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The adoption of new technologies of industry 4.0 in the Warehouse  
Operation Management in Food Industry



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## The adoption of new technologies of industry 4.0 in the Warehouse Operation Management in Food Industry

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**Abstract**

This thesis studies the new technologies resulting from the 4<sup>th</sup> Industrial Revolution, and the utility they have in the operation of logistics warehouses, specifically food management warehouses.

First, a reference is made to the concepts of new technologies (such as the Internet of Things, Automation and Robotics, and Big Data Analytics). Then, qualitative research is conducted. The research process begins with structured interviews, where respondents are asked to answer a series of questions specifically designed to explore the function of these technologies in domestic food warehouses.

Specifically, four interviews have been conducted with food warehouse managers who participated in the research by responding to five key questions.

Subsequent of the interviews, the data collected is consolidated (which called grounded theory), and the process of analyzing the information is carried out to draw the final conclusions of the existing research.

The new technologies stemming from the Fourth Industrial Revolution are premature for Greek data. From the interviews with the managers, it is evident that the Greek industry and Greek logistics have a long way to go in fully adopting these new technologies. It is noted that a part of these technologies has been partially adopted, but not to such an extent that it is perceived that Industry 4.0 is part of Greek logistics.

**Keywords:** Industry 4.0, Warehouse Operation Management, Internet of Things (IoT), Automation and Robotics, Big Data Analytics, Food Industry

## Περίληψη

Η παρούσα διπλωματική εργασία, μελετά τις νέες τεχνολογίες που απορρέουν από την 4<sup>η</sup> Βιομηχανική Επανάσταση, και την χρησιμότητα που έχουν οι ίδιες στην λειτουργία των αποθηκών logistics, και συγκεκριμένα των αποθηκών διαχείρισης τροφίμων.

Αρχικά, γίνεται μια αναφορά στις έννοιες των νέων τεχνολογιών (όπως είναι το Internet of Things, Automation and Robotics and Big Data Analytics) και στην συνέχεια διεξάγεται μια έρευνα με την μέθοδο της ποιοτικής έρευνας. Η διαδικασία της έρευνας γίνεται αρχικά με την μορφή δομημένων συνεντεύξεων, όπου οι ερωτώμενοι καλούνται να απαντήσουν σε μια σειρά ερωτήσεων που έχουν δημιουργηθεί με έμφαση στην λειτουργία των τεχνολογιών σε εγχώριες αποθήκες τροφίμων. Συγκεκριμένα, έχουν πραγματοποιηθεί τέσσερις συνεντεύξεις, σε υπεύθυνους αποθηκών τροφίμων, οι οποίοι ανταποκρίθηκαν στην έρευνα απαντώντας σε πέντε ουσιαστικές ερωτήσεις.

Ύστερα από την ολοκλήρωση των συνεντεύξεων, ακολουθεί η συγκέντρωση όλων των δεδομένων που συλλέχθηκαν (το λεγόμενο grounded theory), και γίνεται η διαδικασία ανάλυσης των πληροφοριών με σκοπό τα τελικά συμπεράσματα της υπάρχουσας έρευνας.

Οι νέες τεχνολογίες που απορρέουν από την 4<sup>η</sup> Βιομηχανική επανάσταση, είναι πρόωρες για τα Ελληνικά δεδομένα. Από τις συνεντεύξεις των υπευθύνων είναι εμφανές πως η Ελληνική Βιομηχανία και τα Ελληνικά Logistics έχουν «πολύ δρόμο» μπροστά τους για να υιοθετήσουν κυριολεκτικά τις νέες αυτές τεχνολογίες. Διαπιστώνεται πως εν μέρει έχει υιοθετηθεί ένα μέρος αυτών των τεχνολογιών, αλλά όχι σε τέτοιο βαθμό ώστε να είναι αντιληπτό ότι το Industry 4.0 είναι κομμάτι των ελληνικών Logistics.

**Λέξεις-κλειδιά:** Βιομηχανία 4.0, Διαχείριση Λειτουργίας Αποθήκης, Διαδίκτυο των Πραγμάτων, Αυτοματισμός και Ρομποτική, Ανάλυση Μεγάλων Δεδομένων, Βιομηχανία Τροφίμων



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## 1. Introduction

The 4<sup>th</sup> Industrial Revolution, like the previous ones, brought with it strong developments in technology that affected many sectors around the world. A key area is also Logistics.

In light of this revolution, the terminology "smart factory" and "smart warehouse" have been now established, meaning that IT systems now manage the processes that take place, creating a virtual copy of the physical processes that take place in a factory or warehouse logistics.

This means that the processes are automated therefore, decentralized decisions can be made.

The new technologies have helped and help the communication and collaboration of people within a business, in real time, having immediate information about every process and change. The information systems in every part of a company that deal with storage and production have direct communication with each other 24 hours straight.

This is one of the main characteristics of the new technologies of the 4<sup>th</sup> Industrial Revolution. A second and equally important is, as mentioned above, the automation of processes within a warehouse or production. Both features are interrelated and reinforce the term "smart warehouse" and "smart factory".

The purpose of this thesis is to explore to what extent the managers of food warehouses in the domestic food industry are following the new technologies of the Fourth Industrial Revolution.

As a matter of fact, it examines whether they are informed about these technologies, whether these technologies are implemented in existing warehouses, and whether the managers are willing to install new technologies they will oversee in the future in the food warehouses. The interviews discussing these matters are the key to this research, as the managers express themselves freely and respond sincerely to structured questions.

The approach to the subject of this thesis is through qualitative research, where the main conclusions of the study are drawn from the structured interviews and the analysis of the collected data at a later stage.

The new technologies refer to the technologies that have evolved after the Fourth Industrial Revolution and have an impact on various sectors, including the field of logistics and food storage. When referring to new technologies, we mean Internet of Things, automation and robotics, cloud computing, artificial intelligence, big data analytics, cybersecurity, and blockchain.

In this thesis, the main focus is on Internet of Things, automation, robotics, and big data analytics, which are the fundamental concepts of these technologies.

Internet of Things refers to the interconnection of devices and machinery in warehouses, as well as the ERP (Enterprise Resource Planning) information systems wirelessly, over the internet, or through Bluetooth.

Automation and robotics involve all the machinery that operates automatically within the warehouse and partially replaces human labor, to an acceptable and necessary extent for improving the work of warehouse managers.

