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The Impact of the Internet of Things (IoT) on Inventory Management in Warehouses

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ABSTRACT

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The paper's purpose is to conduct in-depth research on the impact of the Internet of Things (IoT) on inventory management in Vietnamese warehouses in order to provide a comprehensive picture of the negative and positive effects that IoT implementation has currently brought to the Vietnamese warehousing industry, where Vietnamese organizations are still hesitant in applying new technologies in their warehousing operations. In this study, the author chose Quoc Hung TST Co., Ltd, a Vietnamese manufacturing specialist, as my case company to investigate.

The study's primary methodology is qualitative research, which means that the author conducts interviews to collect primary data for the research. Therefore, the interviewees' practical experiences and opinions on the topic are crucial in the data analysis process because of their realistic reflection of the situation and the users' perspectives. Secondary data, in addition to primary data, are gathered to support the analysis.

The final results of the research present the benefits, business opportunities, and challenges of IoT integration in inventory management in warehouses, which allows Vietnamese companies to better understand IoT applications and, as a result, consider deploying this technology in their warehouses. Furthermore, the findings also reveal future trends in IoT technology, which are derived from users' expectations of technological applications to express their perspectives and desires of future IoT applications toward technological organizations. In conclusion, it is expected that this study will shed light on the impact of IoT on inventory management in warehouses, enabling the warehouse industry not only to access advanced IoT applications in inventory management but also to propose creative ideas for technological enterprises to improve their technological products in the future.

Keywords Internet of Things (IoT), inventory management, warehouse, IoT applications, IoT technology

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ABBREVIATIONS

IoT	Internet of Things
RFID	Radio Frequency Identification
WSN	Wireless Sensor Networks
MOM	Message-Oriented Middleware
ESB	Enterprise Service Bus
ORBs	Object Request Brokers
CAGR	Compounded Annual Growth Rate
EMR	Expert Market Research
IIMM	Indian Institute of Materials Management
MRO	Maintenance**,** Repair and Operating
JIT	Just-In-Time
SKU	Stock Keeping Unit
FIFO	First In, First Out
LIFO	Last in, Last Out
FIFO	First Expiry, First Out
SaaS	Software-as-a-Service
AMR	Autonomous Mobile Robots
CEO	Chief Executive Officer
GPS	Global Positioning System

MIT	Institute of Technology
AR	Augmented Reality
VR	Virtual Reality

1 INTRODUCTION

1.1 Research background

In today's changing society, international trade has become popular, enabling the overall global economy's outlook to be brighter and more promising. This is a positive signal for enterprises all over the world. However, Llamazares (2015, 5) defined international trade as a different form of activity than domestic trade, and it is more complicated because the buyer and seller are located in different countries, and they must overcome several obstacles. With such characteristics of international trade, a majority of businesses have been enhancing the number of products to be ready for expanding their market, which leads to raising the complexity of supply chains and causes remarkable challenges to warehouse management where inventory management is one of the crucial parts should be focused due to the rise of goods.

Simultaneously, technology plays a crucial role in the development of most sectors. With the constant development of technology, advanced technological applications are gradually proving their vital impacts on different areas, including inventory management in warehouses, which has a significant revolution thanks to a wave of new technologies. More specifically, in the 4.0 era, the Internet of Things (IoT) is known as one of the pillars of Industry 4.0, which allows for the establishment of full integration, automation, and optimization in industries (Vaidya, Ambad & Bhosle 2018, 233 – 236). It is a new technological paradigm that envisions a worldwide network of machines and devices that can communicate with one another (Lee & Lee 2015, 431). These networked smart sensors can recognize, network, and process a large volume of data, opening up new commercial opportunities (Ju, Kim & Ahm 2016, 884). By 2022, it is predicted that over 18 billion IoT devices would be in use around the world. They will enable a global reach to be across effectively with those simple and tiny devices (Novo 2018, 1) Hence, enter-

prises are investing in IoT and integrating it into inventory management in warehouses to improve performance and increase productivity, for example, tracking materials. Yet, IoT has elements that businesses should take into consideration when implementing it. Specifically, IoT is considered a complicated technology that must be comprehended for commercial goals.

In that context, in order to develop sustainably and boost supply chain performance and productivity, businesses must deploy IoT applications in warehouse management, notably in inventory management. Indeed, using IoTs in warehouses is not a novel concept in developed countries these days. However, for developing countries like Vietnam, this is still a modern phenomenon. After becoming aware of the issue, the author decided to undertake this study with the primary goal of providing an overall picture of the impact of the Internet of Things on Inventory management in the warehouse as well as challenges and business opportunities when applying this technology in order to support the companies in Vietnam to have a deeper understanding of IoT applications. Furthermore, the author hopes to discover user expectations toward technological applications through this research to convey their perspectives to technological organizations, assisting not only businesses in being able to access novel technological applications in inventory management as quickly as possible but also proposing new ideas for technological enterprises to improve their technological products in the future.

1.2 Objectives and research questions

The main purpose of the research is to explore the positive and negative effects of IoT applications on warehouse inventory management. In addition, the author investigates potential business opportunities and challenges associated with employing IoT applications to manage inventory, as well as future user expectations for technological products for inventory management. Accordingly, the information obtained in this research will be beneficial for companies in Vietnam who

would like to automate their warehouse operations or organizations that are involved in the technological industry. To accomplish these objectives, the author will collect information to answer the following questions:

- How have IoT applications affected warehouse inventory management?
- What commercial prospects exist for companies using IoT applications to manage inventory?
- What are the challenges that organizations face when using IoT technologies to manage inventory?
- What are the future trends of IoT in warehouse management?

1.3 Company overview

Quoc Hung TST Co., Ltd, established in 2008 in Vietnam, is a specialist in the manufacture and design of industrial machinery, as well as related services. The company specializes in designing, processing, and maintaining mechanical systems, as well as designing and implementing electrical and industrial automation networks, as well as providing material for industrial electrical, temperature, and flexible accessories. It also provides a wide range of machinery, as well as sanitation and cleaning room equipment. Lastly, the organization provides and installs the telephone operator system, network, video equipment, as well as fire and theft reporting systems.

Despite the fact that Quoc Hung specializes in various types of mechanical and automatics, the company is currently focusing on two of them: shoe manufacturing machines and industrial conveyors, which are utilized in the agricultural, seafood, and shoe industries. Quoc Hung is attempting to prove its capacity and reputation in the enterprise community not only in Vietnam but also internationally, by utilizing and applying leading innovation as well as current technology and machines. Currently, the warehouse of company is located at 2822/3A An Phu Dong street, An Phu Dong Ward, District 12, Ho Chi Minh city.

1.4 Thesis structure

The basics of a thesis paper are delivered in the first chapter, which includes the research background, objectives, research questions, and general company information, on which the author focuses on collecting data for the research.

The theoretical frameworks are developed in the following chapter to give audiences an understanding of the Internet of Things common current applications in warehouse inventory management, as well as the impacts and obstacles when applying them to inventory management. In addition, this chapter covers warehouse operations in general and warehouse operations in Vietnam in specific, as well as inventory management functions.

In chapter 3, the author presents the entire research procedure to attain the intended objectives after the theories are well-grounded. In particular, the empirical study is explained in great depth, from methodological selection to data collection planning and execution to data analysis. In addition, the background information about the respondents is provided at the end of this chapter.

Subsequently, chapter 4 summarizes the study process's results and key discoveries. This is the crucial section of the study that explores the influence of IoTs in warehouse inventory management, commercial opportunities, and potential challenges from deploying IoT applications in inventory management, as well as IoT future trends through discussions with interviewees.

The final chapter is devoted to closing the research. To emphasize the conclusions, the researcher examines the similarities and discrepancies between the theories and the results of the practical study. Furthermore, this section is for evaluating the research process, such as the validity and reliability of findings, as well as the study's limits in general. In addition, a suggestion for further research is proposed to expand the research topic in other areas that were not included in this study.

2 THEORETICAL BACKGROUNDS

In the theoretical section, the author presents in detail fundamental IoT technologies that are currently in use, such as radio frequency identification (RFID), wireless sensor networks (WSN), middleware, cloud services, and IoT application software. In addition, this chapter further delves into the characteristics and functions of warehouse operations and inventory management, as well as the integration of IoT in inventory management and its benefits. Finally, the difficulties of deploying IoT applications are discussed as well. These are basic theoretical backgrounds for the findings that the author will present through this research.

2.1 Essential IoT technologies

Internet of Things contains a variety of technologies in real practice and five of which are key technologies that are required for IoT deployment on products and services as listed below: (Lee & Lee 2015, 432)

- Radio frequency identification (RFID)
- Wireless sensor networks (WSN)
- Middleware
- Cloud computing
- IoT application software

2.1.1 Radio Frequency Identification (RFID)

One of the essential IoT technologies is RFID. Technically, this technology is a type of wireless information and communication that can identify, record, verify and process data related to a majority of tangible items, including the goods' physical location and the associated movement or variations thereof. Besides, RFID also supports intangible tasks consisting of data processing and data execution operations which are associated with providing services (Graham, D., & Manikas, I. (Eds.) 2013, 199). In particular, by utilizing radio waves, a tag, and a reader, RFID enables

users to recognize and capture automatically inventory quantities which are measured against time, date, and location. On the other hand, this technology can be used to monitor the ambient conditions consisting of temperature, humidity, and pressure, which created a preference for such technology in specific sectors such as perishable goods and pharmaceuticals. As such, RFID technology allows for more data to be stored than a conventional barcode.

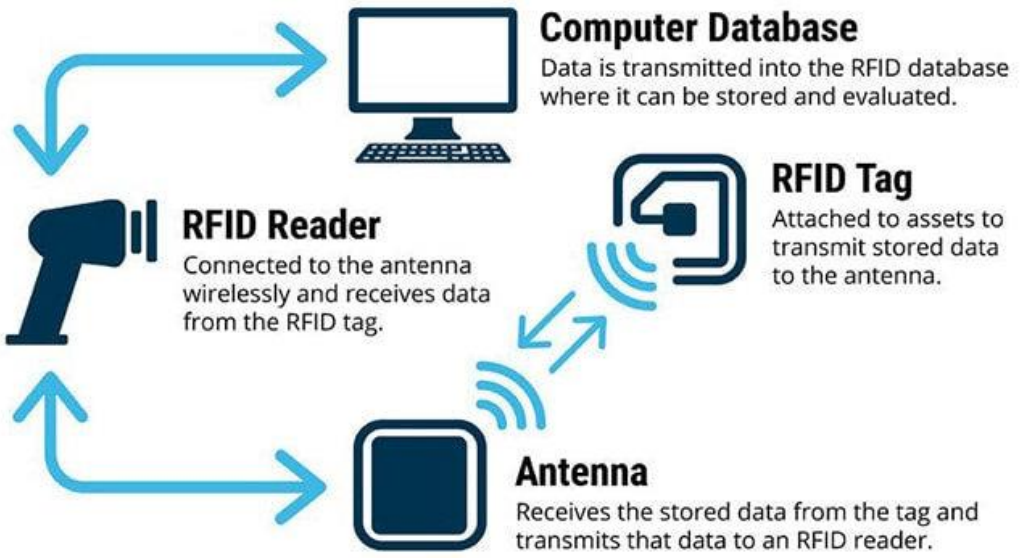


Figure 1 How RFID works

However, in addition to the benefits stated above, using the RFID system also has cons; for example, misplacing the RFID tags can be one of the first issues since these tags are similar to traditional name tags, users may mistakenly place the wrong tags on products, resulting in errors in statistics, picking up process, material or goods management, and so on. Secondly, hackers can hack the RFID system, allowing them to enter a secure environment and do whatever they want, including stealing data. Furthermore, the system is extremely expensive to set up because it necessitates the connection of machines, computers, readers, tag printers, and more. (Baballe, 2021, 522)

In practice, there are three different types of tags that are used to identify data. Firstly, Passive RFID, which is based on radio frequency, does not require batteries and is extensively used in supply chain item tracking. The second one is Active RFID which necessitates a battery supply tag and can communicate with the reader on its own. It is commonly used in production. The third form, known as Semi-passive RFID, is a combination of the previous two. This type needs batteries to operate and derives its energy from the reader. Normally, with much more advanced features, the price of active and semi-active tags is higher than for passive ones (Lee & Lee, 2015, p. 432). According to Graham and Manikas (2013, 199), nowadays, RFID is used in a wide range of industries, from retail to banking, and is particularly useful in inventory management and control, as well as tracking and security.

2.1.2 Wireless Sensor Networks (WSN)

Wireless sensor networks (WSN) comprise devices that are equipped with autonomous sensors and distributed spatially to monitor physical or environment variables or able to function in tandem with RFID systems to track the status of objects' location, temperature, and movement (Atzori, Iera, & Morabito, 2010). In other words, thanks to such features of this technology, organizations can acquire sensor data in an IoT environment to comprehend the information of the outside reality, which is one of the most crucial aspects of data collection (Chi, Yan, Zhang, Pang & Da Xu 2014, 1417).

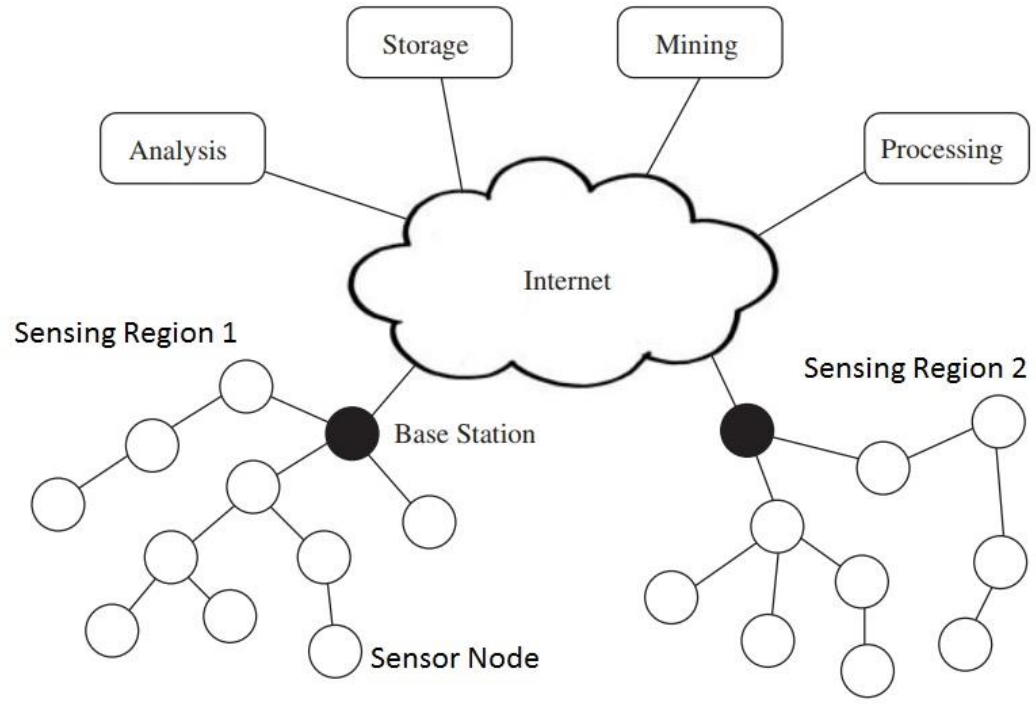


Figure 2 Wireless Sensor Networks

However, in many cases, there are challenges in real-time still occurring. For example, WSNs must deliver sensor data promptly so that observations and actions can be taken appropriately. So far, there have been few results in terms of meeting real-time requirements in WSN since most protocols ignore real-time or just process as quickly as possible in the hope that that speed will be sufficient to meet the deadlines. Moreover, challenges in power management still exist because the surveillance nature of many sensor network applications demands a long lifetime; therefore, a type of energy-efficient surveillance service for a geographical area should be researched more and provided later (Indu et al., 2014, 684). Currently, this technology has been applied in cold chain logistics, for example, to ensure that the temperature is maintained during the transit process (Lee & Lee 2015, 432).

