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ÁP DỤNG CÔNG NGHỆ RFID ĐỂ GIÁM SÁT LOGISTICS CHUỖI LẠNH Ở VIỆT NAM: TÌNH HÌNH HIỆN TẠI VÀ ĐỀ XUẤT

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Tóm tắt

Nghiên cứu này tìm hiểu về việc triển khai công nghệ Radio-Frequency Identification (RFID) để giám sát logistics chuỗi lạnh tại Việt Nam. Tình trạng hiện tại của logistics chuỗi lạnh ở Việt Nam đang phải đối mặt với những thách thức, bao gồm sự biến động nhiệt độ và việc giám sát không đúng cách. Công nghệ RFID đưa ra giải pháp bằng cách giúp cho việc theo dõi chính xác, kiểm soát nhiệt độ và tạo ra khả năng giám sát theo thời gian thực. Nghiên cứu này đánh giá cơ sở hạ tầng hiện tại, chỉ ra những lợi ích tiềm năng của RFID và đưa ra các đề xuất để có thể tích hợp công nghệ này thành công. Các kết quả nghiên cứu cho thấy rằng RFID có thể nâng cao hiệu suất và độ tin cậy của logictics chuỗi lạnh tại Việt Nam, đảm bảo việc bảo quản chất lượng sản phẩm và tuân thủ các tiêu chuẩn quốc tế. Các đề xuất tập trung vào giải quyết các vấn đề hiện tại, tạo điều kiện cho việc chuyển đổi sang một hệ thống logictics chuỗi lạnh tiên tiến và mạnh mẽ hơn.

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Từ khoá: nhận dạng qua tần số vô tuyến (RFID), logistics chuỗi lạnh, Việt Nam

IMPLEMENT RFID TECHNOLOGY TO MONITOR COLD CHAIN LOGISTICS IN VIETNAM: CURRENT STATUS AND RECOMMENDATIONS

Abstract

Our research investigates the implementation of Radio-Frequency Identification (RFID) technology for monitoring cold chain logistics in Vietnam. The current state of cold chain logistics in the country faces challenges, including temperature variations and inadequate tracking. RFID technology offers a solution by enabling precise tracking, temperature control, and real-time visibility. This research assesses the existing infrastructure, highlights the potential benefits of RFID, and provides recommendations for successful integration. The findings suggest that RFID can enhance the efficiency and reliability of cold chain logistics in Vietnam, ensuring the preservation of product quality and compliance with international standards. Recommendations focus on solving ongoing problems to facilitate a seamless transition to an advanced and robust cold chain logistics system.

Keywords: radio-frequency identification (RFID), cold chain logistics, Vietnam

1. Introduction

In the dynamic landscape of global logistics, the integration of advanced technologies becomes imperative to ensure efficiency, accuracy, and safety in the transportation of goods. Cold chain logistics, vital for preserving the integrity of temperature-sensitive products, demands a robust and reliable monitoring system to mitigate risks and enhance overall supply chain performance.

It is essential to acknowledge the transformative power of technology in optimizing logistical processes. The current landscape of cold chain logistics in Vietnam, with its unique challenges and opportunities, necessitates a comprehensive examination of how RFID can revolutionize the monitoring and management of temperature-sensitive products from origin to destination. This research aims to contribute valuable insights to the ongoing discourse on optimizing supply chain operations in Vietnam.

By employing a systematic approach to aggregate, integrate, and interpret secondary data, our study hopes to extract valuable insights from the context of global cold chain logistics in general and RFID applications in particular to evaluate the pros and cons and recommendations for Vietnam.

2. Literature review

Cold chain is a series of actions and equipment applied to maintain a product within a specified low-temperature range from harvest/production to consumption (International Institute of Refrigeration, 2024), while logistics can be loosely defined as the business of transporting and

delivering goods (Oxford University Press, 2024). Therefore, cold chain logistics's definition can be interpreted as transporting and delivering products maintained within a specific low-temperature environment throughout the entire supply chain.