Lastly, big data analytics is a term that refers to the volume of data that a company has in its electronic systems. It is a broad and complex term.

Thanks to these technologies, the field of logistics has been digitized to a certain degree, providing a positive boost to the operation of production, storage, and distribution departments of large companies.

The aim of this thesis is to analyze the concepts of the aforementioned new technologies, conduct effective interviews, and study the data resulting from the experience of each warehouse manager.

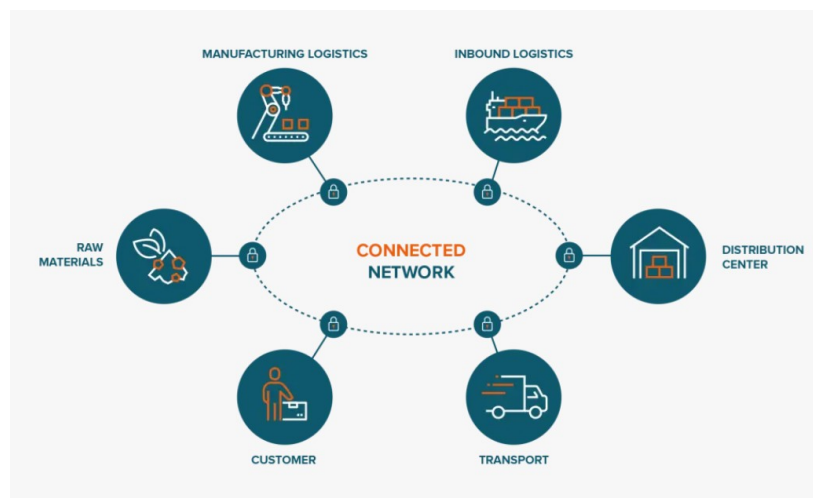
The goal is to achieve as much analysis as possible during the structured interviews with the managers in order that fundamental conclusions can be drawn regarding the adoption of these technologies in Greek warehouses today.

## 2. Supply chain

The term supply chain refers to the production, distribution, and delivery of products or services. Supply chain is all the procedure from the procurement of the raw materials which are needed for the production of goods and services until the time when the consumers take the products to their hands.

Behind this term, there is a network of suppliers, manufacturers, distributors, retailers and customers, where the flow of materials and information and the flow of financial transactions happen every day.

The goal of supply chain is the delivery of goods and services to the customers on time with the lowest cost and the highest profit.



*Figure 1-connected network*

The activities included in the supply chain are a lot and every activity has its own procedure. The activities are:

- Procurement: The process of sourcing raw materials and components from the suppliers
- Production: The manufacturing process of finished products by the use of raw materials.
- Inventory management: The management of stock levels in the warehouse and the monitoring of the inventory through the WMS system, so that there will not be shortage or excess stock.
- Order fulfillment: first there is the procedure of receiving the customer orders from the outbound department of the company, then the procedure of picking and packing of the products from the pickers and storekeepers and last procedure is the shipping of them on the lead time that the customer has determined.
- Logistics and transportation: the procedure of movement of materials and finished goods throughout the supply chain. This happens by warehousing, distribution and transportation.

- Customer service: the goal is the satisfaction of the customers through timely and accurate delivery and through the delivery of qualified goods.
- Demand planning/forecasting: The estimation of the customers’ demand and the forecasting (daily, monthly, yearly etc.) of production of new products and of the inventory levels.
- Optimization and improvement: Analyzing the logistics processes to minimize the costs, to maximize the profits, to enhance the productivity and the efficiency and to improve the performance. This can be succeeded by the tracking and the evaluation of the supply chain management using indicators like KPIs<sup>1</sup> and metrics.

Key performance Indicators (KPIs) impact to the functioning of a logistic company. The KPIs associated with the industry 4.0 technologies are: The risk management capability, the supply chain visibility, data quality and data visualization capability, the resource optimization capability, the sustainability capability, flexibility, reconfigurability.(Sharma, 2022)

## 2.1 Food Supply chain

Food supply chain consists of the activities of production, distribution and consumption of food products. It covers all the stages from the farm to fork. It includes the sourcing of raw materials, the agricultural production, the storage, the packaging, the distribution and delivery, the retail and last the consumption of food by the consumers.

Some crucial features of food supply chain, are:

- Food safety and quality

The ensuring food safety and quality are the most important things in the food supply chain. The certification standards (ISO), the regulation about food safety and the quality control are very crucial for the protection and trust of the consumers.

- Seasonality and agricultural factor

Different weather conditions, crop yields and harvest seasons are some factors which have impact to the food supply chain. The pricing and the sourcing of food ingredients depend on them.

---

<sup>1</sup> Key Performance Indicators



*Figure 2- food supply chain*

- Perishability

The perishability is a key characteristic of many products which have limited shelf life. For this reason, these goods are transported and are delivered rapidly, they are conserved in cold chain logistics warehouses, the condition of storage are very special and at specific temperatures.

- Traceability and transparency

One of the most crucial characteristics in the food logistics. The trace of origin product, the procedure of production and the way of distribution are very important for the safety and the trust of consumers. There are traceability and transparency systems and technologies where track and monitor the all-supply chain procedure.

- Food security

Food security has advanced over time. The basic dimensions of this term are stability and availability which are related with the food supply chain.

- Product innovation and new technologies

The innovation and the new technologies are influenced the food supply chain. The traceability, the efficiency and the customer support are enhanced because there is innovation to the logistics procedure because of the digitalization.

Managing the food supply chain needs risk management, high quality of foods, ISO and sustainable food for the healthy nutrition of consumers.

## 2.2 Supply Chain Digitalization (SCD)

After every Industrial Revolution (from 1784 until today) there is an evolution. From the steam and electricity, we arrived to the information technology and its digitization.

Supply chain digitalization is the process of leveraging digital technologies optimizing the supply chain management. Digital tools and systems collaborate to improve the efficiency, visibility and the decision making. The key benefits of the SCD are:

- Supply chain visibility

The digitalization provides real time visibility into logistics operations, including production progress, inventory levels and status of orders.

- Automation and robotics

Digital technologies are deployed increasingly in supply chain processes. Some of them are automated material handling, robotic arms and autonomous vehicles. They improve the operational efficiency, the speed of labor and reduce the human errors.

- IoT (Internet of Things) technology

The IoT connects different devices, objects and sensors automatically and the same time for exchanging information data. This kind of connection provides the real time data.