2.1.3 Middleware

Middleware is a software layer that is located between software programs and makes communication and input/output easier for developers. Its ability to hide the intricacies of various technologies is critical for IoT developers to be free from

software services that are not directly relevant to the IoT application (Lee & Lee 2015, 432). In other words, this technology is a type of computer connectivity software supporting software applications beyond the capabilities of the operating system. To put it simply, middleware programs serve as messaging services, allowing data management and communication in distributed applications (Herren, 2021). Middleware became prominent and popular in the 1980s as a result of its important role in making the integration of legacy and technological advances easier. It also enabled the development of innovative services in a distributed computing environment simpler (Lee & Lee 2015, 432). In addition, with such features, it facilitates the flow of real-time information access within and among network systems. In business it assists in streamlining processes and improving organizational efficiency, maintaining the integrity of information across a network of systems. Furthermore, thanks to its wide range of applications in a variety of software systems, Middleware is considered as the manna of developers since it allows them to create better various types of networked applications. Nevertheless, there are disadvantages existing parallelly with advantages. For instance, not every business can afford to maintain and grow the potential of Middleware due to prohibitively high development costs, or Middleware benchmarks have yet to be established, so there are few standard marks for Middleware performance levels. Besides, Middleware can often jeopardize the real-time performance of some systems (Herren, 2021). Several typical examples of Middleware that must be mentioned are procedural middleware, message-oriented middleware (MOM), enterprise service bus (ESB), data integration, and object request brokers (ORBs) (Herren, 2021).

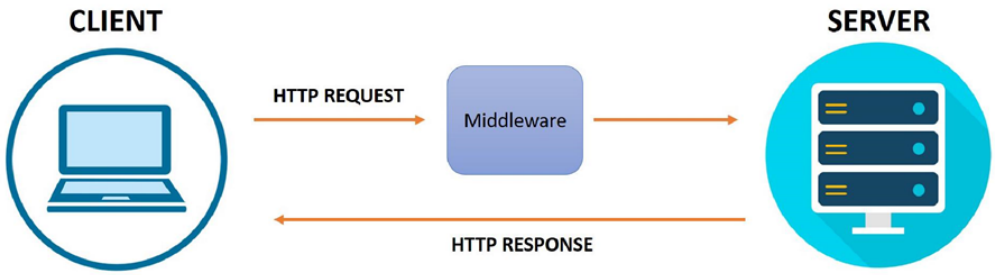


Figure 3 How Middleware Works

2.1.4 Cloud computing

Cloud computing is a technology referring to accessing on-demand a shared pool of configurable resources, including computers, networks, servers, storage, applications, services, and software (Lee & Lee, 2015, p. 433). With the support of high processing performance, this technology allows information to be stored and accessed wherever it is needed. It is a cost-effective, secure, and efficient technology that enables businesses to pay just for the data storage they need to run their business (Belgaum, Soomro, Alansari, Alam, Musa & Suud 2018, 1-2).

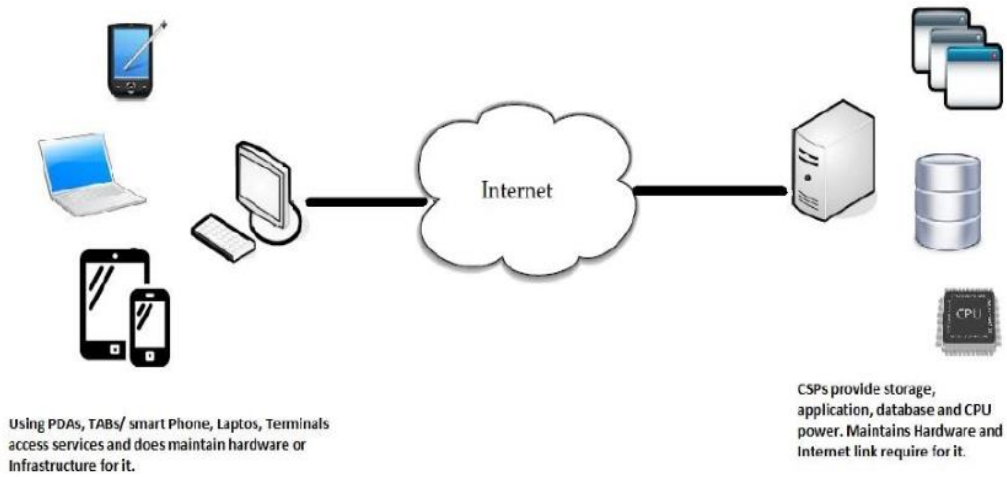


Figure 4 The operation of cloud computing

Still, it is necessary for businesses to consider when choosing cloud computing over traditional data centre or server room-based options because of the following possible threats and challenges. The first issue that should be mentioned is the technical issue. This is understandable because, regardless of how high the standards of maintenance that cloud service providers maintain, access to information and data from the cloud could be denied at any time and from any location if a serious malfunction or dysfunction occurs. Besides that, a strong Internet connection is essential for staying always logged onto the server, as consumers are frequently stranded due to network and connectivity issues. Secondly, security is also a major issue that should be aware of before using cloud technology because all organization's data or information might be surrendered to a third party. Consequently, businesses will be pushed into jeopardy once this happens. Furthermore, being prone to attack and copying data could be a threat to organizations. This could occur completely because nothing on the Internet is perfectly secure; there is always the possibility of sensitive data being stolen. Therefore, Cloud computing, like any other technology, has advantages and disadvantages. It can be a valuable asset to a user; however, it can also be harmful if not properly understood and applied. The business's duty is to consider carefully to avoid consequences later (Kelkar, 2015, pp. 2720-2724).

2.1.5 IoT application software

In fact, the Internet of Things application software enables the creation of a wide range of IoT applications which are invented based on specific industries and users. Supportively, IoT application software facilitate device-to-device and human-to-device interactions in a trustworthy and potently. Accordingly, IoT applications integrated into devices must ensure that information is received and processed in a timely way. In practice, IoT application software is being deployed in various areas, promoting the development of digital communication in industries. Transportation and logistics applications, for instance, are used to keep track of the status of carried goods including fruits, fresh vegetables, meat, and dairy products, or

monitor the conservation status such as temperature, humidity, and shock. Furthermore, IoT applications are created based on a human-oriented are attempting to provide users with information as visually as possible to support users to understand data and interact with the environment more easily. Indeed, the software which processes the information in an intuitive way can allow users to make better decisions. Being similar to other technologies, security, cost and network are also challenges that the companies who are intending to apply IoT application software must notice (Lee & Lee 2015, p. 433).

Figure 5 IoT software

Overall, essential IoT technologies play an important role in establishing a foundation for developing various IoT applications that are widely used in industries in general and warehouses in particular. Before obtaining into the meat of the topic, the following sections will discuss the fundamental definitions and operations of warehouses and inventory management.

2.2 Warehouse operation

Richards (2021) adapted the definition of the warehouse from Van Den Berg (2013) that a warehouse should be regarded as a temporary storage location for

inventory as well as a buffer in supply chains. It functions primarily as a static unit, matching product availability to consumer demand, and as such has a primary goal of facilitating the movement of goods from suppliers to customers, meeting demand in a timely and cost-effective manner (Richards 2021, 1). Indeed, warehouses do play an important role in the supply chain and in business. Its operation will affect the general operative efficiency of the companies and even customer satisfaction, which determines the existence of the companies in the current harsh market. As a result, to be more effective in business operations, most enterprises are building and customizing their warehouses to serve for operations. In that context, Vietnam is also focusing on developing warehouses with the aim of efficient performance.

2.2.1 Warehouse industry in Vietnam

In Vietnam, currently, most industrial parks in cities and provinces have warehouse systems ready to meet the needs of storage, yards, and transportation of goods for businesses. Rapid urbanization, the rising warehousing industry in Southeast Asia, and growing public and private collaborations are driving the Vietnam warehousing market. The market is predicted to increase at an 11 per cent CAGR[1] from 2022 to 2027 (Figure 6), thanks to mass production and lower tariff barriers (”Vietnam warehousing market report and forecast 2022-2027”, n.d.).

[1] The compounded annual growth rate (CAGR) is one of the most precise methods for calculating and determining returns for anything that might change in value over time. (Fernando, 2022)

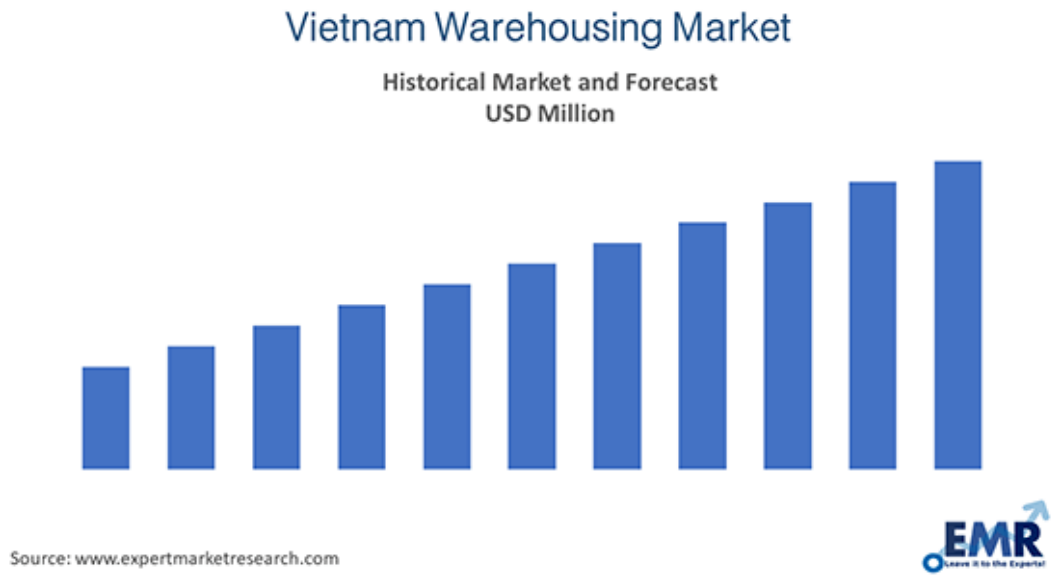


Figure 6 The historical market and forecast from 2017 to 2027

Meticulous research was conducted by Expert Market Research[2] (EMR) to investigate the Vietnamese warehousing market. It indicates that the Vietnam warehousing sector can be divided into general warehousing and cold storage warehousing, among other categories, based on their types. The market is segmented into the consumer goods, textiles and footwear, retail, food and beverage, timber products, healthcare, and chemicals, along with many other end-use sectors (Figure 7). (*"Vietnam warehousing market report and forecast 2022-2027"*, n.d.).

[2] Expert Market Research (EMR) is a leading industry research and business intelligence firm that provides customized and syndicated reports to help our clients keep track of ever-changing market circumstances. (expert market research website, n.d.)

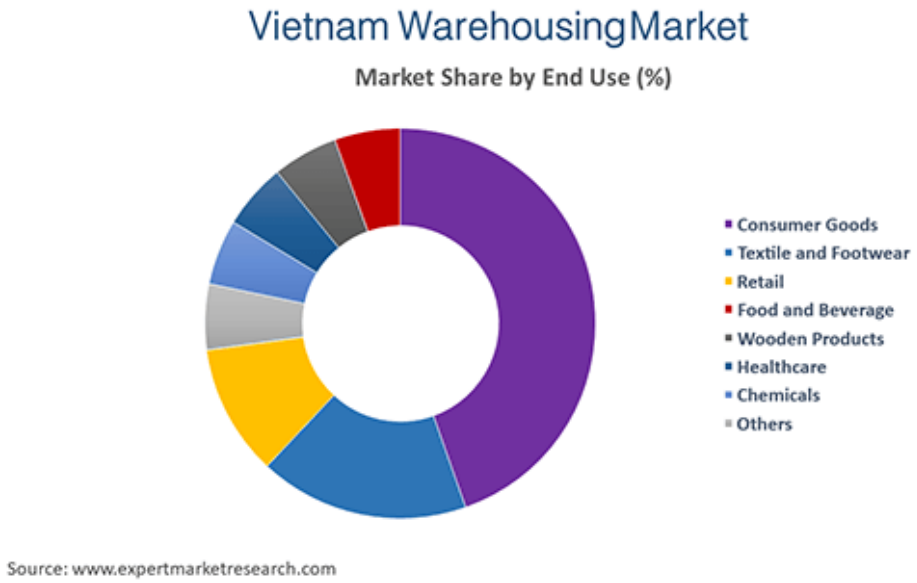


Figure 7 Market share by End users

Characteristics of the warehouse system in Vietnam

Currently, the demand for warehousing is still on a strong upward trend despite the fluctuations in the economy. The reason is that manufacturing enterprises are stepping up operations; on the other hand, warehouse rent is also forecasted to grow at an average rate of about 1.5% to 4% per year. According to a report from the Ministry of Industry and Trade of Vietnam, the warehouse system in Vietnam is unevenly distributed. More than 70% of the warehouse area is distributed in the southern economic centres since the logistics market in the southern region is considered to be more vibrant thanks to the system of highways and more deeply connected seaports and ports. In the Hanoi area, the warehousing and storage system will mainly focus on Hanoi and coastal cities such as Hai Phong. However, the North is receiving more and more attention from foreign investors; thus, if the supply of warehouses remains as limited as it now, the rental price will increase and the vacancy rate will decrease. (Nguyen, 2022)

The current situation of warehouses in Vietnam today

In general, the current situation of warehouses in Vietnam is a shortage of warehouses. The reason is that the current industrial land areas are still at quite high rental rates because the current rental demand is still increasing strongly. Accordingly, the land for lease in industrial zones has become scarcer. (Nguyen, 2022)

In addition, warehouse management faces many challenges when the employees do not have expertise and experience. Some difficulties in warehouse management such as:

- The inspection of goods: This task is usually recorded in a book or stored in the file system for easy inspection, which is normally time-consuming and is prone to data errors, especially for businesses with various types of goods. (Nguyen, 2022)
- Inventory control: Regarding this job, it needs to be done regularly since if it is not done periodically, it easily drives reporting process too difficult and time-consuming. Therefore, warehouses should enter the data every three months or six months. (Nguyen, 2022)
- The arrangement of goods: Plainly, having a good plan for arranging goods makes it easier to check goods as well as to move goods more conveniently. Reversely, unreasonable arrangements will hinder the export and import of goods for enterprises. In fact, the lack of skilled and experience-obtained labours is one of the reasons causes less-efficiency in the arrangement of goods. (Nguyen, 2022)

Due to such issues in the warehouse industry in Vietnam, it is necessary to take action to solve them, and deploying IoT software applications in inventory management is one of the effective solutions that some companies in Vietnam should consider (Nguyen, 2022).