2.1. The importance of temperature management in cold chain logistics

Inadequate temperature control has been identified as the fundamental cause of food waste (Pang et al., 2011). Insufficiently low temperatures can lead to freezing damage, while excessively high temperatures have the potential to accelerate enzymatic activity and/or product spoilage (Badia-Melis et al., 2018). It is imperative to store and transport fresh foods in a controlled temperature environment to preserve, and ideally enhance, their quality (Thakur & Foras, 2015). Consequently, failures in cold chain logistics can result in various detrimental effects such as excessive ripening, weight loss, softening, alterations in color and texture, physical degradation, bruising, and susceptibility to rot and molds. These factors significantly impact the freshness, desirability, and marketability of agricultural products (Jedermann et al., 2009). Therefore, investigating enhancements in monitoring cold chain logistics for agricultural products is crucial for reducing waste and, consequently, boosting the profitability of agri-businesses.

2.2. Implementation of RFID technology in cold chain logistics

Various studies advocate for the implementation of RFID, an emerging technology, with a particular emphasis on its utilization in temperature management within the food supply chain (Badia-Melis et al., 2016). Opara (2003) highlights RFID's effectiveness in recording the temperature history of products, providing precise localized measurement results that adhere to accepted standards. Kumari et al. (2015) assert that RFID's capability to capture time-temperature information at consistent intervals offers valuable data on temperature fluctuations experienced by-products.

Hui Zhou (2021) notes the increasing preference for RFID information technology in cold chain logistics management, given its relevance to temperature control logistics. This trend has led to a growing demand for RFID systems equipped with temperature sensors. In the distribution process, RFID tags can be affixed to delivery items, automatically identifying them based on unique identifiers assigned to each tag. By integrating information from RFID and temperature sensors, the relationship between items and their environmental conditions can be established (Michael & McCathie, 2005; Amador et al., 2009; Amador & Edmond, 2010; Kim et al., 2016).

The concept of incorporating RFID and wireless sensors in refrigerated vehicles was initially proposed by Qingshan et al. (2004). These vehicles can accommodate various sensors to detect, identify, log, and communicate events during the transportation of perishable products. RFID's ability to function in harsh conditions, such as temperatures as low as minus 40 degrees Celsius, is a notable advantage in cold chain logistics monitoring (Michael & McCathie, 2005; Abad et al., 2009). Gras (2006) suggests that implementing RFID in the transport system can address supply chain issues through automatic identification. Unlike manual scanning, RFID eliminates the need for manual intervention, providing remote and continuous data transmission. Continuous

temperature monitoring and precise temperature readings of perishables, achieved by embedding temperature sensors within the loads (Ruiz-Garcia et al., 2008), enable RFID to trace and address any issues that may arise during the product's journey (Ogasawara & Yamasaki, 2006; Erdem et al., 2008).

In parallel, Pi et al. (2013) utilized RFID technology to create a temperature control system for cold chain logistics, developing a real-time temperature control model through LabVIEW simulation software. Zhou et al. (2010) introduced a real-time temperature control system for cold chain logistics using RFID. Ma et al. (2014) proposed an integrated temperature sensor and Wi-Fi active RFID tag, overcoming limitations in data transmission distance. Feng et al. (2018) established a simulation system for temperature control in mutton cold chain transportation using Matlab. Yong Sun and Haiwen Wang (2018) recommended using RFID to establish a third-party cold chain logistics platform. Lishuan Hu et al. (2020) presented a traceability model for agricultural production based on RFID.

2.3. Implementation of RFID technology in cold chain logistics in Vietnam

Bui et al. (2019) proposed that the refrigeration equipment used in Vietnam remains relatively simple, such as refrigerated containers, transport management software, enclosed trucks, and barcodes. Only a few businesses are utilizing RFID for source tracing.

2.4. Research gap

While there is a growing body of literature highlighting the application of RFID technology in cold chain logistics, with a particular focus on temperature management, there is a noticeable gap in the research concerning the practical implementation of RFID technology in the context of cold chain logistics in Vietnam. The existing literature emphasizes the importance of temperature control in preserving the quality of agricultural products during transportation, with RFID technology being recognized as a promising solution. However, there is a lack of specific studies that delve into the challenges, opportunities, and effectiveness of implementing RFID in the cold chain logistics of perishable foods within the Vietnamese agri-food industry. The study by Bui et al. (2019) provides an initial overview of the current state of refrigeration equipment in Vietnam and mentions the limited utilization of RFID for source tracing. However, there is a need for more in-depth research that investigates the feasibility, barriers, and benefits of integrating RFID technology into the cold chain logistics system in Vietnam. This research gap poses a hindrance to a comprehensive understanding of how RFID can be practically implemented to enhance temperature management, reduce food waste, and improve overall efficiency in the Vietnamese agri-food supply chain. Closing this gap will not only contribute valuable insights to the academic literature but also offer practical recommendations for businesses and policymakers aiming to enhance the cold chain logistics of perishable products in the Vietnamese context.