- Digital Platforms and e-commerce

They play a vital role in the supply chain procedure because through this kind of digitalization there is the opportunity of online marketplaces, streamline transactions, digital storefronts and directly communication and support to customers.

- Blockchain technology

This technology enhances the traceability, the origin of goods, the safe and secure tracking and the verifying certifications.

- Real time monitoring and alerts

Via digitalization, for example, it is controlled the real time temperature and humidity of products in the warehouses by on line systems.

With the advent of the digital era, the supply chain changes rapidly and most of the procedures become digital. The analytical algorithms behind the supply chain have become the basic competitive factors in the new era. (Ivanov and Dolgui, 2021)

After the COVID-19, which caused cities blockades and the logistics were disrupted, came the remote working rapidly, without paper operation. Due to this pandemic, the digital transformation came very fast and changed the structure of supply chain. Most companies succeeded to copy with the risk of disruption quickly. (Ardolino et al., 2022) For example, the healthcare industry adopted the digital platform technologies and created digital solutions to develop the digital healthcare services. (Chakraborty et al., 2021)

The Blockchain technology has been applied to the supply chain of food helping companies, wholesalers, stakeholders to control and trace the food production. **(Rogerson and Parry, 2020)**

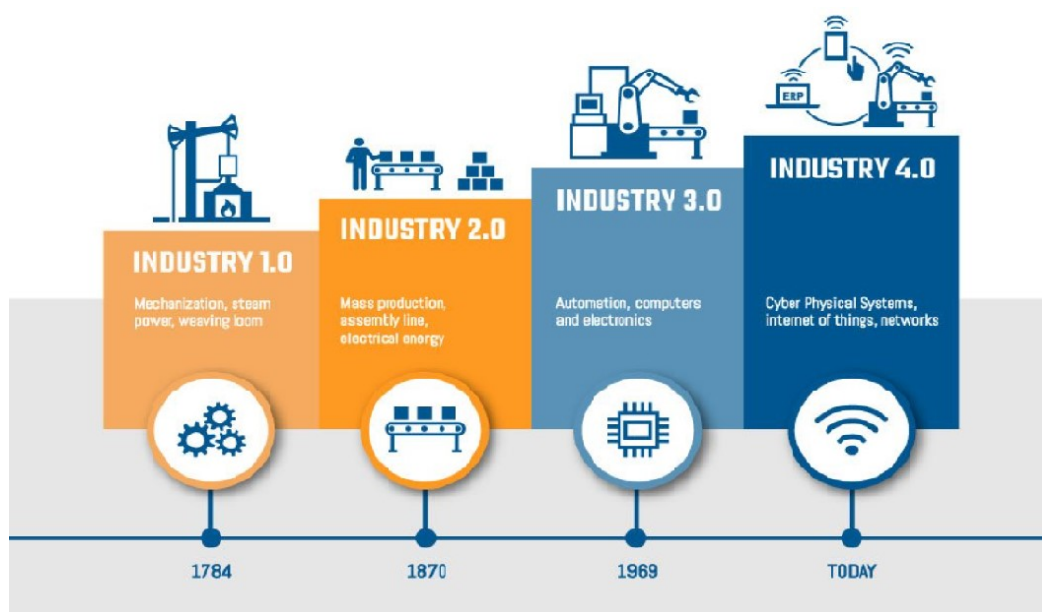
The digitalization era helps companies to make digital goals introduced digital strategies, digital culture and digital talent. The supply chain digitalization driven by the new technologies of Industry 4.0 has attracted more research from the Universities and from the industries generally.

The SCD refers to the combination of technologies such as Big Data analytics, IoT, Artificial Intelligence, robotics and Blockchain, where by the integration of them the supply chain can focus to the new way of operational process :the “data-driven decision making”**(Colombari et al., 2023)**

### **2.3 Industrial Revolutions and Industry 4.0**

The First Industrial Revolution (Industry 1.0) started at the end of 18<sup>th</sup> century, in 1784, in the United Kingdom and rapidly spread to the rest of Europe and America. It was the time when the mechanization of the production of goods began, using the steam power for energy instead of using the purely human and animal power.

The industry 2.0 came at the end of 19<sup>th</sup> century, in 1870. It began from Germany and America and after a while, it spread very fast in the rest of world. During this revolution, the invention of electricity occurred. The first electric motors, telegraphs, telephone and electric light bulb came. Afterwards, the industry 3.0. made its appearance, at the end of 20<sup>th</sup> century, in 1969. The information technology came. Microchip, personal Computers, smart software, internet and wireless internet are some of the things that arrived in the human’s life. The new electronic age started and slowly became digital in every process, mainly in production. One case is the automation of mass production. **(Lasi et al., 2014)**



*Figure 3- Industrial Revolution*

The industry 4.0 started in 2009 and it's the continuation of Industry 3.0. This revolution came to change the way that we think until now. It is characterized by increasing automation using smart machines. The factories are now smarter because new technologies are created, like the Internet of Things (IoT), the robotic science, the artificial Intelligence (AI), the cloud computing and the Big Data analytics.

Through these technologies, the factories can achieve information transparency and better decisions, because they collect all the data that there are in the factory field combining them with the other operational data that the enterprise has. By this way, the decision making and the productivity are more effective.



## 2.4 The new Technologies of the industry 4.0

Technology in recent years has been developing rapidly and has an influence on many sectors, such as the health sector, the food, the production and distribution sector generally.

Some of the most important technologies “were birthed” since the 4<sup>th</sup> Revolution, are: Internet of things (IoT), Automation and Robotics, Cloud computing, Artificial Intelligence and Big Data analytics.

Below, follows an analysis to the IoT, Automation and Robotics and Big Data analytics.

### 2.4.1 Internet of Things (IoT)

The term of Internet of Things was coined in 1990, by the entrepreneur Kevin Ashton<sup>2</sup>. The philosophy of IoT is the connection of a wide variety of electronic things by a local area network (with a unique IP address for every device). It is a communication network between different types of devices which are connected to a platform where includes data from all the devices and then they share these data by the use of applications. The devices keep automatically the information which are important and useful for their operation.

It is important to point that IoT is not software, but it is the process of inter connecting devices by the Internet. With the IoT the world achieves a technological revolution. One of the industries that the IoT has influenced is the supply chain-logistics. The Internet of Things in the global logistics had market size 34\$ billion in 2019. Estimations expect that in 2026 the value of it in the market will be 63.7\$ billion with CAGR<sup>3</sup> app. 12.4%<sup>4</sup>.