2.2.2 Warehouse operation

The roles of warehouses

In the supply chain, the warehouse plays a significant role in promoting efficient logistics processes and a seamless supply chain. Specifically, the warehouse selecting, and dispatching products accurately is critical to delivering the right product in the right quantity. Additionally, to deliver the right goods to the right clients at the right time, products must be properly labeled and placed onto the right vehicle with sufficient time to meet the delivery requirements. Furthermore, products in the warehouse must be ensured in good condition. In order to maintain and ensure such activities occur smoothly, different roles for a warehouse are highlighted in the supply chain today (Richards, 2021, pp. 6 - 7). Figure 8 below describes the involvement of the warehouse among entities in the supply chain. In particular, Richards (2021) stated that raw materials suppliers, component and finished goods manufacturers, wholesalers, retailers, and reverse logistics companies could all use warehouses to implement operational tasks. Besides, owner-operated warehouses can be subcontracted to third-party logistics firms (p.7). Accordingly, the following functions (table.1) are performed by these warehouses:

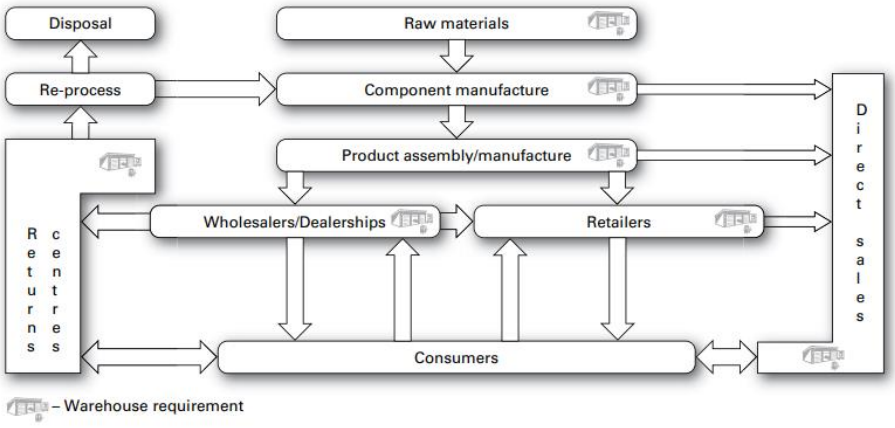


Figure 8 Warehousing in the supply chain

Functions of warehouses	Explanation
Raw materials storage	Used to store raw materials near the point of extraction or near the point of manufacture to ensure the continuous production. Plastics, precious metals, sand, aggregates, and other materials fall into this category. (Richards, 2021, p. 7).
Intermediate, postponement, customization, or sub-assembly facilities	➢ With the roles as being intermediate and customization facilities, businesses can use warehouses to temporarily store products at various stages of production and customize products before delivering them to customers (Richards, 2021, pp. 7 - 8). ➢ To perform functions as postponement and sub-assembly facilities, warehouses can be used as places for activities such as changing/ adding labels for goods printed in different languages or assembling varied graphic cards or memory chips, etc. (Richards, 2021, pp. 7 - 8).
Finished goods storage	Hold ready-to-sell products for manufacturers, wholesalers, and retailers. They serve as a buffer or safety stock for businesses, allowing them to stock up in anticipation of new product launches, anticipated increases in demand, and seasonality. (Richards, 2021, pp. 7 - 8).
Consolidation centres and transit warehouses	Receive products from various sources and combine them for delivery to customers or onto a production line. Furthermore, they can become retail stock consolidation

	warehouses, where consolidate products from a diversity of suppliers to deliver them to stores (Richards, 2021, p. 9).
Cross-dock centres[3]	Being viewed as "the future for warehousing" since cross-docking necessitates deliveries into these centres be labeled to get ready for onward delivery, which enhances efficiency and promptitude in responding to consumers and within the retail operation. Items should be kept in the warehouse for the shortest amount of time possible, promoting the target of receiving and dispatching goods on the same day (Richards, 2021, p. 10).
Sortation centres	Letter, parcel, and pallet distribution companies are the most common users of sortation centres, where goods are collected from all over the country and sorted by zipping or postcode. Subsequently, items are distributed to respective locations for onward delivery. (Richards, 2021, p. 10)
Reserve logistics[4] **centres**	Today, warehouses operating as reserve logistic centers are popular because businesses realize that returning products to stock or disposing of them quickly can improve cash flow. Consequently, numerous warehouses have been established to handle returned items. Unwanted and defective items returned to retailers will be consolidated and sent to returns centres, where they are checked, repackaged, repaired, recycled, or disposed of. (Richards, 2021, p. 11)

[3] Cross-docking facilities are more of a "sorting centre" than a traditional distribution centre, with goods passing through quickly due to limited storage space. (PLS Logistics Services, n.d.)

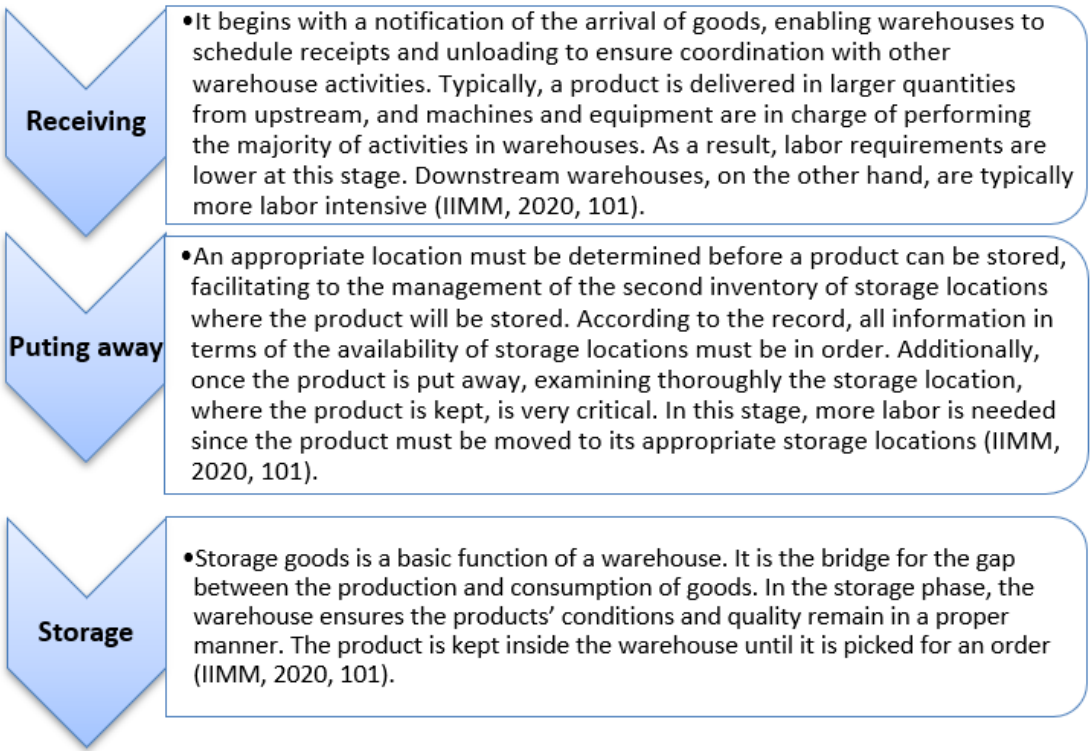
[4] Reserve logistics refer to good flow being transferred back from customers to suppliers. (logistiikanmaailma, n.d.)

Public sector warehousing	The establishment of these warehouses is the result of the rise in the number of natural disasters (e.g., Earthquakes, droughts, and tsunamis), third-party organizations are opening warehouses in strategic locations around the world, which are closer to the disaster areas, allowing them to respond faster. (Richards, 2021, p. 11)

Table 1 Functions of warehouses

Warehouse operation

A warehouse's primary function is to receive larger quantities of products, divide them into smaller quantities, and distribute them to users (IIMM[5], 2020, 100). With such a function, the process of warehousing includes:



[5] The Indian Institute of Materials Management (IIMM) is the National Apex Body who represents a diverse range of professionals involved in various aspects of Material Management, including planning, sourcing, logistics, and supply chain management (IIMM.org, n.d.).

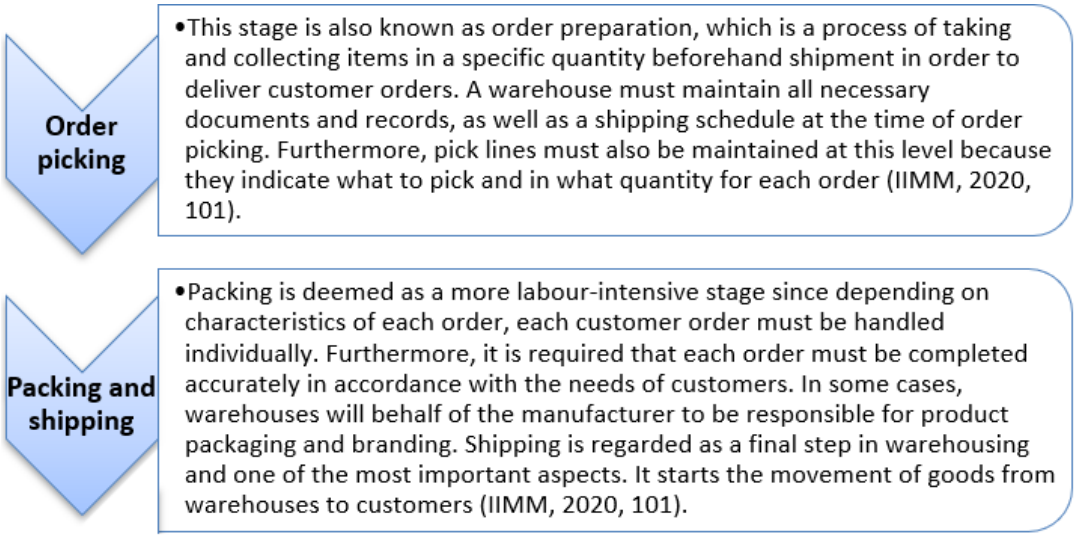


Figure 9 Process of warehousing

Through such a specific process of warehouse management, it can be seen that the warehouse's function is very vital for businesses, in which inventory management is the primary part. Therefore, the fundamentals of inventory management will be covered in the following section.

2.3 Inventory management

According to Chalotra (2013), inventory management is a business operation process that controls and ensures the flow of goods and services in response to demand (p.213). Also, when it comes to the definition of inventory management, Viale (1996) stated that inventory management helps to deal with the question of how much inventory is required to buffer against forecast, customer demand, and supplier delivery fluctuations (p.3). In that context, inventory is a list of items (e.g., raw materials or finished goods) and their quantities. In general, inventory management is an important part of the warehouse operation, its primary function is to maintain desired stock levels of products or items. Inventory planning and control systems must be based on the product, the customer, and the process (either manufactured or purchased) that makes the product available (Toomey, 2000, 1).

2.3.1 The fundamentals of inventory management

Basically, a warehouse contains various inventories which are categorized based on their functions in business operation. Particularly, to have an effective inventory management system in warehouses, primarily, businesses must understand inventory categories which are classified based on their position and their purpose in the supply chain as follows:

CATEGORIES	NAME	EXPLANATION
BASED ON POSITIONS IN THE SUPPLY CHAIN	**Raw material**	This type of inventory compasses all parts and direct materials that are purchased to be used in final products, and gains value as it is assembled into subassemblies, assemblies, and finally the shippable product (Viale, 1996, p. 7).
	Work-In-Process	Regarding this inventory, it is in process of being assembled into final products. In detail, direct labourers and machines are assembling raw materials, which are released from inventory and moved to a work centre, together as subassemblies, assemblies to complete the final products (Viale, 1996, p. 7).
	Finished Goods	These products are shippable inventories which can be delivered to distribution centres, retailers, wholesalers, or customers directly (Viale, 1996, p. 7).

	Distribution Inventory	This is inventory that is kept in locations as close to the customer as possible and pending delivery to the final customers. Distribution locations can be warehouses or stores that might be owned and operated by manufacturers or independently owned and operated (Viale, 1996, p. 7).
	Maintenance, Repair and Operating (MRO) Supplies	Basically, most businesses hold these inventories which are frequently low-cost, and consist of office and operating supplies as well as services. As a result, it is obvious that all organizations (e.g., manufacturers, wholesalers, retailers, banks, hospitals or even the Federal Reserve) are concerned about this type of inventory since it supports the business operation to take place smoothly (Viale, 1996, p. 7).
BASED ON PURPOSES	**Cycle stock**	Cycle stock, also known as base stock, refers to the parts that are the most "active" in the inventories. It indicates the amount of inventory that is available to meet average demand during a given period (Viale, 1996, p. 8).
	Safety stock	The purpose of safety stock (finished goods), also known as buffer stock, is to protect against fluctuations in demand or supply. It replenishes inventory held to protect against forecast fluctuations,

		changes in a customer's order, or late shipments from a supplier. In a manufacturing environment, safety stock has the effect of releasing an order and bringing inventory in before it is truly needed. To protect against forecast error, safety stock is kept in the master schedule (Viale, 1996, p. 8).

Table 2 Primary categories of inventory in warehouses

Because of such a wide range of inventories in warehouses, inventory sorting and inventory forecasting are two essential techniques for ensuring the efficient flow of inventory management in warehouses.

2.3.2 Inventory tracking

Definition

Inventory tracking refers to the systems and methods that a company employs to track the movement of raw materials or finished goods through the supply chain. The goal of having the right amount of stock to meet customer demand is fundamental to generating revenue (Jenkins, 2020).

Inventory tracking methods differ depending on the industry, the type of product sold, and the amount of stock held by the company. There are some following concepts, technologies and tools businesses have been using:

- **Manual Tracking**

This method is intended for businesses that are not yet ready to implement an inventory tracking system. As a result, businesses track their inventory with pen and paper. Companies using this method will need to update a master data sheet that categorizes all inventory at regular intervals or whenever a transaction occurs (Jenkins, 2020).

- **Card System**

Kanban [6]is a just-in-time [7](JIT) system designed to limit excess stock. This technique is also known as the visual signal or card method. Instead of attempting to forecast demand, Kanban is a pull system [8]in which cards are used to track stock, production, and inventory and signal when more is required (Jenkins, 2020).

- **Spreadsheets**

This method is used to organize and categorize large amounts of data. However, manually entering and managing data is prone to errors and is neither efficient nor scalable (Jenkins, 2020).

- **Open-source software**

For inventory management, some small businesses use open-source software to track inventory. In general, these platforms typically include interfaces, basic dashboards, and tracking capabilities. However, they frequently lack many advanced features, such as integrating with the rest of the company's systems, resulting in a data silo[9](Jenkins, 2020).

- **Third-Party providers**[10]

[6] The system was created by Japanese automakers, and the name Kanban is derived from the Japanese word for sign (Jenkins, 2020).
[7] Just in Time inventory is a management strategy that directly aligns raw-material orders from suppliers with production schedules (Banton, 2022).
[8] A pull system is a Lean method used for reducing waste in any manufacturing process. Using a pull system allows you to start new work only when there is a demand from a customer. This allows you to cut costs and optimize storage (Kanbanize, n.d.).
[9] A data silo is a collection of raw data in an organization that is separated from and not accessible to other parts of the organization. As a result, there is a lack of transparency, efficiency, and trust in the organization (Webopedia staff, 2021).
[10] Any unaffiliated person, company, or entity that performs services for a company is referred to as a third-party service provider. Third-party service providers are compensated for their services but have no ownership, stake, or equity in the company (Third-party service provider, 2020)

Retailers and eCommerce businesses that are entirely online or would like to outsource inventory management and logistics will use third-party providers since these parties technically receive, store, move, and track inventory for their customers. As such, businesses can avoid the costs of physical warehouses by using this strategy.

2.3.3 Inventory sorting

Definition

In inventory management, inventory sorting (inventory classification) assists organizations in allocating time and money. Furthermore, the systems of inventory classification allow businesses to deal with different product lines as well as a large number of stock-keeping units (Agboyi et al., 2019, p. 188).