3. Theoretical Background

3.1 Overview of RFID

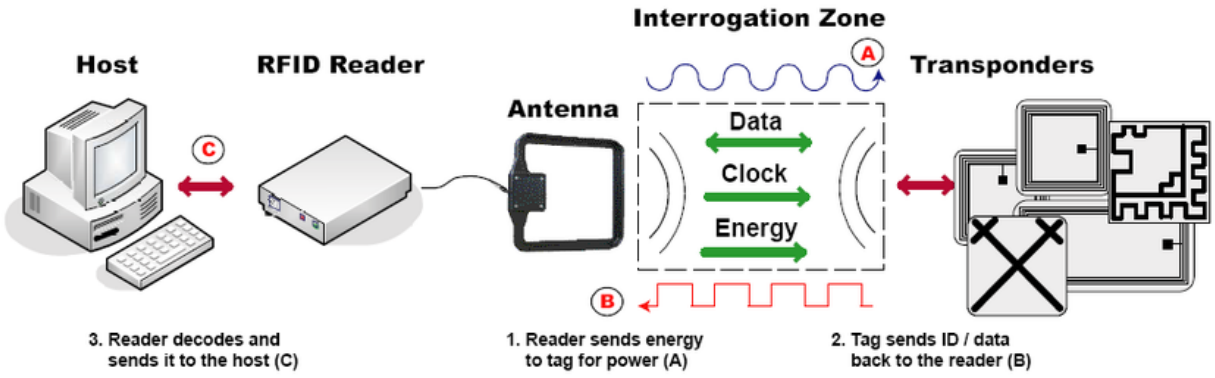

Figure 1: RFID system components

Source: RFID system components (Glasser et al., 2007)

Radio Frequency Identification (RFID) is a prominently emerging wireless automatic recognition technology system using different radio frequency signals to identify static or moving objects and exchange digital information. It requires no manual physical control, can read information through many materials, and can function well in various extremely harsh environmental conditions. It consists of three components: a tag (with a microchip and antenna), a reader (emitting signals and capturing tag responses), and a computer (analyzing data and executing applications)

- The tags use radio waves to transmit information to the readers and can be read from up to hundreds of meters away. They are usually pasted on a pallet, package, or directly on the product. Electronic tags can store from one serial number to several pages of data, which can be used to track tools, equipment, inventory, assets, etc. They can be read in large quantities and at high speed at the same time when passing near a reader, even if it is covered, not visible, or not within the line of sight, which means that the tags can be embedded inside the tracked goods such as containers and boxes.

- The reader is attached by an antenna that sends radio waves away to and receives them back from the tags, which can be transmitted to the connected computer. They can be mobile, mounted on a fixed position, or built into container-style constructions.

3.2. Role of RFID technology in cold chain logistics monitoring

The technology's quick instrumentation and collection of real-time information on the quality status of the product favors its application in cold chain logistics monitoring, which requires real-time decision-making. Continuous temperature control of perishables enables it to trace any problem arising throughout the product's journey. RFID provides a means to identify a defective

product, assisting in quickening reactions to any quality problem and preventing recalling products and associated costs.

3.3 Applications of RFID technology in cold chain logistics monitoring

3.3.1. Warehousing and Distribution

An attached RFID electronic tag records the information of the goods on the packaging, then the goods are loaded onto the pallet with the same RFID tag, which records the number of the pallet, the shelf and location after warehousing, and the basic information of the goods on the pallet. When the goods pass through the warehouse door, the RFID tag will send the recorded information to the reader above the door, and the staff can directly inspect the goods from the display screen.

For the goods currently in stock, the RFID reader fixed on the shelf can automatically update the inventory information, monitor it in real-time, and utilize the automatic replenishment function. The temperature sensor can provide real-time temperature information when the goods are stored. In the case of abnormal temperature rise or drop, the system can alert for timely cooling or heating measures to ensure product quality.

During distribution, RFID readers can obtain the location information of the containers and the location of the picking equipment to track and monitor the process. To be more specific, in the outbound process, pickers use handheld readers to update location-specific cargo information, and reviewers cross-check delivery details with RFID handheld devices. Throughout distribution picking, strategically positioned RFID readers track goods and equipment positions. RFID tags with temperature sensors ensure paperless monitoring of the cold chain process, supporting meticulous supervision in fresh food logistics (Lawo et al., 2020).