*Figure 4- Internet of Things*

<sup>2</sup> Kevin Ashton was born in 1968. He is a British technology pioneer who cofounded the Auto-ID Center at the MIT (Massachusetts Institute of Technology). He invited with a team of scientists the way of connection of devices by the internet through a RFID tag.

<sup>3</sup> Compound Annual Growth Rate

<sup>4</sup> <https://www.forbes.com/sites/forbestechcouncil/2023/02/21/the-iot-powered-logistics-industry-use-cases-benefits-and-challenges/?sh=78cfbd5f6622>

**Some of the applications that the IoT has, are:****❖ Shipments tracking and monitoring**

The logistics companies have the ability to track shipments' locations by the use of wireless devices such as RFID tags and GPS (Global Positioning System) sensors. Also, they have the ability to control and monitor the containers' temperature in real time. By the IoT technology, the AI (Artificial Intelligence) algorithms process the all-data information improving the security, predicting emerging issues, this way preventing problems from occurring.

**❖ Fleet management**

The fleet management by IoT technology offers real-time vehicle location, management of the vehicle status and speed control. It is very crucial development for every business which has fleet for the logistics procedures, because they can achieve efficiency and profitability in the company. The businesses can optimize the schedule of the daily routes, achieving reduction to fuel costs, delivery of goods with full capacity of vehicles, so possible in the future they need fewer vehicles than now for the transportation of goods. This means less fleet and labor than before the IoT technology.

**❖ Inventory management**

By the use of IoT, the inventory management is automated. Logistics companies use RFID Technology for the items, mainly RFID tags for tracking the all goods locations and for monitoring and checking the inventory levels in real time. It is very helpful in the companies with smart shelves and IoT sensors because the business can control very fast the stock levels and can make demand planning and forecasting.

**❖ Predictive maintenance**

The IoT devices collect big data which can help automatically to the prediction of failures in equipment and schedule maintenance.

**Challenges and possible solutions:**

The adoption of the new technology IoT faces some challenges, as every new technology that comes suddenly. Some of these challenges are

**1. Scalability**

By the use of all these devices and sensors that are interconnected by the IoT technology, the whole data that are created and are shared to each other devices, need detailed analysis and carefully monitoring and processing. It needs a strong infrastructure to manage all these data in the logistics procedures.

**2. Staff skills**

It is the most important step for the business which imports this technology in the WMS and ERP system of the whole logistics company. The step is the skills. The staff must be trained in

the new technologies that comes in the company and this is the most difficult part. Some employees do not accept the changes, or they want to learn something new and different from this that they know so many years in their work life. For this reason, it is a big issue for every company to succeed good training to the staff, as it is necessary to achieve this way the adoption of technical knowledge in their daily work.

### 3. Security

Every logistic company nowadays should be able to protect their data, and having the IoT technology must be more protective. All the devices and sensors are interconnected wirelessly with a unique IP address each one. The cyberattacks in the data of businesses is very common, so the IT department should be able to prevent unauthorized accesses to the data. It needs high security measures.

Devices that are connected by IoT technology are smart fire alarms, cars with sensors, smart door locks, smart security systems, smartwatches, temperature sensors, RFID reader, Barcode scanner, wearable technology, voice picking, AGVs<sup>5</sup>, AMRs<sup>6</sup>, etc. As we said before, the “things” are numerous and are used in different occasions.

Some of them are analyzed below:

#### **RFID Technology:**

RFID is a technology which creates radio waves and can identify or track objects or persons wirelessly. It consists of the components: RFID Readers, Tags and Software.

- ❖ RFID tags are very small electronic devices which contain antenna. The tags are attached to the objects or boxes for identifying and tracking. These are in various forms like stickers, key fobs, microchips or cards. These can be attached in every product or packing.
- ❖ RFID Readers are devices which emit radio waves and by this way they record and transmit all the data from the tags. Specifically, the readers consist of an antenna for the emitting and receiving of radio waves and of a transceiver for the connection with RFID tags. They are usually handheld devices or installed devices into large software systems.
- ❖ RFID System is software which focuses on the collecting and processing of data which are gathered from the RFID readers. By this software, the whole RFID is controlled and managed. There are applications which have filters and scan the data history, make data storage, manage the inventory of the warehouse and the access control.

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<sup>5</sup> Automated Guided Vehicle

<sup>6</sup> Autonomous Mobile Robots

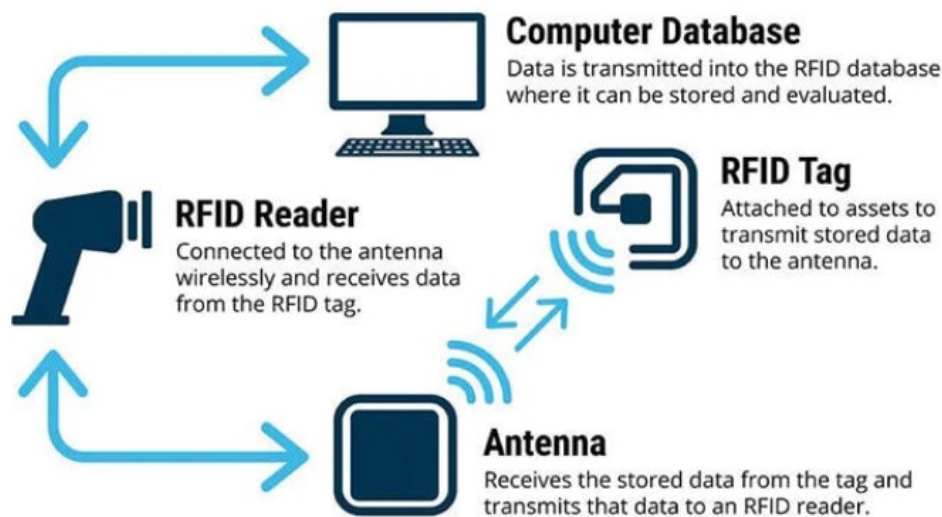


Figure 5- RFID technology

When an RFID tag is in the range of an RFID reader, the reader emits the radio waves and it is connected with the tag's circuit. Then, the tag sends back a unique identifier and any possible additional data of the product. The RFID reader collects automatically the information and sends them to the software of RFID for processing.