Types of inventory sorting

As mentioned above, in warehouses, there are a variety of types of inventories and in order to manage and classify them effectively, companies are using common techniques as follows:

- **Stock Keeping Units (SKUs)**

A Stock Keeping Unit is known as a scannable bar code that enables warehouses to automatically track inventory management. The SKU is an eight-character alphanumeric combination which is a code that keeps track of the price, product information, and manufacturer. Enterprises can easily track the number of available products by adding SKUs to each product. They can set threshold limits to alert them when new purchase orders are required (Bloomenthal, 2021).

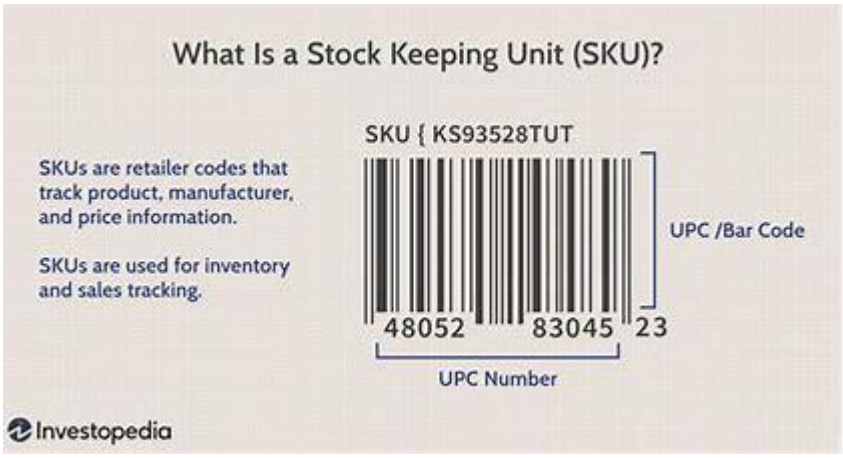


Figure 10 Example of SKU (Source: Image by Sabrina Jiang © Investopedia 2020)

- **ABC Inventory Classification**

ABC Inventory classification is used to determine the importance of each item of inventory in terms of value. In other words, ABC classification is a method of categorizing inventory items based on their monetary value to a company and this method was developed based on the Pareto principle[11] (Rohan Nadkarni et al., 2016, p. 24). In particular:

- Class 'A' items typically account for 10 per cent to 15% of total inventory items and account for 70% to 75% of total annual consumption value. (Rohan Nadkarni et al., 2016, p. 24).
- Class 'B' items typically comprise 15% to 20% of total inventory items and account for 20% of total annual consumption value. (Rohan Nadkarni et al., 2016, p. 24).
- Class 'C' items typically account for 70 per cent to 75 per cent of all inventory items and 5 per cent to 10 per cent of total annual consumption value (Rohan Nadkarni et al., 2016, p. 24).

[11] The Pareto Principle, named after economist Vilfredo Pareto, states that 80 percent of the consequences result from 20 percent of the causes. Other names of this principle are the Pareto Rule or the 80/20 Rule. (The Investopedia Team, 2022)

ABC classification ensures closer and more stringent control over high-value items. In addition, it frees up working capital that would otherwise be locked up for a more profitable channel of investment and allows for the relaxation of control for the 'C' items, allowing for the creation of a sufficient buffer stock (Rohan Nadkarni et al., 2016, p. 24).

- **FIFO Principle (First in, First Out)**

The FIFO method (first in, first out) is defined as a method of valuing First In, First Out inventory in which the first item purchased is the first item used or sold, regardless of the actual physical flow. The strength of this method is in the flow of data reported to the balance sheet since the first purchased item is the first one removed from the inventory account, and the remaining balance consists of items at lower cost prices, driving the price entered into the balance sheet to become balance (Sembiring et al., 2019, 2).

- **LIFO Principle (Last in, Last Out)**

LIFO is an efficient method of storing goods that do not have an expiration date. Items that have recently been imported will be prioritized for use or export. In inventory management, warehouses can use LIFO to sort stock such as coal, sand, brick, steel, plastic, or construction materials. Notwithstanding, this technique is not yet widely used in Europe (Dinh, 2020, p. 33).

- **FEFO Principle (First Expiry, First Out)**

In general, this principle is similar to the FIFO; yet the difference is the expiration date. To sort the items, the FIFO procedure uses the receiving and selling dates, whereas the FEFO procedure uses the expiry date. In practice, FEFO is a highly efficient method of controlling the stock of perishable items such as medical products, groceries, and pharmaceuticals. Despite the fact that the main purpose of

FIFO and LIFO are indistinguishable, the FEFO technique ensures that expired dates are checked on a regular basis (Dinh, 2020, p. 33).

With such a variety of inventory sorting techniques, warehouses can select the most optimal option to help to manage the inventory effectively, and obviously, this depends on both external and internal factors such as the sorts of products and purposes of the companies.

2.3.4 Inventory forecasting

Definition

Speaking of inventory forecasting, accurate demand forecasting plays a critical success factor in inventory management. According to Kerkkanen (2010), forecasting is the estimation of a future event or condition that is beyond the control of an organization and serves as the foundation for managerial planning. Basically, demand forecasting assists businesses, who are not able to know what their future demands are, not only to make long and short-term decisions in inventory management but also to reduce the risk of warehouse understocking and overstocking (p.13). Viale (1996) states that this estimate could be created by using mathematical formulas, data from unofficial sources, or a combination of the two. Forecasting is important to the success of any business planning system (p.29). The continuous change in inventory demand has been influenced by many trend factors, including seasonality and economic issues (Bon and Chong, 2009, p. 3937). As a consequence, inventory forecasting is a crucial technique for optimizing demand volatility and stock variability (Dinh, 2020, p. 34). Specifically, a thorough understanding of demand fluctuation is frequently necessary for forecasting inventory demand. To do so, descriptive and explanatory approaches are used to examine the demand fluctuation (Brown, 1977, p. 73).

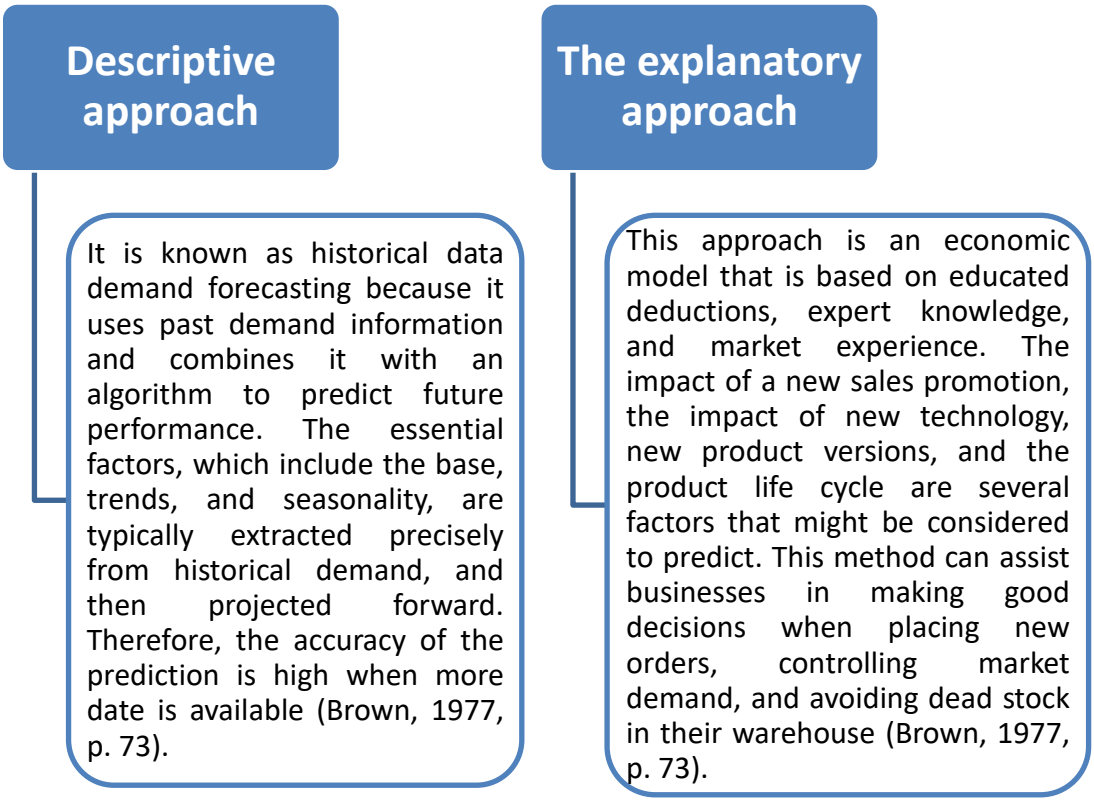


Figure 11 Approaches are used to examine the demand fluctuation

2.4 The revolution of inventory management

The history of inventory management has changed significantly since the past. Depending on the development periods of society and technology, inventory management methods have transformed from manual approaches to advanced ones. In particular, Lusk (2017) stated a stage-by-stage breakdown of inventory management reform as follows:

Manual counting

Prior to the Industrial Revolution, manual counting was used to calculate the number of goods sold or leaving the warehouse in a day. At the end of each day, shopkeepers and merchants would count the number of units sold and determine how many items were sold. Furthermore, merchants typically forecast future demand based on their intuition and working experiences. It would take hours or even days

to counting manually physical inventory if the stock was overloaded. In general, this method is prone to errors and has a low level of accuracy.

Punch card

As efficiency and mass production became the primary goals of businesses during the Industrial Revolution, the inventory management process was completely transformed. In the 1930s, Harvard University researchers developed the punch card system, which was used to track inventory from manufacture to warehouse and point of sale. Punch cards could correspond with catalogue items that were readable by computers thanks to the tiny holes in sheets of paper. The information would be relayed to employees in the storeroom, who would then bring the item to the customer's front door. Based on the punch cards customers filled out, businesses could keep track of which products were ordered and record inventory and sales data. Regrettably, this process was too costly and too slow to remain widely used and meet rising business challenges.

The Modern Bar Code

In the 1940s and 1950s, the first barcode model was developed, which included ultraviolet light-sensitive ink and a reader to accumulate item labels and track inventory. The development of computers and software from the 1980s to the 1990s has made the barcode method more flourishing and efficient today. At the time, scanning equipment replaced manual inventory tracking; however, data loading into systems was still done by hand.

The Radio Frequency Identification (RFID)

During the 2000s, RFID (radio frequency identification) technology became commonplace in warehouses, factories, and retail stores. RFID employs a microchip to transmit product information, such as type, manufacturer, and serial number, to a data collection device. With the introduction of RFID technology, businesses no longer needed to manually enter data, which assists to eliminate the likelihood of

errors and reduce the burden of time. This technology also allows for database updates and continuous access to real-time sales data.

2.5 IoT integration in Inventory management

Previous research has discussed the integration of IoT into warehouses in general, and inventory management in particular. The majority of research indicates that IoT integration in inventory and warehouse management is creating an evolution in businesses and supply chain management.

According to Ding (2012), traditional warehouse management models are less efficient due to business evolution and rapid changes in product demand. The proper use of warehouse data in conjunction with IoT inputs is bringing about a new warehouse and inventory model known as the Smart Warehouse Management System. An intelligent warehouse and inventory model are promising for current businesses since traditional inventory methods and warehouse operations, which are technically based on a manual interpretation of the large data, are time-consuming and inefficient, and can result in tremendous losses if errors occur (p.204-207). In another research, Riad & al., (2018) stated that with the crucial role of inventory management in the supply chain, businesses are constantly seeking new technologies and models which are able to help them to improve the efficiency of inventory management. Linking IoT to inventory management has several advantages, including location and quantity tracking, environmental monitoring, and predicting production machinery damages and errors (p.1-2). Due to such high demand for IoT integration into inventory management, there are IoT applications have been invented and applied to inventory management based on the essentials of IoT mentioned in the 2.1 section:

Radio frequency identification (RFID) tags, readers

As mentioned in the 2.1.1 section, RFID tags have the ability to store more data than barcodes. They can provide additional information about each item, such as

its size, manufacturer, expiration date, serial number, production line, and other details. An RFID reader can scan up to 200 tags at once, which is faster than barcodes (Bhatt, 2021). This technology is one of the evolutions for warehouses because it allows them to ensure that their products are always available and gives them constant access to real-time data, which benefits tracking, authenticating products and shipments, and accurate demand forecasting (Lusk, 2020).

Wearable devices

Warehouses can instantly identify the product and the packages by using connected devices such as **smartwatches** and **smart glasses**[12] (Bhatt, 2021). Warehouse managers can use these devices to view visual displays of order-picking instructions and item location information. Also, warehouse managers can decide where to place a specific item/product on the cart by using smart glasses. Furthermore, smartwatches and smart glasses are user-friendly, reducing onboarding and training times (Aditi, 2019).

Sensor devices

You can track products and stocks at each stage of the supply chain by incorporating sensors. If a specific temperature is required for inventory, warehouses can use humidity and temperature sensors to monitor and mitigate product damage risks (Bhatt, 2021).

Software-as-a-Service (SaaS)

With inventory tracking features, a SaaS solution enables warehouses to easily keep an eye on the stock. This is an application created based on cloud computing

[12] Smartglasses, also known as smart glasses, are wearable computer glasses that display information in addition to or instead of what the wearer sees. (Wikipedia Foundation, 2022)

and especially beneficial for startups that are not yet ready for a full-fledged enterprise inventory management solution (Jenkins, 2020).

Autonomous Mobile Robots (AMR)

AMR is known as a popular IoT technology that businesses use to move or handle products in the warehouse. Autonomous robots can move independently and use sensors and cameras to navigate. It is critical for smart warehouses to apply AMR to their operation since robots are used by businesses to transport and move shelves to workstations, which helps to reduce order picker travel. Autonomous robots have an integrated scanner that confirms the selected item. AMR also has sensors that track data so that warehouse managers can receive feedback (Aditi, 2019).

2.6 IoT Implementation Benefits

In general, deploying IoT applications into inventory management has brought about benefits for businesses, which were discovered by various researchers. Several significant points can be highlighted as follow:

According to Rejeb (2020), IoT is the background for smart inventory management by optimizing key processes in warehousing operations, lowering labour costs, and increasing throughput time. IoT applications allow reusable assets (e.g., inventory totes and pallets) to be tagged with IoT tags or devices that guide and direct warehouse pickers to their storage locations. Consequently, IoT not only helps to automate warehousing activities such as packing and picking, but it also increases effectiveness by reducing the manual handling times spent on locating the exact position of materials and products in warehouses. More importantly, IoT contributes to saving costs and reducing error since human intervention is mitigated by automation (p.6).

Similarly, Yerpude & Singhal (2018) emphasized that IoT gathers and transmits real-time data over the internet, which is then streamed into business models,

allowing for quick real-time decisions (p.8). Furthermore, Yerpude and Singhal (2018) discovered that IoT can achieve a radical shift in a warehouse, transforming it into a proactive, smart, and progressively productive organizational entity, assisting organizations in saving costs and increasing warehouse productivity with the same resources. (p.11).

In the research "the effect and impact of IoT on Supply chain management" (2019), Sharma & Sharma concluded several benefits of IoT-enabled inventory management. In particular:

- Actual inventory levels are measured using real-time data from sensors. (Sharma & Sharma, 2019, 308)
- Real-time inventory count updates, as well as alerts for mismatches between inventory data in ERP[13] and actual inventory in the warehouse. (Sharma & Sharma, 2019, 308)
- Stock-output losses are avoided as the restocking process becomes more efficient. (Sharma & Sharma, 2019, 308)
- Automated Warehouse Navigation. (Sharma & Sharma, 2019, 308)
- End-to-End Inventory Visibility. (Sharma & Sharma, 2019, 308)

According to The Daily Plan IoT, applying IoT systems to track inventory improves forecasting accuracy. Specifically, IoT devices aid in determining the lead times required to assemble all of the required manufacturing parts. Accordingly, excessive lead times can be identified, preventing bottlenecks caused by missing critical parts. (Grainger Editorial Staff, 2020)

Fedyk (2020) also highlighted the advantages of IoT implementation in inventory management such as reducing the need for manual labour and minimising human

[13] Enterprise resource planning (ERP) is a business process that manages and integrates the critical components of its operations. Typically, planning, purchasing inventory, sales, marketing, finance, human resources, and other functions can all be integrated by an ERP software system. (The Investopedia Team, 2021)

errors, bringing more economical and faster development, expanding the role of machinery efficiency and better goods and equipment inspection, and improving visibility and transparency of the inventory process.