3.3.2. Transportation

Using RFID temperature sensor tags and an onboard reader, the temperature change of the goods in the transport vehicle can be monitored at any time, and the route and time of the transport vehicle can be tracked. Refrigerated transportations are equipped with sensors on tags supervising the state of perishable goods while delivering. Through the fixed reader installed in the car, the temperature change in the car is transmitted to the temperature control center in real-time, which recognizes the logistics conditions of the goods. This comprehensive approach enables monitoring and managing the entire transportation process, ensuring transparency, enhancing distribution efficiency, and maintaining transportation quality.

4. Methodology

4.1. Research design and approach

This study aims to address the feasibility of applying RFID technologies in Vietnam's cold chain logistics industry. The research provides comprehensive perspectives and practical

recommendations for the market. To achieve these objectives, our team conducted reviews of available documents in both English and Vietnamese related to the cold supply chain, logistics industry, and RFID technologies in Vietnam. Data collection involved the following:

Database: Compiling a list of government regulations, industry reports, journals, and reputable academic research published on platforms like Google Scholar and science.gov.

Publish duration: Materials collected are published or effective between 2000 and 2023, and gathered in January 2024.

Research question: Exploring the application of RFID technologies in Vietnam's cold chain logistics industry and providing recommendations.

Search syntax: Utilizing keywords such as cold logistics, cold chain, logistics Vietnam, and RFID to identify relevant articles.

After synthesizing the database to meet research objectives, our team employed a qualitative analysis method introduced by Bowen (2009). This method primarily involves using documents as data sources, including skimming (superficial examination), reading (thorough examination), and interpretation.

4.2. Data collection methods

This paper will employ a secondary data collection method to create the most comprehensive overview and suggestions for the application of RFID technologies in Vietnam’s cold chain logistics.

The decision to utilize said method stemmed from several considerations. First and foremost, primary data collection especially when conducted in the logistics industry is expensive given the fieldwork and extensive data needing to be gathered from multiple nodes in the supply chain. The key advantages associated with secondary analysis include cost-effectiveness and convenience (Ramos et al., 2021). As so, we have opted for secondary data to more efficiently allocate resources toward analysis.

Secondly, as this conundrum has yet to have a synthesized overview, a qualitative method using secondary data collection is deemed appropriate. Systematic aggregation, integration, and interpretation of data can contribute to a more comprehensive and holistic understanding of the industry, leading to the generation of new insights and recommendations within the context of this research (Saini and Slonsky, 2012).

5. Current Status of Cold Chain Logistics in Vietnam

5.1. Market analysis

Vietnam's cold storage logistics industry is expected to reach US$295 million by 2025, growing at a rate of 12% annually, as per Cushman & Wakefield. However, until recently the

sector is still underutilized, with only 48 warehouses and 8.2% of domestic food manufacturers using cold chain systems as of 2022. Export manufacturers, on the other hand, accounted for a significant 66.7% in 2020. The cold chain logistic services have had a surge of demand in recent years owing to the increase in imports and exports of perishable goods as well as medicines and vaccines.

5.2. Transportation

Cold transportation plays a crucial role in the logistic chain, ensuring the temperatures and quality of the goods in between each node in the chains. According to recent data provided by Fiin Research (2019), in 2018, there were over 700 refrigerated trucks (bulk) in Vietnam, and the trend is expected to continue in the foreseeable future. As per the Vietnam Association for Logistics Manpower Development (2022), the refrigerated transport market in Vietnam remains fragmented, with a few large enterprises and numerous small transporters operating on diverse routes due to demand-side characteristics. Challenges such as improper harvesting, packaging, preservation, and inconsistent transportation stages contribute to uneven product quality (Nguyen, 2018).

Modes of cold transportation in Vietnam encompass all three of the traditional ones land, air, and sea. Regarding air transportation, reefer containers are necessary, but the limited availability of dedicated cargo flights, often combined with passenger flights, makes them dependent on passenger demand and relatively expensive (Nguyen, 2018).

In the case of land transportation, it primarily serves domestic cold transportation, yet the refrigerated vehicle system ensures cold transportation remains limited and utilized primarily by big logistic companies. Refrigerated containers are the primary mode, with only a few large businesses or supermarkets equipped to use this system. In addition, rail transportation introduced the use of railway reefers in late 2017 on the Nanning-to-Vietnam route, employing new technology reefer containers generating independent electricity at each container.

