals in this area. To address this, investing in training and development programs for existing staff, as well as partnering with educational institutions to nurture future talent, can be beneficial. These programs, often facilitated by government agencies, industry associations, or larger firms with existing RFID expertise, can equip SMEs with the necessary technical skills for effective implementation and management of RFID systems. Additionally, seeking external expertise from companies specializing in RFID systems can be beneficial, particularly during the initial stages of system design, integration, and data migration. This approach can save time and resources for SMEs while ensuring the proper setup and functionality of their RFID systems

Focusing on long-term benefits

Beyond addressing the financial and technical challenges, it is crucial for Vietnamese fashion firms, particularly SMEs, to shift their focus from short-term cost reduction to the long-term benefits associated with RFID technology. By emphasizing the potential for cost savings through improved inventory management, reduced shrinkage, and increased operational efficiency, SMEs can begin to view RFID as a valuable investment with a positive return on investment (ROI). Furthermore, highlighting the technology's ability to enhance customer experience through features like self-checkout, faster product information access, and personalized recommendations can further incentivize adoption. Finally, promoting the role of RFID in fostering transparency and sustainability within the supply chain can resonate with environmentally and ethically conscious consumers, ultimately enhancing brand value and fostering greater customer loyalty.

5.3. Recommendations for government to support businesses in implementing RFID technology in supply chain management

In the context of Vietnam's burgeoning fashion industry, the integration of Radio-Frequency Identification (RFID) technology into supply chain management presents a transformative opportunity. To facilitate this adoption, the government can play a pivotal role by implementing a series of strategic recommendations:

Offering financial incentives for technology adoption

The government could offer subsidies to reduce the initial cost barrier for small and medium-sized enterprises (SMEs) looking to integrate RFID systems into their operations. Additionally, tax breaks could be provided to businesses that demonstrate a commitment to modernizing their supply chain through RFID investment. These fiscal measures would not only make the technology more accessible, but also signal the government's support for innovation in the sector. By alleviating some of the financial risk associated with adopting new technologies, these incentives would likely spur a wave of RFID implementation across the industry, leading to greater efficiency and competitiveness.

An illustrative example of financial incentives for businesses implementing RFID technology can be seen in Singapore's approach. The government offers grants covering up to 70% of the cost for small and medium-sized enterprises that adopt technology and digitize the business (Oakwood Corporate Services Pte. Ltd., 2023) , significantly lowering the financial barriers to entry. Vietnam could consider a similar incentive structure, providing substantial subsidies or tax relief to businesses that demonstrate a clear plan for RFID integration in their supply chain management. Such incentives would not only support the initial investment but also encourage ongoing innovation and adaptation of RFID systems, ensuring that Vietnamese fashion businesses remain agile and competitive in a rapidly evolving industry

Creating a regulatory framework that supports data privacy and security

Establish a regulatory framework that standardizes RFID applications across the industry would ensure interoperability and efficiency. This framework should aim to standardize RFID applications across the industry, ensuring that all stakeholders adhere to uniform protocols and quality standards. By providing clear guidelines and a consistent approach to RFID implementation, the government will instill confidence among businesses, encouraging them to invest in this promising technology.

Take a look at the European Union's approach as an instructive example. The EU has established regulations that mandate certain standards for RFID use, such as the requirement for tags and readers to be compatible across different systems and borders (EUR-Lex., 2011). This ensures that a garment tagged in one country can be seamlessly tracked throughout the EU. Vietnam could adopt a similar model, creating regulations that require uniform standards for frequency, data format, and reader compatibility. Such a framework would not only facilitate efficiency within the national supply chain but also position Vietnamese fashion businesses to compete on an international level by aligning with global standards.

Investing in infrastructure development, particularly in technological hubs and logistics networks

By creating dedicated spaces equipped with the latest technology, businesses can test and refine RFID applications in a controlled environment. Furthermore, enhancing the logistics network ensures that the data collected through RFID can be efficiently processed and utilized, leading to improved supply chain visibility and decision-making. Such investments not only support the immediate needs of RFID deployment but also lay the foundation for future technological innovations, keeping Vietnam at the forefront of industry advancements.

A practical example of infrastructure investment can be drawn from the 'Smart Nation' initiative of Singapore, where the government has significantly invested in creating a network of Smart Hubs. These hubs serve as centers for innovation, providing state-of-the-art facilities for businesses to develop and test RFID technologies. Similarly, Vietnam could establish its own network of technological hubs, strategically located near major fashion manufacturing and distribution centers. This would enable seamless integration of RFID systems into existing logistics networks, enhancing the efficiency of the entire supply chain from production to retail. Such proactive investments would not only bolster the current capabilities of the fashion industry but also ensure its long-term resilience and adaptability to new technologies.

Encouraging partnerships with technology providers

Fostering partnerships between technology providers and fashion businesses can drive innovation and tailor solutions to specific industry needs. For instance, a technology provider could work closely with a fashion retailer to develop an RFID-based inventory management system that integrates seamlessly with the retailer's existing operations. By encouraging these synergistic relationships, the government can help ensure that the benefits of RFID technology—such as improved inventory accuracy and reduced labor costs—are fully realized by the industry.

Providing training programs to enhance the workforce's technical skills

Lastly, the government could support the development of specialized training programs in collaboration with universities and tech companies. These programs would focus on equipping current and future employees with the necessary skills to operate and maintain RFID systems effectively. For example, a certification course in RFID technology could be offered, providing hands-on experience with the latest RFID equipment and software. By investing in the workforce's technical education, Vietnam can ensure that its fashion industry has a pool of skilled professionals ready to leverage RFID technology for improved supply chain management.

6. Conclusion

Despite impressive growth, the Vietnamese fashion industry grapples with inefficiencies, limited product visibility, and rampant counterfeiting. This research unveils the transformative potential of Radio Frequency Identification (RFID) technology to address these challenges and propel the industry forward.

A data-driven approach pinpoints specific pain points and deploys targeted RFID solutions, leading to significant improvements in inventory management, product traceability, and counterfeit prevention. Pilot programs mitigate risks before wider adoption, while collaboration with

stakeholders fosters knowledge sharing, cost reduction, and industry-wide acceleration.

Furthermore, RFID promotes responsible sourcing and reduces waste, aligning with growing consumer demands for ethical and sustainable fashion, ultimately enhancing brand image and customer loyalty.

In conclusion, while still nascent, widespread RFID adoption in Vietnam's fashion industry holds immense promise. A strategic approach that addresses challenges, leverages collaboration, and prioritizes data security will unlock the transformative potential of RFID. This is not just technological advancement, but a crucial step toward reshaping the industry and solidifying Vietnam's position as a global leader in sustainable fashion.

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