Examples of key business players applying IoT technologies to warehouses

- **Amazon Warehouse Automation**

Amazon is a major American multinational technology corporation that specializes in e-commerce, digital streaming, cloud computing, and artificial intelligence. It employs semi-automated warehouse management services, in which robots collaborate with store managers. IoT devices handle routine tasks like scanning barcodes and moving packages. To perform these basic tasks, Amazon's automated warehouse employees employ 400 robots. Therefore, employees can use IoT devices to track inventory, improve productivity, and make the entire supply chain process smoother and more efficient (Aditi, 2019).

- **DHL Smart Warehouse**

DHL is a global logistics leader. It offers logistics services to industrial supply chain management, including national and international parcel delivery, international express, e-commerce shipping, and fulfilment solutions. DHL has tested a wide range of IoT devices in its warehouses. In its warehouse, the organization employs robots, smart glasses, autonomous vehicles, and drones. These IoT devices allow store managers to easily identify products and sort through parcels (Aditi, 2019).

2.7 Opportunities of IoT integration

By improving tracking, traceability, quality management, and compliance, updating legacy inventory management systems with IoT devices increases overall efficiency. Accordingly, IoT devices are quickly becoming a cost-effective and efficient solution for inventory management for many organizations. The massive amount of real-time data generated by IoT devices can assist organizations in identifying

opportunities to improve overall logistics, inventory, warehouses, and supply chain management (Grainger Editorial Staff, 2020). Also, Aditi (2019) opines warehouses are more than just inventory and storage facilities in the present era. Most businesses are investing in IoT-enabled warehouses to improve operational efficiency and reduce costs in their supply chain. Moreover, according to Dinh (2020), the global impact of the covid pandemic has put unprecedented strain on the modern supply chain. The business's operation and productivity have been hampered by a lack of workers and social distancing policies (p.45). Therefore, now is an excellent time for businesses to take more action and be proactive in IoT applications and automation. It could be a step forward for businesses looking to incorporate new technologies into their operations.

2.8 Challenges of IoT integration

Besides the benefits and opportunities of implementing IoT applications in inventory management mentioned above, using technological applications, in general, always contains challenges that cause enterprises to be afraid to deploy advanced technological devices into operation. In this context, the author would like to present obstacles that companies could face when applying IoT to inventory management and these obstacles are gathered from previous research.

In their research, Abdelhadi and Akkartal (2019) clarified the limitations and challenges of using RFID. To begin with, technological issues are mentioned as one of the main challenges because tag read-range distances are insufficient to consider for consumer surveillance, which is understandable given that most tag read range depends on antenna size and transmission frequency. Furthermore, a limitation in storing information in tags, as well as defective and poorly constructed tags, can be the source of technical issues when using these IoT tags. Moreover, the lack of development of appropriate information management tools leads to difficulties in effectively managing data, as well as high costs for tag deployment. Above all, the greatest challenge of using these tags is that confidentiality and privacy may be violated as a result of the information being compromised (p.29-30).

In another research, Shee and Vass, and Miah (2020) also concluded that currently, the main barriers to IoT adoption are investment costs, a lack of management vision, and general staff issues, which can be described as employee resistance to change and fear of new technologies (p.21). Additionally, according to Grainger Editorial Staff (2020), warehouses have evolved into critical business hubs in recent years, increasing efficiency and speed across the entire supply chain. Many businesses have begun to use IoT devices for inventory management. However, there are some concerns about IoT implementation that should be addressed. Specifically, businesses must consider the cost, security, and scalability of integrating IoT devices into their existing inventory management system. Besides, Chabanon (2019) listed three main challenges when applying IoT technology in supply chain management. Chabanon believes that security is the main barrier to businesses who are intending to use IoT devices since every internet-connected system faces serious security concerns. Particularly, there has been an increase in cyber-attacks in the world recently, and IoT technology could be an enticement for hackers. This is a significant challenge that may necessitate the development of new practices by companies that adopt this technology to ensure maximum security and stability by incorporating more advanced cyber threat protection solutions into their network. Subsequently, the author hopes that enterprises will consider reliability and integrity, because with any new technology comes the question of reliability, and enterprises implementing IoT will expect backup solutions in the event of a technology failure, which could disrupt the entire supply chain and result in irreversible damage. As a result, it is essential for industrial enterprises to clearly define the objectives and boundaries of their IoT projects. Eventually, Chabanon pointed out the last challenge, which is relevant to the future development of enterprises, is the scalability of IoT systems as IoT systems must be adaptable and scalable enough to supply tailored solutions to a wide range of industries. Therefore, enterprises must take the development orientation of the companies into account if they desire to implement IoT technology into industrial systems.

All in all, the theoretical sections mentioned above have provided a pretty solid foundation for the thesis topic before the author begins the data collection and analysis stage. Accordingly, the following research process will present all of the steps and methodologies used to gather information for the thesis.

3 RESEARCH PROCESS

3.1 Choice of research methodology

Research is defined as a diligent search, studious inquiry, investigation, or experimentation with the goal of discovering new facts and findings (Adams et al. 2014, p. 1). A research project can broadly refer to any subject of inquiry involving gathering information, interpreting facts, and reviewing existing theories or laws in light of new facts or practical ideas (Adams et al. 2014, p. 1). Simultaneously, Adams et al. (2014, p. 6) stated that “research methodology is the science and philosophy behind all research” since it enables us to comprehend the various ways in which knowledge can be created. In general, there are two principal methodologies of research that can be found in the literature, which are quantitative and qualitative research. Depending on the purpose of specific research, the researchers can choose the appropriate methodology for their studies or even combine both.

First of all, quantitative research is concerned with identifying and explaining reality as it currently exists. Numerical data is employed to explain and define problems and objects that occurred as well as explore the correlation among subjects. Accordingly, the term quantitative is frequently used interchangeably with statistics (Biddix et al. 2018, p. 162). In reality, the most common quantitative tool used by researchers is a survey or questionnaire, which is designed to collect data and statistically analyze it.

Qualitative research, on the other hand, aims to investigate and represent reality as it exists in a context, as well as to illuminate how individuals experience that reality since individual experiences and perceptions are complex, and thus cannot be evaluated by using conventional data. Therefore, by emphasizing and exploring the characteristics of an individual, place, process, or phenomenon, qualitative methods answer "how" and "why" questions of the study (Biddix et al. 2018, p. 76).

Because the purpose of this study is to focus on exploring individuals' experiences and perceptions to answer research questions, qualitative research was chosen as the primary research methodology in this paper. Furthermore, using this method, the researcher could indeed discover the participants' feelings and expectations (Neelankavil 2015, p. 51). As a result, it is explicit that qualitative research is both useful and appropriate in this study. In this paper, primary and secondary data are gathered for the paper to conduct a qualitative analysis of the research.

3.2 Data collection

Data collection is the process of gathering and analyzing pertinent responses provided by target participants (Pritha, 2020). The procedure for arranging these data for theoretical and empirical research will be proposed.

Firstly, secondary data was collected to serve this paper. Secondary data is information derived from the works and publications of other authors, which means the author gathered secondary data primarily from books and previous research or articles that were both physically and electronically available. The data was collected based on the main topics as well as relevant ones in both English and Vietnamese. Additionally, the author also reviewed newspapers which convey related information to the topics. Accessibility is a benefit of using secondary data in academic research. Secondary data are more easily accessible than other types of data, making the data collection process easier (Neelankavil 2015, p. 60). Furthermore, writers can benefit greatly from secondary data for their research process as secondary data analysis refers to the evaluation of the data previously studied and condensing it into a more concise form (Smith 2008, p. 20). From the author’s perspective, using IoT devices in inventory management in warehouses is becoming increasingly popular, and several experts and researchers have conducted relevant studies, which facilitates the author to consult a plethora of information sources to research. Primarily, secondary data is used to establish the foundation for the theoretical part because this section is typically structured based on principles and knowledge that are widely available.

Secondly, the primary data for this study was attained through authentical analysis and assessment of the information gathered from participants since the author chose qualitative research as the approach for this research. Consequently, in this paper, the primary data is gathered from interviews. Adam et al. (2014, p. 8) emphasized that primary data is considered "empirical" because it is created "based on evidence and real-world events". In particular, primary data is used and presented in the results and findings section to enlighten research questions and thesis topics. In that way, the author is able to withdraw the conclusion as well as new findings in comparison to the theoretical parts.

3.3 Interview method

According to Biddix et al., (2018), interviews appear to be the most commonly used method of collecting primary qualitative data in qualitative research (p.75). This is understandable since Hammersley (2013) opined interviews primarily support research designed to explore individual perspectives and opinions, which is rather suitable for this research. In general, there are several methods for designing and constructing an interview and a semi-structured interview is one of the examples. Regarding this type of interview method, it is conducted by using questions that were defined beforehand and these questions assist to guide the interview (Adams et al. 2014, p. 144). In particular, the semi-structured interviews enable participants and interviewers to involve in the interviews more relaxed and open manner, especially, since the interviewees appear to be able to express their original thoughts more freely. Thanks to that, the author can take advantage of this interview method to explore deeply aspects by developing the questions based on participants' answers.

In order to collect the primary data for this research, the guiding questions (Appendix 1, 2, and 3) are conducted, which are designed based on the research questions and theoretical sections. The question lists are constructed and divided into five categories to effectively collect data from the participants, including general questions, the impact of IoT on the inventory of warehouses, the opportunities,

and challenges of deploying the IoT in inventory management as well as future expectations (trends) of IoT in inventory management in particular and in warehouses or supply chain in general. The purpose of categorizing the question lists is to help the author analyze the process and to make it easier for interviewees to grasp the idea and respond.

In the next step, to conduct the interview, before the official interviews, the author approached all participants to briefly explain the purpose of the interview and arranged a suitable meeting date for both sides. Because the researcher is a considerable far distance from the interviewees, the interviews were conducted remotely via Microsoft Teams. To carry out the interviews effectively, the questions were sent to interviewees in advance so that they could preview, prepare, and add comments if any, which is truly beneficial to the interview process. In addition, due to the characteristics of the interview method, information is primarily gathered through conversations, which means that the information is conveyed without any physical paper. Therefore, before beginning any discussion, the author asks the interviewees for permission to record the session so that the results of the interviews can be easily transcribed. During the interview process, it is very crucial for the interviewer to organize, meditate and arrange the interview flexibly, which makes interviewees feel at ease and open-minded. Consequently, the interviewees express their thoughts and perspectives as well as experiences about diverse aspects.

3.4 Respondents' background information

In this research, the author carried out interviewing five participants from the Quoc Hung TST Co., Ltd. The participants are individuals who are working in positions in warehouses and positions being impacted by the warehouse's operation. In particular, the list of interviewees encompasses the chief executive officer (CEO), one warehouse manager, one logistics manager, and two employees who are working in the company warehouse. The participants were chosen based on

the purpose of the thesis. Specifically, the author would like to explore the different perspectives as well as experiences of various positions to present how participants think and evaluate the IoT integration into inventory management in warehouses. Furthermore, through interviewing the CEO of the company and employees who are daily using those IoT devices, the thesis would disclose the factors that influenced the CEO's decision to apply IoT devices in warehouses along with realistic thoughts and feelings when working with IoT warehouse systems.

Because the interviewees' identities are kept private, the researcher used positions to represent each participant's point of view, and for two employees, the author used aliases which are employee A and employee B.

Full titles	Name/ alias used in the thesis
Quoc Hung company's Chief Executive Officer	CEO
Quoc Hung company's Warehouse Manager	Warehouse manager
Quoc Hung company's Logistics Manager	Logistics manager
Warehouse employee	Employee A
Warehouse employee	Employee B

Table 3 List of participants in interviews

4 RESULTS AND FINDINGS

After five interviews, the author gathered useful information from participants and afterwards, the author implemented an assessment and analysis process of primary data. As a result, the findings were distributed and arranged in below specific sections.

4.1 The benefits of IoT in inventory management in warehouses

When asked about the benefits of IoT in inventory management in warehouses, the interviewees responded pretty positively to questions. Especially it can be seen plainly by giving points for the level of impact of IoT on inventory management in the warehouse from scale one to five. (Table 4)

INTERVIEWEES	POINTS (1-5)
CEO	3.5 - 4
Logistics Manager	4
Warehouse Manager	4
Employee A	3.5
Employee B	4

Table 4 Interviewee's evaluation of the level impact of IoT on inventory management in the warehouse from scale one to five

Besides, the interviewees also provided primary IoT devices that the company is using in the warehouse as follows:

- RFID tags and readers: Mobile computers with RFID or Global Positioning System (GPS) are full independent computers that include all the peripherals and interfaces required to collect, manage, and store data collected via RFID tags.
- RFID Printers
- Smart glasses
- IoT Software Platform
- RFID rugged tablet devices: These devices can read RFID tags from up to 22.9 meters away, allowing workers to read up to 1300 tags per second.

Specifically, they all agreed that IoT has brought significant advantages to the company since the year the company started applying IoT in the warehouse. In particular, the CEO expressed that IoT integration into the warehouse has helped inventory management more effectively, which pushes productivity to increase remarkably. The CEO explained that although the warehouse also used computer software (e.g., spreadsheets) to be able to understand warehouse operations in the past, periodic inventory must still take place, and normally, the difference between real information and information on the machine is still very different. This was because entering data manually was still required when using spreadsheets and sometimes human errors are unavoidable. However, since the adoption of IoT, each item and shipment are analyzed through IoT-enabled warehouse management software to identify bottlenecks and track the minute-by-minute movement of inventory to identify warehouse performance. From an expertise perspective, the company is a manufacturer; thus, the warranty of the number of materials serving for assembling and production always available is very crucial for the company's operation. The constant up-date for the actual inventory level facilitates the companies to be more proactive in preparing materials for the manufacturing process. Once the material number is equipped sufficiently, the production process is not interrupted. Accordingly, the customers receive products and orders promptly. Back years before the year 2020 when the company had not applied the

IoT to warehouses yet. There were plenty of orders piled up due to a lack of raw materials. Notwithstanding, from 2020 to backwards the situation has become better when the inventory management has improved after IoT integration into the warehouse. The coordination of input and output of the raw materials has been efficient and stable in the warehouse, which optimizes the warehouse space efficiently. This is especially important when the warehouse's functions vary, such as storing raw materials, acting as a sub-assembly facility, and storing finished goods. The CEO emphasized that it is obvious to state that customer satisfaction is one of the biggest targets that every organization aims to and Quoc Hung company is not an exception. According to his opinions, the IoT not only brings effectiveness in inventory management and warehouse operation but also enhances the reputation of the company in the customer's eyes.