Finally, sea transportation is widely utilized due to its potential cost-effectiveness, particularly for fruits, vegetables, dairy products, meats, and fish products produced distant from markets with shelf lives that exceed the trip duration. Reefer containers play a crucial role in various cold transportation modes.

5.3. Cold storage

The cold supply chain, particularly the cold warehouse system, is crucial for supporting the import and export operations of frozen seafood, fresh fruits, and vegetables, as well as the distribution network in Vietnam. As of the latest available data, approximately 60% of cold warehouses in Vietnam are situated in the southern region. The primary economic triangle in this area, comprising Ho Chi Minh City, Binh Duong, and Dong Nai, hosts the majority of the country's cold storage facilities, as reported by Bui and Nguyen in 2021.

Many of these cold warehouses are plagued with outdated infrastructure, lacking features such as shelves and temperature control centers, and relying on manual-based processes. Common tools

used in these facilities include plastic pallets, inverter pallets, moving freezers, and water heaters (Bui and Nguyen, 2021).

In terms of cooling technology, the majority of cold warehouses in Vietnam utilize three main traditional methods for food storage: static cooling, dynamic cooling, and spray cooling. Static cooling involves slow cooling with natural convection of cold air in the room, without additional ventilation fans beyond the basic indoor unit.

6. RFID Technology for Cold Chain Logistics in Vietnam

6.1. Assessment of current monitoring practices and technologies in Vietnam's cold chain logistics

According to Vietnam Cold Storage Market report 2019, The equipment being used to serve refrigerated goods in Vietnam is still quite simple such as refrigerated containers, transport management software, closed trucks, and barcodes. Only a few businesses use RFID for traceability or blockchain.