This technology has more advantages than the traditional barcodes system. Specifically:

The identification of products happens without eyes contact. The RFID tags can be read even if there isn't line of sight, that is, they are not directly visible to the reader. This means the automated identification of multiple items simultaneously without eyes scanning.

The speed of scanning is increased and efficient. The RFID systems can read quickly a lot of numbers of tags in a short time with a single scanner, thus reducing the operational delays and enhance the productivity. This is very useful and crucial to the field of supply chain, mainly in the inventory management and in the tracking of products. It can store data up to 2000 bytes within a single tag and can read multiple tags in short time at high speed. After research, the pickers can pick up (e. g twelve products) just in one second. This is a very fast and comfortable way of picking.

The RFID tags are durable. In contrast with the traditional barcodes, these tags are more durable and reusable. They withstand the changing environments like temperature variation (i.e., frozen warehouses -25°C). Also, the tags can be rewritten with a new data of information.

The choice of manual scanning is not first anymore. The automatically capture of data is the choice of RFID tags. By this way, the human errors are eliminated and the big data of information are more accuracy.

RFID technology is adopted by a lot of industries around the world, ten years now. The reason is that the costs of this technology have reduced. Some of the most important cases, where the

warehouses of industries use RFID, are the inventory tracking, the materials management, the employee tracking, the access control. (Sarac et al., 2010)

**Barcode Scanner:**

The barcode scanner has a scanner reading label which has black bars in width. Every barcode label has different black bars in different series. This happens because every label must have a different character, so every barcode of the products is unique inside a warehouse. The barcode scanner can only be scanned once a time, in contrast with RFID which consists of multiple tags and scans at once more than one product using single scanner. So, one of disadvantages of barcode scanner is the delay of scanning in a daily basis.



*Figure 6- Barcode Scanner*

**Wireless Temperature sensors:**

In food storage, there are temperature monitors which control the temperature of foods. These systems control the temperature and the humidity of foods reliable and automated 24/7.

The wireless sensors perform readings uninterrupted 24 hours and the warehouse managers are sure that the requiring temperature stay in the right level 24/7, because they can control and manage it from their mobile also. If any technical failure happens, for example at night, where in some industries there are not shift workers, then the alert rings to their mobiles automatically because of the sensors.





*Figure 7- Temperature Sensors*

The temperature wireless monitoring system integrates wirelessly all the sensors regardless of the location in any device. There is a specific software which can be downloaded to the manager's tablet or mobile. By this software they can efficiently monitor the temperature and also, they can search the historical readings about the temperature measurements.

By these proactive notifications, the managers can handle the problem 100% and they protect the business from potential losses, as soon as possible.

### **Biometrics:**

Biometrics is the automatic recognition of a person. It is any automatically measurable, distinctive and robustness characteristic which is used for the identity of an individual. Measurable means that the characteristics are represented to a sensor and are converted then into a digital form. Distinctiveness is the measure of the differences in the biometric pattern. If the distinctiveness is in a high level, then the results of identity is more individual. On the other hand, if it is in a low level, the results of the biometric pattern suit with the general population. For example, the fingerprint has lower degree of distinctiveness than the iris recognition system which is a unique characteristic and it does not change over the years.

The Biometrics are used for the personal recognition by the identification and verification way. By the identification, the biometric system tries to answer to the question "Who is X?". The biometric device reads the sample and compares the sample with all the other samples which there are in the database. This procedure is called "one-to-many" search (1: N). The system makes the "best" match or possible matches.

The verification happens when the system asks the question "Is this X"? The biometric system requires from the user the input, at which time the user is entered via password, user name or the combination of two. The system then requires a biometric sample and compares it with the user-defined template. This procedure is called "one-to-one" search (1:1). The system will match or will not match the two.

The biometric technologies came suddenly and became common increasingly and seem (like something exotic) extraordinary. The MIT Technology Review, in 2001, said that the biometrics will change the world. Some examples of them are the Fingerprint, the Iris scan, the facial and voice recognition which will be analyzed later.

In the warehouses of Industries, the biometrics system is usually called biometric timing clock system. It is a biometric technology which checks the attendance and the working hours of employees in the warehouse environment. By this system, the employees scan their biometric data like fingerprints, facial recognition or iris for their entrance and exit of the warehouse. The warehouse managers can track employee attendance, check their working hours, breaks and overtime. By this way, they prevent the employees from making misconduct behavior.

The biometric timing clock system has some additional skills by the use. The managers can create automated scheduling, they can capture the real time data making daily reporting. These features are very crucial, because the managers can observe the productivity of the employees and the trends of clock in and out of company, preventing the time fraud, where one employee enter in on behalf of another (e.g., with his/her card).

The Biometric system are mainly used by enterprises and organizations with a big number of employees, because it is difficult to control and track the clock in and out by the manner of punch cards and timesheets. It is more secure and accurate method and the managers have also the ability to integrate the payroll system calculating the working hours, overtime and the total wages of employees automatically.

As we said before, the types of biometrics devices are:

### **1. Fingerprint scanners**

The fingerprint scanner is an automated digital version of the old ink and paper method. The old method was used for more than a century for identification and verification mainly and firstly by law agencies. Now, the fingerprint method is used by law and also by the enterprises checking the clock ins and out of the employees. It has three main application arenas. First, the AFIS (Automated Finger Imaging Systems) in large scale which is used for law enforcement purposes, second for the physical and computer access and third for the prevention to access in entitlement programs.

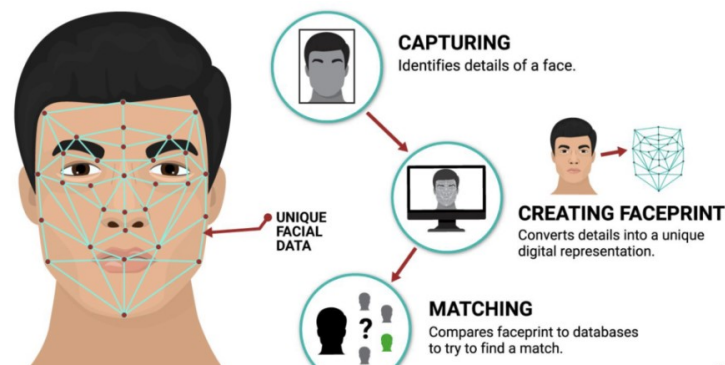
It is the most common in the warehouses, nowadays. Every working day the employees scan their fingers on the scanner device verifying their identity. The data are recorded and the manager checks their attendance on the tablet automatically. If a missed clock ins or clock out happens, or the fingerprint has a technical problem, the system sends alert to manager's tablet or mobile, automatically.