In addition, when it comes to this point, the logistics manager also opined his perspective that, from 2020 and earlier, the company received quite a lot of complaints from customers due to slow delivery. At that moment, the issues usually derived from the slowness of picking goods up and especially the losses of shipments during the shipping period. Mostly, the products would be loaded into the company's transportation to ship to the customers and during the delivery time, the logistics team would be updated information by the shippers. Nowadays, everything has changed, IoT devices have contributed an important role in the shipping process. With RFID tags tagged in products or pallets, the shipments are able to be scanned by using the machines (e.g., Mobile computer with GPS or RFID readers), and the status of shipments (e.g., picked up, delivered, etc.) can be updated immediately on the monitoring system, which helps the logistics team follow up the delivery process of the orders and their status. It can be understandable because IoT devices such as GPS monitors can track everything from the location of a shipment to its current temperature, providing up-to-the-minute information that helps Logistic managers understand real-time data. IoT integration in ware-

house has assisted the shipping to become more easily to monitor than ever. Consequently, the company avoids losses of shipments as well as ameliorates the logistics management.

On the other hand, the warehouse manager also revealed his point of view that a properly implemented IoT system has helped to improve the enterprise's availability of sufficient raw materials and demand forecasting for tools and materials used to serve maintenance and service levels because the IoT system supports the company in re-ordering materials for manufacturing and maintenance. By automatically collecting data, IoT system improve data accuracy and provide with better documentation. IoT improves data collection operations in a variety of ways. First, it greatly reduces the impact of human error in data collection. It allows data to be collected at any time or at defined intervals, which saves labor time to collect data manually. It can then allow businesses to collect data that is difficult or impossible to collect manually. Furthermore, speaking of inventory management, inventory control is an important part of warehouse and supply chain management and in this case, the Quoc Hung company's inventory management contains adequate characteristics of typical fundamentals of inventory management. By using advanced IoT sensors that automatically track and analyze inventory locations and inventory levels, warehouse managers and employees can create an accurate and up-to-date inventory tracking system every minute.

The employee A intimated that the IoT inventory control system automatically adjusts the inventory counts with records, making counting work unnecessary and improving consistency and reliability. Therefore, minimizing human error has also become possible thanks to IoT. Besides, the employee B indicated a standpoint of the benefits from IoT integration in warehouse. Specifically, tracking goods' locations facilitates the picking and packing products become more simply and effectively thanks to smart glasses and mobile computer with RFID or Rugged sled accessory for iPad device. In that way, the performance of warehouse activities is also boosted, and it simultaneously promotes the delivery process quickly.

In general, the opinions from interviewees demonstrated that the benefits of the IoT integration to warehouse are undeniable. Applying IoT devices or connecting products to IoT Platform strives warehouse's activities in particular and the company's operation in general more efficiently. Indeed, this information could be an encouragement to other Vietnamese businesses who are specializing in the manufacturing or have the same line products as Quoc Hung company. However, considering the broader perspectives, advantages mentioned above are also suitable for other sorts of businesses such as retailers or stores. It is explicit because most of businesses have the different products and goods which they are offering to customers. From manufacturers to retailers either involve in inventory management and warehouse operation. As such, fast packing and picking goods, optimizing of the warehouse’s space, providing the actual inventory level and effective monitor shipments as well as reasonable and constant demanding forecast of goods could be advantages that businesses could obtain when implementing the IoT in warehouses. Consequently, it can be seen that IoT implementation in inventory management in warehouse might be a promising model that most of businesses should consider at the moment. As the CEO stated, the IoT implementation into the warehouse has brought to the company remarkable benefits and he completely believes in the positive support of IoT in improving inventory management in the future when the machine runs really smoothly. At the present time, this is a good signal not only for Quoc Hung company but also the Vietnamese businesses because it indicates that somehow the effectiveness of IoT integration to warehouse to the company's general operation.

4.2 Opportunities of IoT integration into inventory management in warehouses

When it comes to opportunities of IoT integration into inventory management in the warehouses, the CEO of Quoc Hung company expressed that this is a good opportunity and appropriate time for Quoc Hung company to apply IoT when other businesses in Vietnam are hesitant to use it because then, the business can be called ahead and gain many advantages in this industry. Currently, there are

many companies in the world that have used IoT for warehouse management and have recognized the increased convenience and efficiency when using IoT. In the Vietnam market, IoT technology is new, but compared to the world, IoT technology has been widely applied; therefore, using IoT in warehouse management is appropriate and right. Furthermore, the CEO also shared that one of the main reasons why companies in Vietnam hesitate is because they are too familiar with the old system, the transfer process costs a lot, and it has to change the whole machine and retrain the source. Manpower also takes a lot of time. However, it is undeniable the benefits that IoT technology has brought to the current and probably future development of warehousing when applying technologies inherited from IoT, which made Quoc Hung's board decide to apply this technology to the Quoc Hung business. Especially, this integration could bring potential opportunities for the finance area later once the operation becomes smoother. This can be comprehensible as applying IoT devices helps the company cut down the labor cost at some points, and the CEO believes that this financial opportunity can be seen more clearly in the future when using the IoT devices is steady. Furthermore, at the time of the epidemic peak, production flow could not be made much, so the warehouse was also more static, easier to apply the transition process than when goods went in and out of the warehouse continuously.

In terms of the warehouse’s perspectives, he completely agreed with the opinions expressed by the CEO above since once the company can keep pace with the advanced technology, which is good leverage for the company to reach out to the world market. Moreover, from the warehouse manager’s side, applying the IoT to the warehouse has facilitated warehouse employees to access to new technologies being developed and applied worldwide. The more the employees get familiar with new technologies, the easier the company invests and approaches novel technologies in the future.

The Employees A and B also stated that working with IoT devices in the warehouses has made not only them, but also other colleagues develop their skills significantly, which contributes to building a skilled workforce down in the line. Indeed, warehouse manager and employees A, and B confirmed that thanks to applying IoT devices in warehouse, most of the employees have been able to read figures and recognize goods and product data quite quickly, from which communication between employees and devices become more systematic, and warehouse workers can handle tasks effectively. Especially, the company discovered new talents after applying IoT technology. Several new talents performed their unexpected capability in the technical area. In particular, they can understand faster than the remaining employees in overall, which would be a great advantage for the company if the company desire to invest and develop further in the technology field in the future. Aside from that, once there are any updates related to IoT devices and technology in general, they would be a potential workforce to support the company in instructing and training other colleagues during working time owing to their good knowledge and grasping ability. Therefore, the company could cut down the training expenses for IoT experts' lessons. It could be said that IoT integration in warehouse is not only a good opportunity for development orientation but also for the company's financial status later.

In the same context, from the logistics manager's perspective, since inventory management also affects the logistics process to a great extent, the logistics specialized work has also been optimized. Searching for product information in order to process the import or export procedure is now more efficient with all the data being stored and retrievable in the IoT network. This proves that the IoT integration in the warehouse has brought opportunities for optimizing the access capacity of goods' data for the logistics team, leading to increase the effectiveness in the preparation and delivery process.

Last but not least, the CEO revealed a remarkable point from his observation and experiences. In detail, it can be seen that most partners would like to come to the

business premises such as warehouses and manufacturing places to observe the overall production process, equipment and machinery systems or how the workers are working there. Accordingly, partners would have remarks and judgements themselves and make decisions to establish the partner relationships in the future based on their observation and impression of the company's facilities and operation. As such, the implementation IoT devices and machines in the warehouse is also play a crucial role to impress the partners at the first sight since this indicates the professionalism, industrialization, and modernization of the company. Indeed, professionalism can be illustrated not only through operation but also facilities and infrastructure, especially, when technology become advanced and popular with businesses in the world. Adopting IoT technology in the company's operation could help to enhance the business's reputation and image, which is very vital because the company is targeting to reach out the international market, it would be an invisible catalyst to obtain the trust of customers and promote in building long term partner relationships. In addition, once gaining the trust from customers and building well its reputation, the company could attract investment because investors might see a good capacity and effective performance of the business, which would be a good launch pad to support Quoc Hung to go further in the market in the future.

4.3 Challenges of IoT integration into inventory management in warehouses

Speaking of the challenges of IoT integration into inventory management in the warehouse, the interviewees shared plenty of ideas and opinions to explain the difficulties that the companies have faced since applying IoT technology in the warehouse. The first challenge partially mentioned by CEO in the section 4.2 above is the high cost of machinery and switching from the old system to the new system. Obviously, in order to bring the IoT to the warehouse, the company has invested quite a lot in IoT devices which are advanced machines and systems, and the more advanced the devices are, the higher the cost is. Besides that, applying the new technology also means the company requires to pay more for training and at the

beginning stage to have the company's employees trained and used the new system and devices. Errors or difficulties can occur when using, especially when businesses do not have a clear plan at the early stage of product development, which makes technicians appear frequently and directly repair. Not only that, software failures, server issues, network latency, and infrastructure challenges can also add up to the associated costs. These are extremely expensive fees. In this stage, the financial requirements are considered as a challenge that the company had to calculate thoughtfully. Furthermore, the shipping from the old system to the high technology system led to difficulty in human resources. Ensuring and arranging the workforce to learn about the new system and devices was extremely struggling because the switching occurred when the Covid 19 has transformed quite complicatedly and dangerously in Vietnam. The training period kept postponed due to quarantines, which caused higher costs and a delayed process. In the meantime, although the transformation focused only on inventory management, it also affected other parts of the supply chain, so it was also difficult for employees to work with a new apparatus.

Concurrently, the logistics manager shared some similar thoughts with the CEO on this subject. From his point of view, inventory management has been changed to new apparatus, which means other teams of the company must be aware of how the new system is running as well since other departments sometimes need some data, and they should know how to get those. For example, the logistics team regularly updates the status of the shipments or data of products. To do so, the logistics team is also required to have knowledge of new devices and systems. Certainly, in the beginning, it could be complicated and relatively sluggish regarding training the personnel to adopt the new way of working. Because in order to use IoT to the full extent to make the process in the warehouse more efficient, it requires extensive training and upgrading skills for the employees.

Simultaneously, regarding workforce challenges, the warehouse manager shared his perspective that the biggest barrier could be that the employees have the fear

of adopting new things, especially things related to new technologies because they all know that in order to understand and use the new high-tech devices and systems are not easy. It is understandable because the workforce of the company is too familiar with the old system and learning about new devices would make them feel more pressure and stress in working. Indeed, Vietnam is a socialist country, people's lives are still poor, and the level of scientific and technological knowledge is not really uniform. Therefore, convincing people to use technology applications that require thinking and creativity is extremely difficult. With traditional thinking and the fear of change and the fear of approaching new things, it is not an easy problem for the IoT trend to penetrate every Vietnamese business. For the warehouse manager, the financial challenge or even the delay of training and slowness in approaching IoT technology in the warehouse is not the biggest barrier because those could be solved by various methods. However, the fear of learning new things would be the biggest problem if the company could not find the solutions because the fear belongs to the spirit and will of humans and they can determine how people can approach intentionally matters and understand them or even the success of applying IoT technology in warehouse and inventory management. As a result, once the employees keep that fear in their mind, they would not be able to learn and access the new devices and systems since they think that they can never get that.

Additionally, employees A and B opined that one of the human resource challenges is the structure of labour would be changed. It is explained that because the workforce in the warehouse includes a diversity of ages and two third of labourers have been working for Quoc Hung Company for a long time and they are not good at using new devices and technology. The employees, although they have been with the company for a long time, may be dismissed from their current position because the new apparatus does not need so many human resources and they cannot respond to the changes in the company. This is the main concern for employees who are working in the warehouse, especially in inventory management

because once the system is running smoothly and upgraded more and more advanced, a majority of the employees can lose jobs. This can influence on effectiveness and productivity of employees when working because they might pretend to work ineffectively with new devices and systems as well as bring up unwilling strikes.

Objectively, this barrier could be even happening at the moment at Quoc Hung, but it is truly not easy to see this matter because it depends on the employees' intentions. Consequently, the company's leaders should be aware of this point carefully and have an appropriate policy to arrange the workload for the workforce to ensure the job balance for all and avoid undesirable consequences later. In addition to the challenges mentioned, the interviewees also stated network connection could be a barrier since, for IoT connection, all problems become more complex and diverse with greater capacity and intensity. Thus, an urgent issue is that the company must ensure the network providers have a plan to improve management and operation efforts in order for the IoT platform to be able to spread information quickly and in a timely manner. Besides that, searching for appropriate IoT suppliers is a challenge as well if the business does not do research or understand the company’s operation itself since most of the IoT market share for Vietnamese businesses today is provided by big foreign names with many advantages, but these big players often do not understand the reality of production in Vietnam, policies and plans, or are incompatible with the regimes and regulations in the project implementation area. In fact, in Vietnam, mid-range IoT systems in Vietnam are designed and completed by domestic enterprises. The IoT system for businesses of domestic suppliers has the advantage of knowing the operations and needs of domestic enterprises, and strictly complying with domestic regulations and legal standards. With these advantages, businesses have higher IoT application capabilities and higher success rates of deployment. As a result, Vietnamese businesses should take this into account if the business really wishes to implement IoT in the warehouse.

Lastly, the security of data being shared to the IoT network was mentioned as one of the biggest challenges which can affect significantly the overall operation of the company. Undoubtedly, in today's connected world, pointing out a device's weaknesses is extremely easy. For technological devices capable of connecting to the internet, security is still a top concern. The automatic communication of IoT devices makes it much more difficult to ensure security and privacy. This is also a problem that makes businesses afraid to approach new methods of IoT application since once data is attacked or hijacked, which will push the company into a dangerous situation. Consequently, although it is beneficial to use IoT to manage the data, it could still be vulnerable to exposure or leaking, since every bit of data is now easily accessible. Thus, businesses should focus and think more about this aspect of data security when adopting IoT technology in their warehouses.

4.4 Trends of IoT applications in warehouse management in the future

When being asked questions involved in this topic, the shares from the interviewees could become creative ideas for the development of technology in general, and IoT applications in particular.

First of all, the CEO expects that after the company can successfully apply IoT in inventory management, it can be applied to other nodes in the supply chain in the future. Therefore, everything will be linked together, making it easier for businesses to manage many areas of the company, all data will be automatically stored, helping the company to have data to make and develop business plans more easily. For example, it would be great if the IoT application can connect the data of inventory and data of manufacturing. Accordingly, every time there are new orders that need to be produced and assembled, the application would send a notification to announce if the inventory level is still adequate for production; otherwise, the system would predict the number of materials requires to purchase for the orders. At the same time, the information would be transferred directly to the CEO, warehouse manager and purchasing team and the information would be updated constantly to relevant departments. If the IoT would be able to do so, it

would be an excellent application for businesses who specialize in manufacturing as Quoc Hung company since such application would support the company to be active in preparing materials and production process. Also, when IoT is widely applied, its development opportunities will be noticed and innovated even more. Maybe in the future, there will be no need for human presence in operation at some supply nodes, which means automation will be the primary workforce in the future.

Speaking of this topic, the warehouse manager stated Drones could also play an important role in the warehouse of the future. Those Drones could help to check the inventory level and identify the product's location by reading the RFID tags. In fact, this could happen because, in August 2017, researchers at the Massachusetts Institute of Technology (MIT) announced they had set up RFID relay drones as a way to aid in inventory checks. The technology allows the Drone to fly over the production area to read RFID tags from tens of meters away, with an impressive error of only 19 cm, which is worth looking forward to. Furthermore, within the next few years, experts predict that many warehouses will be able to use drones to track inventory. This helps warehouses of all sizes conduct quick and timely comprehensive checks and inventory of their inventory. As such, instead of employees using machines to scan the RFID tags, the Drones could do that quickly, which assists to save time, increase productivity and reduce labor expenses in warehouse in the near future.

Employee A also expressed his desire that one day Virtual Reality (VR) or Augmented Reality (AR) could bring more advanced applications which help workers see the big virtual screen of information and people can use their fingers to move data from the virtual screen. This would be a big breakthrough compared to Augmented Reality Glasses since various employees can discuss and watch the VR data screen at the same time. Employee A believes experts in the IoT technology field would upgrade the security network to a high level in the future. Indeed, the massive growth in the number of devices connected to the Internet certainly means

that there are more and more ways in which technology can be hacked or taken advantage of by those with ill intentions toward businesses. The number and scale of cyberattacks are growing every year - security researchers at Kaspersky say there were 1.5 billion attacks targeting IoT devices in the first half of 2021 - and throughout 2022, it is predicted that this trend accelerate next years. Therefore, it is essential for IoT suppliers to focus on enhancing security for IoT devices and applications through creating an extra layer of security to protect against unauthorized users who have taken possession of business devices.