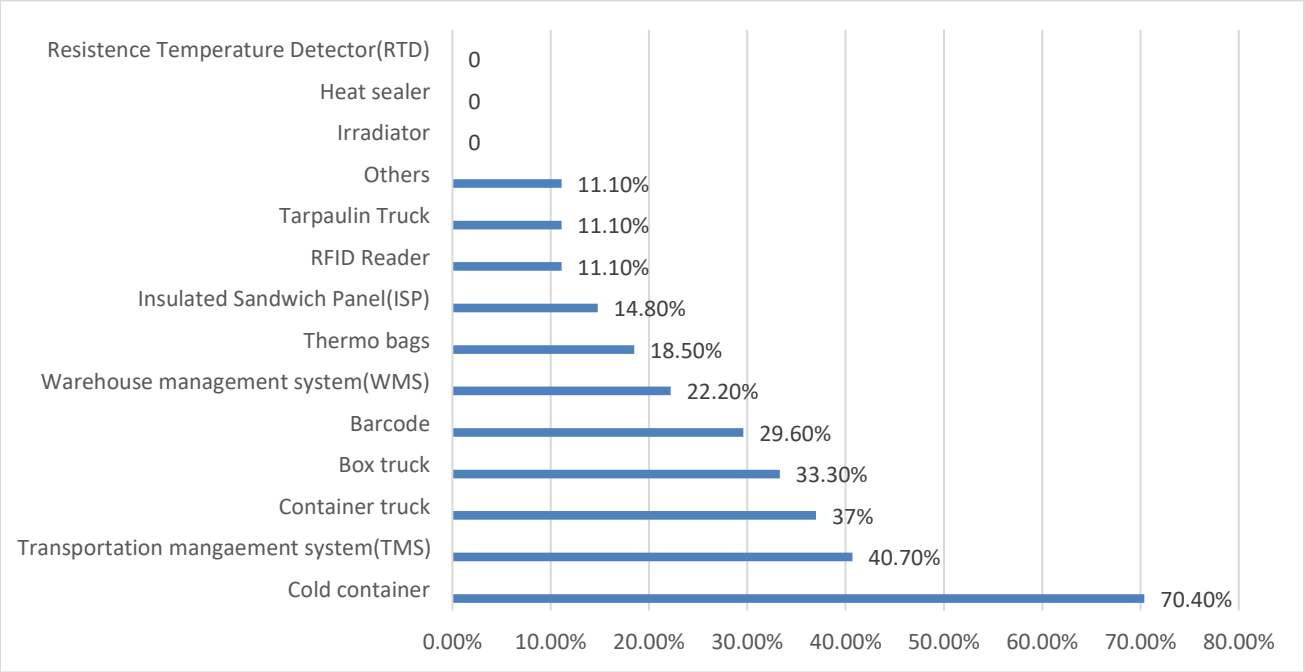

Figure 2: Equipments used at companies providing refrigeration services

Source: Vietnam Cold Storage Market report, FiinResearch, 2019

In general, the use of monitoring technologies in Vietnam's cold chain logistics is still limited. Regarding transportation technology, businesses in the market have yet to widely adopt comprehensive transportation management systems. The focus currently lies in the application of GPS positioning technology, with limited integration throughout the entire transportation process, according to the Vietnam Association for Logistics Manpower Development (2022). Additional

shortcomings appear in the form of end-to-end data retrieval from warehouses to final destinations due to the same lack of integration technologies.

Currently in Vietnam, there has been a significant emergence of applications for traceability in various sectors, such as tracing the origin of pork in the "Safe Food Market Model Pilot Project in Ho Chi Minh City from 2016 to 2020" (TẠP CHÍ CÔNG THƯƠNG, 2020) or tracing the origin of agricultural products (such as dragon fruit from Binh Thuan, Red Dragon fruit for export, and organic vegetables) by TraceVerified Company Limited (TraceVerified, 2019). Although there are numerous applications for tracing the origin of agricultural and aquatic products in Vietnam, most of these systems only utilize QR code labeling, which comes with certain limitations. These limitations include the inability to rewrite data (Read-Only - RO), thus rendering them non-reusable; limited reading range, requiring close proximity for scanning, and sensitivity to environmental factors (such as dust, high-intensity light, or physical damage), leading to potential reading failures. Additionally, these systems often exhibit low levels of security.

When it comes to warehouses, most logistic businesses in Vietnam still use manual temperature monitoring using conventional thermometers as well as static and dynamic cooling systems. To address the limitations of traditional technologies, Vietnam is exploring modern solutions to enhance cold warehouse performance. One notable technology under consideration is the Cells Alive System (CAS), a modern frozen food preservation technology developed by ABI Corporation in Japan, which was transferred to Vietnam in June 2013. However, widespread adoption of CAS is hindered by the high initial investment costs. The cold storage real estate sector in Vietnam is expanding and is projected to achieve a market value of $295 million by 2025, with an annual growth rate of 12%, as indicated by real estate advisory firm Savills Vietnam.

Regarding warehouse management technology, most large businesses have incorporated technology into their operations by implementing cold storage management software or automating various processes. However, smaller businesses tend to use simpler software and have not fully automated their operations. Currently, Vietnamese companies are transitioning to more advanced management technologies. Leading businesses in Vietnam, such as Emergent Cold, PFS, and Lotte, apply technologies that involve dividing warehouse functions into cold storage, cool storage, barcode systems, inventory management, value-added service classification, labeling, and distribution.

6.2. Potential benefits from applications of RFID in cold chain logistics in Vietnam

In Vietnam, RFID technology is transforming cold chain logistics by automating inventory management and distribution processes, ensuring precise stock monitoring and expiration date tracking, while simultaneously reducing labor costs and shipment confirmation time. This technology supports real-time quality control, bolstering risk management efforts and facilitating just-in-time production models for high-quality production logistics. Additionally, RFID facilitates comprehensive traceability across the food cold chain system, from farm to market, ensuring safety, quality, and efficient emergency tracing. By providing insights into product

journeys and enabling quick identification during crises, RFID enhances overall control through continuous monitoring and quality assessments. Integrating RFID into cold chain logistics in Vietnam ensures efficiency, safety, and traceability, aligning with consumer expectations for transparency in the food industry. Moreover, implementing guaranteed low-temperature logistics serves as a strategic marketing approach, catering to diverse market segments with customized products. Despite all these benefits, sustaining a competitive edge in the long term poses challenges.

6.3. Challenges arising from applications of RFID in cold chain logistics in Vietnam

6.3.1. Infrastructure Limitations

Vietnam lacks the necessary infrastructure to support widespread RFID deployment, including reliable internet connectivity, power supply, and transportation networks. Remote or rural areas, where cold logistics facilities are often located, may face even greater challenges in accessing and maintaining RFID systems.