*Figure 8- Fingerprint scanner*

## 2. Facial recognition system:

It is a software application which verifies the identity of employees through the face detection and analysis. It uses camera to scan the facial features and record the attendances. The facial recognition has a clandestine ability to record the face without the person understand and knows that this happens that time. For this reason, the facial recognition system is used for criminals and terrorists in dangerous urban areas and also for the shoplifters and in the entrances of casinos. (Woodward et al., 2003)



*Figure 9- Facial recognition system*

## 3. Iris recognition system

The iris is unique for every personality. The iris scanning measures the iris pattern of a person. The eyes are different. The left eye of a person is different from his right eye. Iris scanning can be used for both identification and verification application quickly, because the system has high robustness and distinctiveness.



It is used in some countries mainly for checking national ID, for security, for e-government services and for automated border crossings with free passport.



*Figure 10- Iris recognition system*

#### 4. Voice/speaker recognition systems

It is a system which needs only the pass-phrase for access. As a sensor to this system, is a telephone or a microphone. So, for this reason it is considered a cheap technology but useful. The only problem is that the recognition of voice can be affected from the environmental noise. For this reason, the technology works for improving the reliability.

The IoT is one of the highest technological developments, nowadays, along with the automation and the mobile internet. (Zhang, 2002)

#### 2.4.2 Automation and Robotics

The automation and robotics are kinds of a new technology, when the industry 4.0 came. This technology has made an impact on the warehouse's operation. In the warehouses operation of the food industry the automation and robotics have also made an impact.

The use of it has revolutionized the manner tasks which are performed, improved accuracy and also enhanced the productivity.

Specifically, some key areas where this technology has made an impact on the warehouses, are:

##### Order picking

The **robotics and robotics arms** help the process of order picking. The picking has changed very much after the presence of robotics. The so-called "collaborative" robots (cobots) work together with the pickers helping them in the picking of boxes or products from the shelves.

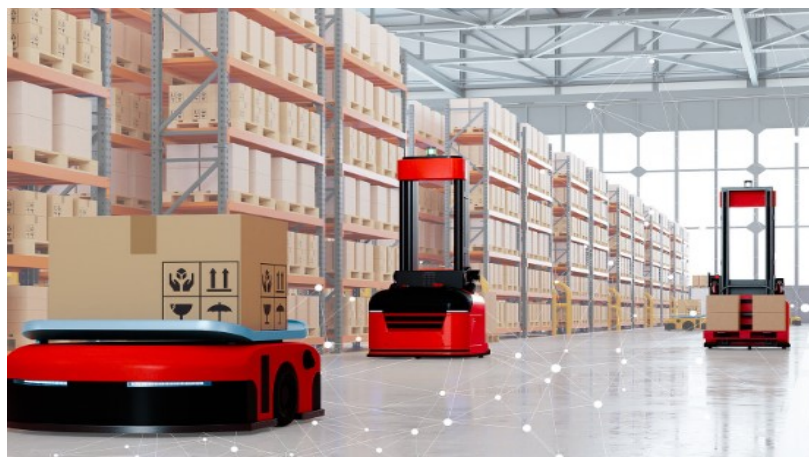


*Figure 11- robotic arm*

The robots can lift loads very heavy, helping the workers to reduce their physical strain. The robotic arms are equipped with a vision system which helps to the identification and picking of items with high speed and accuracy

#### Material handling

**Automated guided vehicles (AGVs) and AMRs (Autonomous Mobile Robots)** are the new technologies which are created after the revolution of Industry 4.0. These two robots are used for the material handling in the warehouses. They have important skills like navigation, transportation and delivery. They can navigate in the warehouse's areas, they transport the goods from any point of the warehouse automatically, they deliver them to the designated points and they handle any kind of boxes, pallets and containers, reducing mainly the manual labor.



*Figure 12- Automated Guided Vehicle (AGV)*



*Figure 13-Autonomous Mobile Robots (AMR)*

#### Packaging and sorting

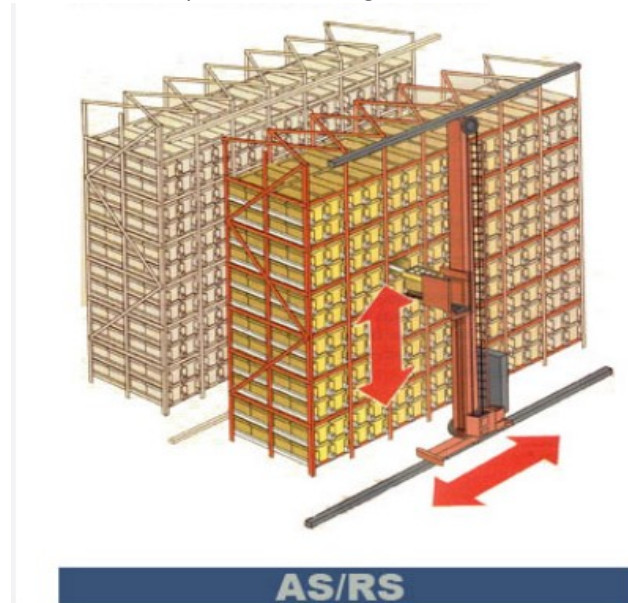
The **robotics** are used also for the packaging and sorting of items in the warehouses. The robots do automatically package, sorting, labeling and palletizing of the products. This increases the efficiency of the work and the consistency of the packaging of the products.

#### Inventory management

The **AS/RS** are automated systems which are called **Automated Storage/Retrieval Systems**. This system helps in the inventory management using the robotics for the storage, retrieve and the movement of inventory items within the warehouse. By the AS/RS, the inventory tracking is improved and the use of space inside the warehouse is optimized.

The AS/RS involves a combination of automated machinery like robotic cranes and systems which are controlled wirelessly and handle the movement of pallets and containers. The system is a very good and useful kind of technology for a very big warehouses with high inventory levels. It maximizes the storage density and on the other hand minimizes the manual labor in some of the warehousing processes.

By this system, the storage and retrieval from a high height where there are the shelves, is very easy procedure, as well as the delivery from the point of retrieval to the point of picking is a very fast process.