The logistics manager reveals his point of view on this topic that the future of IoT technology would develop smart containers or autonomous vehicles to facilitate the shipping process. Firstly, smart containers are smart boxes that are created by including IoT devices and sensors. In that way, smart containers can stream data in real-time while in transit. As a result, with such smart containers, it is easier to attain information on cargo because the smart containers will support inform threats and dangers which are likely to occur during transit as well as the status of goods in the containers. Besides that, using those containers would allow people to track the location of the cargo and prepare beforehand for the cargo loading or unloading planning. Secondly, the logistics manager anticipates that there would be a domination of automation such as robotics and autonomous vehicles thanks to the continuous development of technology. The robotics could be put in warehouses to assist in sorting products and picking up goods. Autonomous vehicles could be used to deliver goods to destinations in permission areas. This anticipation is quite feasible because according to Global Infrastructure Hub (2020), 10 per cent of the world's container fleets will be equipped with smart containers by 2023, and according to the latest technology, Nuro - an American robotics company - has been awarded the state’s first commercial license for self-driving cars on the roads of two counties near the company's Bay Area headquarters. These prove a good signal for potential applications and devices that IoT technology would bring to the world in the future.

In general, it could be said that the above findings provided a picture of the IoT implementation in warehouse management and inventory management partially in Vietnam at the moment. Based on those results, the author will continue to indicate comparisons and limitations for this thesis as well as suggestions for future research relating to the topic in the final chapter.

5 CONCLUSION

In this section, the author begins to analyze the results using a theoretical background in order to draw conclusions about the differences and similarities in practice and theory regarding this topic, and the content of the comparison part will be outlined based on the theoretical framework. This section will also discuss the limitations encountered while conducting the research. Simultaneously, the author will propose additional studies that could be implemented and investigated relating to this topic.

5.1 Comparisons of the impact of IoT in inventory management in the warehouse in theory and practice

5.1.1 Essential IoT technologies

It is clear from the results and findings that the Quoc Hung company is utilizing critical IoT technologies such as RFID, wireless sensor networks (WSN), middleware, cloud computing, and IoT application software. They are all linked and contribute to the successful operation of IoT applications. To begin, in terms of RFID, this technology is widely used in company warehouses. It is understandable given that the company uses RFID tags to label goods, RFID reader machines to scan those tags, and printers to print RFID tags for goods and products in the warehouse. These activities occur on a daily basis at the warehouse, and the employees use them to complete warehouse tasks. According to interviewees, RFID has significantly increased the company's productivity by improving packing, tracking good locations, and managing inventory levels, which was similar to the previous research and was mentioned in the theoretical section. However, while the theory revealed that RFID is widely used in keeping track of goods conditions in warehouses, it appears that the Quoc Hung warehouse has yet to apply this technology to monitor goods conditions. It could be explained that because the company specializes in machine manufacturing for customers, the majority of materials are

spare parts or metallic parts. Furthermore, the characteristics of measuring temperature, humidity, and pressure of goods are becoming more common in specific industries such as food, pharmaceuticals, and beverage.

Second, when it comes to essential IoT technologies, IoT application software plays an important role since it is used to create IoT applications and platforms, and from there, interactions and digital communication between Quoc Hung's employees and devices are developed. Next, Middleware and Wireless sensor networks (WSN) facilitate a convenient physical environment and make it easier for the company to interact with and collect data from it. Finally, Cloud computing is an important part of IoT technology because it allows the Quoc Hung company to store and analyze data on it. In general, the company uses IoT application software, cloud computing, middleware, or wireless sensor networks, but their presence is not as visible as RFID technology. This is due to the fact that they are sort of software and intangible technologies, so they were not easy to see and understand their presence, but their effectiveness and contribution are undeniable.

Aside from the benefits of those IoT technologies, challenges of strong networks, security, privacy and so on still exist, which will be discussed in greater in the challenges of IoT integration into the warehouse part.

5.1.2 Warehouse operation

Regarding warehouse status, Quoc Hung company's warehouse specializes in equipment, spare parts, machinery, and metallic materials. In general, the company's warehouse used to face a period when it could not effectively control inventory levels because everything had to be done on a periodic basis, causing insufficiency and time-consuming. These characteristics are recognized as a common issue for warehouses in Vietnam and are discussed in the section on the current situation of warehouses in Vietnam. This can be explained by the fact that Vietnamese businesses are still hesitant to use and try new things, particularly in the technology field, because this field requires various resources such as finance,

time, human resources, and research before application; thus, not many businesses are attempting to apply these technologies.

Furthermore, the actual roles of the Quoc Hung warehouse correspond well with those indicated in theoretical backgrounds. In practice, the company's warehouse serves several functions, including raw material storage, intermediate and customization facilitation, and finished goods storage. This is understandable given that the company specializes in the design and manufacture of industrial machinery, as well as related services; thus, the company warehouse is a location where the company stores raw materials for the entire production process (raw materials storage), or temporarily stores products at various stages of production and customizes products before delivering them to the customer (intermediate and customization facilities), as well as hold products which are completed and ready to sell (finished goods storage). Accordingly, the findings for this section differ in that warehouses can play a variety of roles, depending on the types of businesses and the purposes of their operations. In this case, Quoc Hung is a manufacturer, so taking advantage of warehousing and arranging its warehouse in this manner is entirely appropriate.

In terms of warehouse operations, Quoc Hung warehouse follows a similar procedure, which includes receiving, putting away, storing, order picking, packing, and shipping. However, due to the characteristics of businesses such as manufacturing, the company's warehouse process is slightly different. Regarding the receiving stage, the warehouse receives the notification of the arrival of a large quantity of raw materials, allowing the warehouse to plan for the unloading schedule as well as other warehouse activities. At the same time, the company decides where to store raw materials (putting away). Following that, the goods and materials are stored in the designated locations. If a company is a retailer or a vendor, it will proceed to the theoretical steps of order picking, packing, and shipping. However, as previously stated, the Quoc Hung company is a manufacturer; thus, the company's warehouse process will repeat stages such as receiving, putting away, and

storing, which can be explained because Quoc Hung's warehouse serves as intermediate and customization facilitation, as well as finished goods storage, so the products that have not been completed will be put back in the warehouse for the next production process, adjustments, and assembly. Once the products are finished and ready to sell, the company will move on to the next stages of order picking, packing, and shipping.

5.1.3 Inventory management

The fundamentals of inventory management

When it comes to inventory management, it can be seen that Quoc Hung's warehouse contains the majority of inventory categories that correspond well with those presented in theoretical findings. The first is raw material inventory, which is the most basic because it includes parts and direct materials for the company's manufacturing and assembling processes. The second type of inventory is Work-In-Process inventory, which consists of unfinished products that require additional raw materials and assembly processes to become finished products. The third category is finished goods, which are finished products that can be shipped directly to customers. These three types of inventories are essential for manufacturing companies, and Quoc Hung is one of them. Furthermore, the inventory of the maintenance, repair, and operating suppliers is included in the Quoc Hung warehouse because the company still requires goods or tools for office and maintenance, which allows the company's operations to run smoothly. In addition to the inventories mentioned above, Quoc Hung warehouse divides its specific inventories into cycle stock as well, because there are parts that must be available in the warehouse at all times, such as basic tools for assembling, equipment or machinery for cutting metallic materials, and so on. Regarding the safety stock, according to the theoretical background, its purpose is to protect against fluctuations in demand and supply, and safety stock is finished products; thus, safety stock is not really suitable for a manufacturer since the company cannot produce various fin-

ished products for demand fluctuations when not receiving any orders from customers, particularly for products such as machinery systems or chain systems. Normally, each order is very expensive and also takes a long time to complete a final product since it demands expenses for designing products and preparing a variety of raw materials. This is the reason why the CEO shared in the trends of IoT application in the future section that, in the future, IoT applications are expected to link inventory data and manufacturing data, so that whenever new orders need to be produced and assembled, the application would send a notification to announce if the inventory level is still adequate for production; otherwise, the system would predict the number of materials required to purchase for the order. It can be seen that the CEO's expectation is completely decent based on the characteristics of the company's operation. As a result, in this case, safety stock should not be finished products as theory background, but rather products used to maintain finished products that were previously sold to customers. This is understandable because the company can forecast when machinery systems will require maintenance or replacement of spare parts, as well as prepare materials and tools for service level, rather than predicting the number of finished products.

Methods of inventory

The first that should be mentioned is inventory tracking. Most businesses who own their warehouses would use this method since it is a basic and common approach to monitor the inventory level of the warehouse, allowing the company to always have the right amount of inventory and control it. Likely, Quoc Hung warehouse also uses this method to track the movement of raw materials or finished products. Before applying IoT applications in the warehouse, Quoc Hung company used to combine manual tracking and spreadsheets concepts in tracking inventory levels. The warehouse's employees had to enter manually input and output data of materials or finished products in sheets whenever new goods and materials arrived, and the raw materials were taken out for production. In addition, manual calculations were performed periodically to ensure that the actual inventory data

matched the data in the spreadsheet. These steps took a long time to complete, but the accuracy of these methods was low, which was indicated in the theoretical parts.

Secondly, inventory sorting is also important for manufacturing businesses because the raw materials of the manufacturers, who specializes in designing and producing machinery system, are mainly metallic; therefore, if the company does not have any inventory sorting appropriately, those metallic materials will be oxidized and corroded over time. With such features of the raw materials, Quoc Hung warehouse decided to sort inventory using the FIFO (First In First Out) principle to ensure material quality. Consequently, it can be seen that the company used the inventory sorting method not because of its strength in the flow of data reported to the balance sheet as theoretical findings, but because of material quality concerns.

In terms of inventory forecasting, as mentioned above, Quoc Hung company is not focusing on forecasting inventory much because of the characteristics of the business's operation. Therefore, only tools and materials used to serve maintenance and service levels should be needed to predict.

5.1.4 Revolution of inventory management in Quoc Hung warehouse

In comparison to the theoretical background, the Quoc Hung warehouse has gone through two major stages: manual counting and RFID. As previously stated, the warehouse used to manually count inventory in order to have the correct number of products and enter the data into the spreadsheet. After recognizing the limitations of the manual method, the company invested time and resources in conducting research to learn more about IoT applications and technologies. As a result, after a lengthy search, the company decided to incorporate IoT devices into the warehouse in order to improve warehouse operations in general and inventory management in particular to a higher level, which also had a significant impact on other departments such as the logistics team. The company did not apply punch

cards or bar codes because before the appearance of the RFID technology, the company was still hesitant about the effectiveness of those models. Only when RFID appeared and the company has done adequate research on it, then the company made the decision to apply RFID which is the main part of IoT technology.

The following sections will present the comprehensive comparisons of IoT integration in inventory management between theory and practice, including benefits, opportunities, and challenges, as well as future trends of IoT applications.

5.1.5 IoT integration in inventory management

Before delving into the main points such as the benefits, opportunities, and challenges, as well as future trends of IoT applications, some IoT applications and devices used in the Quoc Hung warehouse should be mentioned in this part as well.

According to the results, IoT applications and devices mainly used in Quoc Hung warehouse are that RFID tags and readers, Printers, RFID rugged tablet devices and smart glasses as well as IoT software Platforms. These are devices that belong to RFID, SaaS and wearable devices based on the theoretical section. Autonomous Mobil Robots have not been used in the company warehouse, partly because the company wishes to have steady steps in integrating IoT in the warehouse and evaluate the effectiveness of these devices before implementing more advanced models such as Autonomous Mobile Robots. In addition, human resource is still a huge issue to deal with once the structure of the warehouse changes so quickly, which has been mentioned in the challenges of IoT integration into inventory management in the results and findings sections. These are the primary reasons why the company requires additional time to install autonomous robots in the warehouse.

5.1.6 The benefits of IoT in inventory management in practice

Overall, the findings of this section are rather similar to those of the theoretical section. The first point to mention is that IoT integration into the warehouse has improved inventory management, causing productivity to skyrocket. It also aids in

tracking inventory movement on a minute-by-minute basis, allowing businesses to be more proactive in preparing materials for the manufacturing process and forecasting tools for maintenance and service levels. Furthermore, having access to real-time data and tracking products at all times helps to monitor the status of goods and avoid stock losses. Furthermore, it reduces the impact of human error in data collection and saves labor time compared to manually collecting data. Moreover, tracking with IoT devices makes picking and packing products easier and more efficient. These findings are not novel when compared to those of Rejeb (2020), Yerpu-de & Singhal (2018), Sharma & Sharma (2019), or Fedyk (2020) in theory.

However, there are several new findings have been discovered through the results of this study. To begin, the benefits that businesses can obtain from IoT applications include not only the benefits mentioned above but also warehouse space optimization as a result of constant updates for the actual inventory level. Indeed, warehouse space is a critical factor for warehouses, and the Quoc Hung warehouse is no exception, because the more space the warehouse has, the better arrangements the company can make. Particularly when the company warehouses serve multiple functions as Quoc Hung warehouses (e.g., raw materials storage, intermediate and customization facilities, and finished goods storage), a large space for sorting and storing products is required. Therefore, properly circulating unfinished products and raw materials is crucial for optimizing storage space and avoiding bottlenecks in the warehouse. Whenever a bottleneck occurs in a warehouse, it has a direct impact on inventory management, including scanning tags, tracking, picking, and packing products. This causes subsequent consequences such as failure of warehouse operation, delivery delays, or even failure of customer satisfaction. The second revelation from the findings section is that incorporating IoT into the warehouse can help the company achieve customer satisfaction. Indeed, the availability of raw materials in the warehouse has improved thanks to the actual data being updated, which supports the manufacturing process running on time. Along with that, the warehouse space has been effectively

optimized, allowing for better tracking, picking, and packing of goods, resulting in a faster delivery process. Accordingly, customers receive products and orders promptly, increasing customer satisfaction and bringing future commercial opportunities to businesses.

5.1.7 Opportunities of IoT integration into inventory management in practice

In practice, IoT integration into inventory management has provided opportunities to Quoc Hung company such as increasing the convenience and efficiency of operation inventory management, improving the company's financial status, facilitating the company's accessibility to new technology, and enhancing the logistics team's shipping process. These are opportunities which were mentioned by the previous researchers in the theoretical sections. In general, the opportunities explored in previous research and written within the theoretical section are primarily relevant to warehouse operation efficiency, productivity, or financial enhancement. However, in this study, there are new opportunities have been discovered relating to the other aspects that businesses can take into account.

Firstly, according to the findings, the implementation of IoT has increased the accessibility of employees to new technologies, which not only helps the company to have a skilled workforce but also makes it easier for the company to approach new technologies in the future. It can be explained as follows: if a company wishes to invest in new technology, having its workforce become acquainted with new technologies is one of the advantages. Second, finding new talent capable of quickly learning this technology is a huge opportunity for businesses. This is understandable since new talent employees can assist the company in re-training and instructing other employees while on the job, reducing the training expense the company must pay for additional courses. Furthermore, one important discovery that businesses should consider is that using IoT devices and machines in warehouses plays a crucial role in impressing partners at first sight as most partners, especially Vietnamese partners, would like to come to the business premises such as warehouses and manufacturing places to observe overall; thus, demonstrating

professionalism and industrialization in facilities can give a good impression to partners. This contributed to establishing partner relationships and attracting investment from investors.