6.3.2. Cost

In the context of Vietnam, the adoption of Radio Frequency Identification (RFID) technology for logistics, particularly in cold chain management, faces notable challenges primarily related to cost considerations. The primary impediment is the perceived high cost of RFID compared to traditional bar code systems. Even with potential mass production conditions for RFID chips, the cost of bar code systems remains significantly lower, making widespread deployment of RFID on supermarket merchandise challenging. These are certain costs that need to be taken into consideration:

- RFID tag costs: Costs vary based on factors like type, frequency, and quantity. Common options include UHF Passive RFID Labels, ranging from a few cents to several dollars per tag, with different form factors and attachment methods affecting costs.

- RFID hardware costs: Hardware includes readers, antennas, printers, and server infrastructure. Prices vary based on factors like form factor, frequency, and functionality. Antennas and printers should not be overlooked, and server infrastructure may be necessary depending on system complexity.

- Middleware and implementation costs: Beyond tags and hardware, costs include infrastructure installation, system integration, and software development or purchase. Middleware like RAPID RFID can streamline implementation and scalability should be considered.

- Maintenance costs: Routine hardware maintenance, calibration, and software updates are factors to consider, along with vendor support and warranty offerings.

- Total Cost of Ownership (TCO): Calculating TCO involves all costs throughout the system's lifespan, including initial investment, implementation, maintenance, and operational expenses.

Benefits like improved asset management and efficiency should be weighed against costs to determine return of invesment.

Environmental concerns add another layer of challenge, as commercial RFID deployment may have an impact on the environment. Despite this, the use of RFID chips in guaranteed logistics for the cold chain is justifiable. The cost associated with RFID readers and tags in this specific context might not be a significant concern.

However, when considering the broader economic landscape in Vietnam, the cost challenges extend to factors like cloud computing and communication infrastructure. While the development of cloud computing has the potential to lower costs, the current and anticipated costs of 4G or 5G technologies may pose challenges, especially in a market where economic scale factors are crucial.

In summary, while the cost of implementing a guaranteed RFID system for cold chain logistics may be reasonable in specific contexts, challenges persist in the broader economic and technological environment of Vietnam. The economic advantages may need careful consideration to outweigh potential challenges. The economic benefits of ensuring a secure cold chain logistics system, such as the assurance of product quality, may need to be effectively communicated to stakeholders to justify the investment in RFID technology despite initial cost concerns.

6.3.3. Lack of expertise

Although RFID infrastructure requirements will vary based on specific cases, there are several necessary steps need to be taken:

- Site assessment and site survey: During a site and workflow assessment, all requirements are determined. Qualified RFID engineers conduct a site survey to review and analyze the site where RFID infrastructure and equipment will be installed. The survey provides a comprehensive assessment, recommendations, and a report to ensure the RFID processes operate 100% of the time.

- Pre-installation: Whenever possible, preassemble portals, RFID hardware, and mounting equipment before arriving on-site. Installers should have basic hand tools, power tools, tie wraps, beam clamps, fasteners, etc. It is important to check equipment inventory, including hardware, cables, mounting devices, and ensure that the site has necessary provisions such as cable holes, special brackets, antenna masts, enclosures, bollards, and industry-standard network cabling/infrastructure.

- Installation: Install RFID readers, antennas, and other required hardware components. Configure the RFID system and conduct thorough testing to ensure proper functionality.

- Integration: Integrate the RFID system with existing software systems to enable smooth data exchange and synchronization.

- Training: Provide training to employees on how to effectively utilize the RFID system, ensuring they understand its operation and benefits.

- Maintenance: Regularly maintain the RFID system to ensure ongoing optimal performance and reliability. Conduct necessary inspections, repairs, and updates to keep the system functioning properly.

To effectively apply RFID to cold chain logistics, the mentioned requirements have to be fulfilled and this is a challenge for Vietnamese employees. Moreover, the grounded theory process revealed a significant theme concerning the challenges arising from a lack of expertise in applying Radio-Frequency Identification (RFID) technology in the Cold Chain Logistics (CCL) sector. The intricate nature of cold chain operations, encompassing activities like harvest, collection, packing, processing, storage, transport, and marketing (Kitinoja, 2013), demands a nuanced understanding of RFID applications. The Cold Chain Logistics field has witnessed rapid changes in management processes, technology-based operations, and customer requirements (Joshi and Joshi, 2016), introducing a growing need for specialized skills in leveraging RFID effectively.