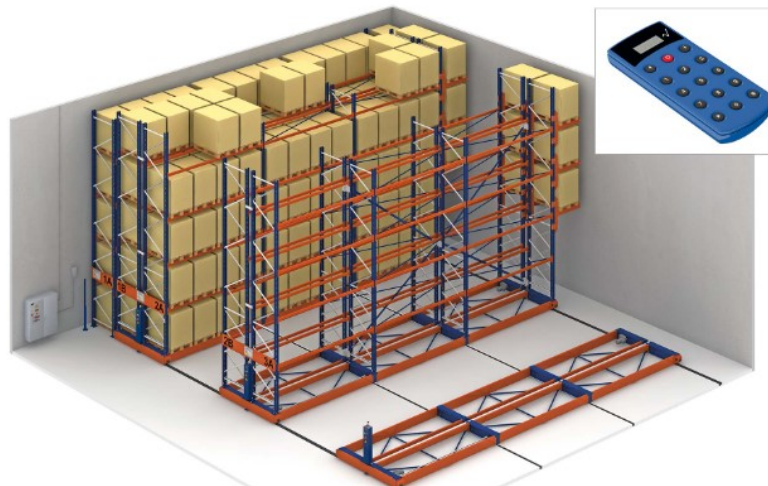


*Figure 14-Automated Storage/Retrieval Systems (AS/RS)*

Another one automation is the **mobile racks** or **mobile shelving** or **mobile pallet racking systems**, as it is called. It is a very smart type of storage solution which optimizes free space in the warehouses, minimizing wasted aisle space. The mobile racks are mounted on wheels or rails and they moved laterally. The key features that characterize the mobile racks, are:

- Mobility on wheels or rails
- Manual operation by the operator or automated operation using motorized systems
- Safety features like locks, sensors and emergency stop buttons preventing unauthorized movement and labors accidents
- Space optimization reducing the open aisle and creating more storage space
- Accessibility and retrieval improving the picking and retrieval operations





*Figure 15-Mobile Pallet Racking*

### 2.4.3 Big Data Analytics

Few years ago, big data was a “problem”. When the big data volumes came in the early 2000s increasingly, the technologies of storage and CPU were overwhelmed by the terabytes of data. The information technology faced crisis because of the problem of scalability of the huge big data. The enterprises had the problem to collect and analyze their data because of the huge volume.

Nowadays, there is the ability of using advanced analytical tools and every business can now study its current state.(P Russom - TDWI, 2011)

The big data technology contains the usage of advanced analytical tools and techniques where the businesses must know for analyzing and processing their large datasets. It operates by collecting and analyzing sources of data improving the efficiency and decision making.

In the supply chain, the big data technology operates, having:

#### Data collection

Data collection means collection of various sources across supply chain, like IoT sensors, GPS tracking, RFID scanners, production machines, ERP system and WMS system. These data sources give the real time data of the logistics company.

#### Data storage and management

Big data technology includes distributed storage systems, such as HDFS<sup>7</sup> or cloud storage solutions to handle the variety of dataset. By these systems the large amount of data can be stored efficiently.

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<sup>7</sup> Hadoop Distributed File System

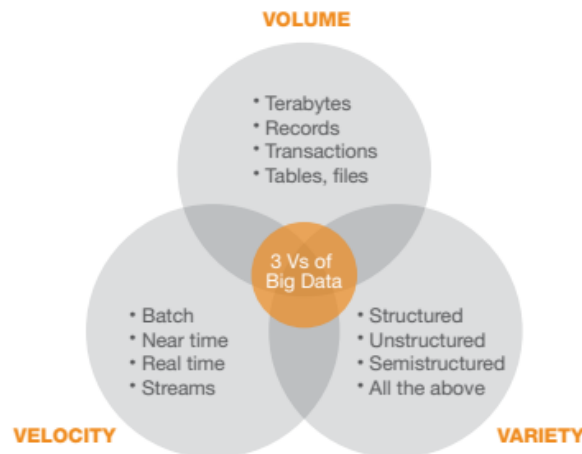
### Data analytics

The tools and techniques which are used to analyze the integrated data are descriptive statistics, predictive analytics and diagnostic analytics. The artificial intelligence, machine learning and advanced analytical algorithms are used for the optimizing supply chain operations.

### Real time monitoring and visualization

The technology of Big Data accepts the real time control of KPIs and metrics through interactive visualizations and dashboards. By this way, the managers can have real time information and updated, so they can do a better decision making and give faster responses to critical events.

The term Big Data is characterized by the 3Vs: Volume, Velocity and Variety. The **volume** refers to the size of the datasets which measure by the byte (terabytes or petabytes or larger). The total data comes mainly from the sensors or social media or transactional systems.



*Figure 16- Big Data Analytics*

The **velocity** refers to the speed of processes. The datasets are created rapidly and require real time processing. The last V is the **variety**. The variety aspect of Big Data recognizes the need to handle and analyze diverse data types and sources. The Big Data technology is included from different types of data, like structured (spreadsheets, databases), semi structured (files, .xml) and unstructured (text, images).

In the food industry, big data plays a significant role, with various data sources including regulatory data, food enterprise data, and media data. Analyzing high-quality big data can aid in the development of the food industry, while low-quality data analysis can have negative effects on market demand prediction and social stability.

Food regulatory data comprises information from food safety supervision and sampling inspections conducted by regulatory departments. Various countries have their own databases, such as the Rapid Alert System of Food and Feed (RASFF) in the European Union, the Import Rejection Report (IRR) and the Inspection Classification Database (ICD) in the United States, and the State Administration for Market Regulation (SAMR) alerts in China. Sharing and

utilizing this data among regulatory departments can enhance intelligent supervision of the food supply chain. However, challenges exist, including limited shared data, a lack of system standards, and inconsistencies in food standards among different countries.

Food enterprise data encompasses the entire food industry chain, from agriculture to processing and restaurants. Technologies like cloud computing, the Internet of Things (IoT), big data, and blockchain can integrate production lines into interconnected intelligent systems, optimizing operations and improving efficiency. For example, sensors and drones can collect data on weather, geography, and crop and animal behavior to assist farmers in making informed decisions. The application of big data and IoT in the food industry can result in cost savings, increased market value, reduced production costs, and sustainable practices. However, challenges include data fairness, lack of information standards, and immature processing of food big data. Standardized protocols, IoT security, and addressing issues related to scalability, fairness, security, and legal aspects of data processing are crucial for the successful implementation of big data in the food industry. (Tao et al., 2021)

In summary, big data in the food industry offers immense potential for improving operations, ensuring food safety, and making informed decisions. However, challenges related to data sharing, system standards, information protocols, and data processing need to be addressed to fully leverage the benefits of big data in this sector.