Generally speaking, it can be seen from this research that it is necessary to have a broader observation to have a detailed picture of the topic, from which many aspects will be discovered, and businesses will catch commercial opportunities.

5.1.8 Challenges of IoT integration into inventory management in practice

Regarding challenges of IoT integration into inventory management, findings derived from the study are quite similar to the theoretical background, including high cost, human resource issues, security, network, reliability and integrity of the IoT applications. In detail, when it comes to high costs, the problems that arise from machinery and switching from the old system to the new system expenses, training and at the beginning stage expenses, and maintenance or upgrade system fee were assessed. Furthermore, software failures, server issues, network latency, and infrastructure challenges can all add to the costs. This is completely understandable given that implementing new technologies is never cheap; it always necessitates consistent funding to cover expenses, particularly for machinery, patents, or errors at the factory at the beginning. Subsequently, human resource issues that correspond to the theory can be mentioned, such as employees' fear of adopting new things, which is also mentioned in Shee, Vass, and Miah's (2020) research. Indeed, according to the findings, this is regarded as the most difficult challenge for Quoc Hung, as it is determined by employees' intentions and has a direct impact on the effectiveness and success of IoT integration into warehouse management in general, and inventory management in particular. Next is the basic challenge for implementing IoT technology, which is security. This could be considered the primary and most common challenge for businesses because technological advancements will increase the sophistication of cyber-attacks, business data can be hijacked at any time if organizations do not prioritize cybersecurity protection.

Furthermore, when it comes to putting IoT applications and devices to use, a reliable network is essential. Clearly, IoT devices and applications are connected and running because of the internet; therefore, businesses must ensure a good network in the physical environment to avoid interruption and data error, as well as to improve device-to-device and human-to-device interactions. As can be seen, this challenge was prominently mentioned in the essential IoT technologies. The final point in the comparison of similar challenges to theory is the reliability and integrity of IoT applications. The results of the challenges section reveal that the challenges of IoT integration to inventory management in warehouses can begin with difficulties in selecting suppliers or partners for IoT applications and devices because this technology is still relatively new to Vietnamese businesses, making it difficult for them to find a reliable supplier to incorporate.

In terms of the differences between practice and theory, this study has shed light on the subject by uncovering new challenges in practice. One of the major barriers is tampering with human resources. Human resource issues usually have a direct impact on the company's operations, especially when they come from long-term internal employees. This could be explained by the fact that knowledge of technological fields among people living in poor countries such as Vietnam is still limited, even at the management level. People become accustomed to manual methods of inventory management in warehouses. Furthermore, in Vietnam, people are oriented to devote themselves permanently to business where they can find benefits that are suitable for them. As a result, they have mostly worked for businesses for a long time, are mostly middle-aged, and have little interaction with new technological devices, which is why they always need more time to learn new things about technology. From this point of view, it is clear that switching from the old system to the new one would result in a mess of the company's human resources, with long-term employees being dismissed for failing to meet new requirements or adapting poorly to the new system. Consequently, using IoT for inventory management may increase business burdens such as job arrangements and finance if companies want to retain long-term employees and move them to

other appropriate positions. Arranging new positions and job rotation for employees would be difficult, especially when the company is in the early stages of IoT implementation. Furthermore, if the company does not have a proper solution for human resource issues, the employee's spirit may be negatively affected, leading to unwilling conflicts. This is why businesses should consider this challenge when implementing new technology in general, and IoT in particular, in warehouses. Second, organizations that plan to use IoT applications should think about natural disasters and pandemics. According to the findings of this study, the pandemic has had a significant impact on the use of IoT in warehouses. In this case, when the Covid 19 pandemic broke out, it usually caused the company to fall into a staff shortage, especially when the pandemic peaked, which caused challenges in training, job scheduling, and IoT implementation progress in inventory management. As a result, taking natural factors into account is critical to the success of IoT integration IoT in the warehouse.

5.1.9 Trends of IoT applications in warehouse management in the future

According to the findings, the interviewees anticipate that there will be prospects and potential trends in the future. The first trend could be the development of new applications or software that connect inventory data to manufacturing data. Accordingly, whenever new orders need to be produced and assembled, the application will send a notification to announce whether the inventory level is still adequate for production; otherwise, the system will predict the number of materials required to purchase for the orders, and this information will be transferred to relevant departments. This has a lot of potential because these applications can help businesses stay active in catch situations while also managing inventory and production processes. Secondly, the prediction that automation will be the primary workforce in inventory management in the future may be partially correct. It can be explained that because currently autonomous applications and devices are not new to inventory management in warehouses in the world and the adop-

tion of these technologies is becoming more and more popular. One of the autonomous technologies could be mentioned is that robotics which is being used in sorting products and picking up goods. In fact, the big players in the worldwide retailer market are using robotics are that Amazon with warehouse automation, DHL with smart warehouse or Amazon, and robotics judged are very useful and high-productive. Besides that, it is expected that autonomous vehicles that will be used in the shipping process will be introduced in the near future. The evidence for this optimism is that Nuro, an American robotics company, has been granted the state's first commercial license for self-driving cars on the roads of two counties near the company's headquarters in the Bay Area. Additionally, smart containers are also predicted to be a new trend in the shipping industry soon. By using these containers, it is easier to attain information on cargo and track the location of cargo because smart containers would be equipped with IoT devices and sensors. Furthermore, it is stated that drone technology could play an important role in the warehouse because drones could help to check inventory levels and identify product locations by reading RFID tags from tens of meters away with an impressive error of only 19 cm. Moreover, the development of VR or AR technology that will allow people to see a large virtual screen of information and use their fingers to move data from the virtual screen is expected. This could happen because VR and AR are growing rapidly in the world, with excellent and magnificent applications and devices; thus, this expectation is reasonable. Last but not least, the expectation of a solid and strong security network would be established with a high level of protection in the future is also stated in the finding.

All in all, the predicted trends and expectations mentioned above are quite feasible because they come up based on experiences and observations in practice. Therefore, it is absolutely reasoned to believe that the anticipations above would come true.

5.2 Validity and reliability

When it comes to validity and reliability, these elements are very important for a research process and findings. According to Biddix et al. (2018, p. 65), while conducting an empirical study, the researcher is required to adhere to research ethics which refer to the researcher's responsible behaviour when dealing with informants and their data throughout the research process. In addition, Merriam & Tisdell (2015, p. 237) also stated that ethical research yields reliable and valid data. Adhering to these principles, the validity and reliability of the qualitative data gathered for this study were carefully considered.

To begin understanding the context, the definition of reliability should be mentioned. Particularly, Adams et al (2014, p. 29) defined reliability as the way by which data was collected and analysed objectively for the research. This could be seen from this paper since a detailed analysis has been derived from the experiences and opinions of the interview participants who are experts relating to the topic. Consequently, it could be stated that the resources for the reasoning and results of the impact of IoT on inventory management in warehouses are realistic and trustworthy.

In addition, the validity of the research is also commonly evaluated based on the methodology used. Since this paper relies on the results of qualitative data analysis, the validity of this study includes internal and external validity. The former refers to the extent to which research findings fit into the real world (Merriam & Tisdell 2015, p. 242). When qualitative data is collected directly from people through interviews, the results are more realistic than when quantitative data is used (Merriam & Tisdell 2015, pp. 243-244). Besides that, internal validity is acknowledged when the research arises from realistic problems being experienced and observed. In this case, the background of the research totally fits. The latter implies the possibility of generalizing the research findings and applying them in other situations, which is evident since the background and purpose of

the study are providing references for Vietnamese businesses who are still hesitant in applying IoT technology in warehouses and businesses who are developing technologies; thus, there are various businesses can use these in-depth results of this research for their operations. For those reasons, external validity is completely appropriate.

5.3 Limitations

According to Felix and Smith (2019, p. 167), the author may encounter certain limitations while conducting research, which is defined as obstacles or drawbacks met while attempting to achieve the research outcome. In particular, the author experienced difficulties in comprehending, seeking, and obtaining information for theoretical parts relating to IoT technology. This is understandable given that the author's major is International Business, and the author's academic knowledge of IoT has specific limitations. As a result, the author only illustrated a few keystones of the feature and operation process of IoT-based applications that were implemented in a warehouse.

Besides, due to the long distance, the research was conducted in Finland and all of the interviewees were conducted online. It would have been better if the author could visit the Quoc Hung warehouse to have a close observation and conversation with employees for additional information as well as understand greater other aspects relating to the topics.

5.4 Suggestions for further research

Since the study was conducted to investigate the impact of IoT on inventory management in warehouses, there are still other aspects of a business that can be explored on this topic. In particular, for a company that specializes in manufacturing machinery systems and chains as Quoc Hung, the production process system and machinery are critical to the company's operation. Furthermore, IoT technology is constantly evolving around the world, and new devices are being introduced in a

variety of fields. As a result, researchers can conduct studies on the impact of IoT on the manufacturing process. In that way, the researchers can discover how IoT integration affects the manufacturing process and learn more about the expectations or aspects that need to be developed to improve the manufacturing process. Besides that, the research can look into the impact of IoT on inventory management and production systems, which allows for the customization of specific devices or applications that connect inventory management and production data. Moreover, because the author used qualitative methodology in this study, it would be more effective if future studies could use both qualitative and quantitative data collection methods. In which, when special questions need to be asked of upper management, such as the CEO or planning production managers, the qualitative methodology can be used to collect specific data. On other hand, the quantitative methodology can be used to collect information from all employees involved in the manufacturing process in order to gain different perspectives and experiences. As a result of the diversity of information, the validity and reliability of the research findings would be increased, and the analysis would be deeper.

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APPENDIX 1

GUIDING QUESTIONS FOR INTERVIEWS WITH PARTICIPANTS IN QUOC HUNG TST CO., LTD.

FOR THE WAREHOUSE MANAGER AND EMPLOYEES

GENERAL QUESTIONS

Are you familiar with the Internet of Things (IoT) technology?

Is your company using IoT devices currently? For instance:

- RFID tags or readers
- Barcode/ RFID Printers
- Smartwatches or smart glasses
- Other sensor devices (e.g. Mobile computers with GPS, rugged RFID sleds, etc.)
- Autonomous Mobile Robots (AMR)

When did the company begin implementing IoT in the warehouse?

QUESTIONS REGARDING THE IMPACT OF APPLYING THE IOT SYSTEM IN INVENTORY AND WAREHOUSE

Are you aware that implementing IoT in the warehouse has had an impact on inventory management?

From your point of view, can you describe the benefits of using IoT system in inventory management in warehouse?

On a scale of 1 to 5, how many points will you give the level impact of IoT on inventory management in a warehouse? Why?

Which aspect of inventory management is the most affected by the IoT system? (Tracking, Sorting, and so on.)

QUESTIONS REGARDING THE OPPORTUNITIES

Do you think the IoT implementation has improved inventory management operational performance? Explain?

Do you think IoT integration has provided warehouse employees with new experiences and learning opportunities?

What other opportunities do you see the IoT integration has brought to inventory management and warehouse operations?

QUESTIONS REGARDING THE CHALLENGES

Are you aware of the challenges for IoT adoption in the warehouse, specifically in inventory?

Could you please describe the difficulties and challenges when using IoT devices in inventory management and in a warehouse?

Do you think those challenges will have a significant impact on warehouse operations?

Could you suggest any solutions for those challenges?

QUESTIONS REGARDING TRENDS OF IOT APPLICATIONS IN WAREHOUSES IN THE FUTURE

Are you expecting any breakthroughs in IoT applications and devices in the future?

Do you think IoT applications could replace all human tasks in the future?

How do you see the future of IoT applications in the warehouse?

Which aspects of IoT applications should be innovated and developed in the future?

APPENDIX 2

GUIDING QUESTIONS FOR INTERVIEWS WITH PARTICIPANTS IN QUOC HUNG TST CO., LTD.

FOR CEO

GENERAL QUESTIONS

Are you familiar with the Internet of Things (IoT) technology?

Is your company using IoT devices currently? For instance:

- RFID tags or readers
- Barcode/ RFID Printers
- Smartwatches or smart glasses
- Other sensor devices (e.g. Mobile computers with GPS, rugged RFID sleds, etc..)
- Autonomous Mobile Robots (AMR)

When did the company begin implementing IoT in the warehouse?

QUESTIONS REGARDING THE IMPACT OF APPLYING THE IOT SYSTEM IN INVENTORY AND WAREHOUSE

Are you aware that implementing IoT in the warehouse has had an impact on inventory management?

From your point of view, can you describe the benefits of using the IoT system in inventory management in the warehouse?

On a scale of 1 to 5, how many points will you give the level of impact of IoT on inventory management in a warehouse? Why?

QUESTIONS REGARDING THE OPPORTUNITIES

Do you think the IoT implementation has improved inventory management operational performance?

What made you decide to use an IoT system in a warehouse when Vietnamese companies are still hesitant to use them?

Do you think the IoT integration has brought to the company financial or operational advantages?

What other opportunities do you see the IoT integration has brought to your company?

QUESTIONS REGARDING THE CHALLENGES

Are you aware of the challenges for IoT adoption in the warehouse, specifically in inventory?

Could you please describe the difficulties and challenges when using IoT devices in inventory management and in the warehouse?

Do you think those challenges will have a significant impact on the company's operation?

Are you looking for solutions for challenges that the company is facing when applying IoT applications?

QUESTIONS REGARDING TRENDS OF IOT APPLICATIONS IN WAREHOUSES IN THE FUTURE

Are you expecting any breakthroughs in IoT applications and devices in the future?

Do you think IoT applications could replace all human tasks in the future?

How do you see the future of IoT applications in warehouses?

Which aspects of IoT applications should be innovated and developed in the future?

APPENDIX 3

GUIDING QUESTIONS FOR INTERVIEWS WITH PARTICIPANTS IN QUOC HUNG TST CO., LTD.

FOR LOGISTICS MANAGER

GENERAL QUESTIONS

Are you familiar with Internet of Things (IoTs) technology?

Is your company using IoT devices currently? For instance:

- RFID tags or readers
- Barcode/ RFID Printers
- Smartwatches or smart glasses
- Other sensor devices (e.g. Mobile computer with GPS, rugged RFID sleds, etc..)
- Autonomous Mobile Robots (AMR)

When did the company begin implementing IoT in the warehouse?

QUESTIONS REGARDING THE IMPACT OF APPLYING THE IOT SYSTEM IN INVENTORY AND WAREHOUSE

Are you aware that implementing IoT in the warehouse has had an impact on inventory management?

From your point of view, can you describe the benefits of using the IoT system in inventory management in the warehouse?

How has the shipping process changed since the company started applying IoT devices in inventory management in the warehouse?

On a scale of 1 to 5, how many points will you give the level of impact of IoT on inventory management in a warehouse? Why?

QUESTIONS REGARDING THE OPPORTUNITIES

Do you think the IoT implementation has improved inventory management operational performance? Explain.

Can you perceive the opportunities the IoT integration has brought to the logistic aspect such as the delivery process?

What other opportunities do you think the logistics aspect has benefited from the IoT integration?

QUESTIONS REGARDING THE CHALLENGES

Are you aware of the challenges for IoT adoption in the warehouse, specifically in inventory?

Could you please describe the difficulties and challenges for the logistics team when using IoT devices in inventory management and in the warehouse?

Do you think those challenges will have a significant impact on the logistics aspect?

Could you suggest any solutions for those challenges?

QUESTIONS REGARDING TRENDS OF IOT APPLICATIONS IN WAREHOUSES IN THE FUTURE

Are you expecting any breakthroughs in IoT applications and devices in the future?

Do you think IoT applications could replace all human tasks in the future?

How do you see the future of IoT applications in warehouses?

Which aspects of IoT applications should be innovated and developed in the future?