Vietnamese managers highlighted the necessity for expertise and skilled professionals capable of navigating the complexities of RFID implementation within their organizations. Key positions, such as managers and operators, technicians and maintenance engineers, cold chain logisticians, and agricultural experts, were identified as requiring substantial human capital investments to address the challenges posed by the lack of RFID proficiency. Managers expressed concerns about employees struggling to adhere to RFID standards, leading to potential issues in maintaining the integrity of the cold chain. The fragmented and unorganized nature of the Vietnamese food industry, coupled with poor working conditions, further exacerbated the challenges associated with the application of RFID technology in Cold Chain Logistics.

7. Recommendations

7.1 Recommendations for logistics companies

- ***Cost consideration***: One approach is to leverage the potential cost benefits of technological advancements. The development of cloud computing and Internet of Things (IoT) infrastructure has the potential to reduce the costs associated with RFID implementation. Cloud computing can provide scalable and cost-effective data storage and processing capabilities, eliminating the need for significant upfront investments in on-premises infrastructure. By leveraging cloud-based RFID solutions, companies can reduce their overall costs while enjoying the benefits of real-time data analytics and improved supply chain visibility.

Furthermore, exploring alternative financing models can help overcome the cost barriers of RFID implementation. Companies can explore leasing or rental options for RFID equipment and infrastructure, allowing them to access the technology without significant upfront investments. This can be particularly beneficial for small and medium-sized enterprises (SMEs) that may have limited capital resources.

Lastly, it is essential to continuously monitor and evaluate the cost-effectiveness of RFID implementation. Regular assessments of the return on investment (ROI) can help identify areas for improvement and cost optimization. By measuring key performance indicators (KPIs) such as reduction in product spoilage, increased operational efficiency, and enhanced customer satisfaction, companies can quantify the tangible benefits of RFID technology and justify ongoing investments.

- Provide more training programs to deal with the lack of expertise: Insufficient education and training at the operational level is frequently mentioned as a key challenge (Gligor, 2018). Unfortunately, in Vietnam, there are very few educational programs available specifically designed for RFID application in cold chain logistics. Vietnam, a country known for its rapidly growing economy and agricultural sector, could greatly benefit from implementing more programs focused on applying (RFID) technology in cold chain logistics for 2 following reasons: it would help reduce post-harvest losses and ensure that products maintain their freshness and nutritional value and enhance transparency and traceability, which bring advantages to the operations. By monitoring temperatures in real-time, any changes that could spoil the products can be quickly identified and addressed. This ensures that the goods stay in optimal condition, preventing waste and preserving their quality. While transparency helps warehouse owners see their inventory clearly, so they can manage stock levels and make smart decisions about storage and order fulfillment, traceability allows them to collect and store data about the products in their warehouse, like when they were made and the temperatures they were kept at.

7.2. Recommendations for Vietnamese government

The Vietnamese government can have significant impacts on the application of RFID by providing financial incentives, grants, or subsidies to encourage businesses, particularly SMEs, to invest in RFID technology. This support can help offset the initial costs of RFID implementation and promote adoption across the cold chain sector. Moreover, the government can sponsor infrastructure improvements such as internet connectivity and transportation networks, especially in rural and remote areas where cold chain facilities are located. Investing in infrastructure upgrades will enhance the reliability and accessibility of RFID systems. Lastly, foster partnerships between government agencies, industry stakeholders, and technology providers to drive innovation and investment in RFID-enabled cold chain solutions. Collaborate on research and development initiatives, share best practices, and leverage collective expertise to address common challenges and achieve shared goals.

By implementing these recommendations, Vietnam can overcome the challenges associated with RFID adoption in cold chain logistics and unlock the full potential of RFID technology to enhance supply chain visibility, efficiency, and product quality.

8. Conclusion

In conclusion, the implementation of RFID technology for monitoring cold chain logistics in Vietnam holds significant promise, particularly with temperature management. Despite the initial higher costs associated with RFID, the economic feasibility of a guaranteed cold-chain system is offset by the use of reusable chips and ongoing technological advancements.

As Vietnam endeavors to optimize its cold chain logistics, these recommendations provide a strategic roadmap for realizing the full potential of RFID technology in transforming the country's supply chain landscape. A thorough examination employing comprehensive methods will be essential to establish a more precise and applicable strategy. The current discussion serves as an initial step in outlining the trajectory for Vietnam to integrate RFID into cold chain logistics, ultimately fostering economic advancement and enhancing the overall well-being of its population.

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