After the analysis of the above technologies, a reference to literature follows, where important authors state their views on the subject.

### **3. Literature review**

This chapter refers to the theoretical views that authors have on the new technologies of Industry 4.0 and how these are applied to food warehouses operation.

After the searching with the key words (new technologies, Industry 4.0, food industry, warehouse operation, IoT, Automation in warehouses, Big Data analytics), some important articles of writing emerged, where they record their views on this subject.

#### **3.1 Authors' review**

Nowadays, the factories and warehouses are considered smart ecosystems. They are included from humans, machines and devices which are interconnected with each other achieving efficient manufacturing of products. The industry 4.0 contains enabler technologies which can change and transform the industrial and warehouses procedures. The adoption of new technologies is difficult procedure and the implementation of them also. It is required changes to the number of practical challenges because of the lack of modernization. (Konur et al., 2021)

The key for the modernization is the digitization of the logistics procedures. By the digitization, the enterprises monitor the real time material flows and the handling of units is easier. By the

authors (**Agnieszka A. Tubis and Rohman, 2023**), the application of new technologies in the logistics procedures should be based on the above principles:

- ❖ Identification and interconnectivity – it refers to the IoT technology which operates by sensors. This technology is able to identify the products and the materials and also it improves the tracking of the products. The sensors help to all these processes. Tracking and tracing can only be effective if they are applied as a sector encompassing systems. (**Fritz and Schiefer, 2009**)
- ❖ Automation and robotics – the new technologies give new equipment and intelligent transportations systems which replace the human labor.
- ❖ Decision support and decision making – the artificial intelligence and the big data analytics lead to the automation of decision-making procedures.
- ❖ Information flow – the IT support makes an integration of IT systems by the cloud computing. By the cloud computing way, there is the possibility of access to the big data from different and multiple sources in the same real time.

Regarding the new technologies, **the IoT** is a manner of connecting any device with other devices at any time. Internet of Things create an advanced processing environment for the farmers, industries and warehouses. It offers a high tech environment in the whole supply chains. (**Kodan et al., 2022**).

The Internet of things platform provides information about the tracking of products. This is a very useful tool, because the consumers have the opportunity to make the best-informed decision. Also, the integration of IoT and blockchain technology can make the transparency and the traceability of the food supply chain. The below authors say that the IoT platform will ensure that the data of products which are collected by sensors from every stage of the logistics process are legally. (**Haroon et al., 2019**) The industries require always an applicable and use friendly traceability technique and low cost also. (**Badia-Melis et al., 2015**)

The supply chain visibility goes to a new stage by the regulations of the governments and also the necessities of the consumers. The food traceability became “a reality which goes from the farm to fork” (**Aung and Chang, 2014**)

Traceability systems used in food sector, show that, by using RFID technology, agri-food enterprises increase their automation level and also their efficiency, in a sustainable way. (**Gandino et al., 2009**)

The **RFID technology** (Radio Frequency Identification) is a next generation of UPC barcodes (Universal Product Code) and more expensive than the traditional UPC, the author (**Kumar et al., 2009**) says. The UPC have been use to standardize the identification process but it is required a clear line of sight between the reader and the tag. So, RFID is the alternative technology which makes faster the handling of goods in the food industry. (**Want, 2006**)

Some of the applications of RFID in the food industry, are temperature monitoring of foods, the procedure of supply chain of products and the ensuring of food safety. (**Brown et al., 2007**) The real time temperature monitoring in the cold supply chain is critical and crucial. The refrigerated foods are very sensitive so every fluctuation of temperature makes problems to the



food ingredients. For this reason, there are temperature indicators (TTIs<sup>8</sup>) which monitor the temperature history of products in a real time. (Gao et al., 2020)

Precise temperature monitoring is crucial for ensuring food safety in the transportation of fresh perishable products. However, existing temperature monitoring systems used in the cold chain, such as strip chart recorders or temperature dataloggers, are expensive, manual, and can only be read at the final destination by opening the container or package. This limits their use to certain parts of the cold chain or specific types of products, leaving gaps in continuous temperature monitoring.

To address this issue, logistic companies often rely on conventional paper labels for traceability information and place strip chart recorders in marked boxes per shipment to monitor temperature. However, this solution has drawbacks in terms of cost and the need for manual reading by opening the boxes.

Recently, there have been advancements in implementing temperature-managed traceability systems using **RFID tags** with embedded temperature sensors. These tags allow for continuous monitoring of temperature throughout the supply chain. Additionally, integrating chemical sensors into flexible tags is a current challenge, as it enables monitoring of factors like ripening or deterioration gases emitted by food products. In the context of the Good Food project, several RFID tags integrating both physical and chemical sensors have been developed. (Abad et al., 2009)

The below Arthur analyzes his experience about the barcode scanner.

Author (Basker, 2012) says that the **Barcodes and barcode scanners** had a significant impact on the grocery industry during the 1970s. To understand the effects of this technology, the author utilized store-level data from the 1972, 1977, and 1982 Census of Retail Trade, which was combined with information on store scanner installations. The goal was to estimate the impact of barcode scanners on labor productivity.

The findings reveal that the early adoption of scanners led to an average increase in labor productivity of approximately 4.5 percent within the initial years. The effect was more pronounced in stores that stocked a greater number of packaged products, indicating the presence of network externalities. In other words, the benefits of the technology were greater when more products were compatible with barcode scanning.

Although the short-term gains were relatively small compared to fixed costs, implying that the initial investment was not immediately offset by productivity gains, the study suggests that the main obstacle to widespread adoption of barcode scanners was profitability rather than coordination issues.

The author (Müller and Schmid, 2019) says that Data carriers such as **barcode labels** and **RFID tags** play a crucial role in enhancing the efficiency of information flow within the supply chain. While their primary function is not to monitor product quality, they serve purposes such as traceability, automatization, theft protection, and counterfeit protection. These data carriers

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<sup>8</sup> Time Temperature Indicator is a device that shows the temperature history of the product at any time

store and transmit information related to storage, distribution, and other parameters, often placed on tertiary packaging.



*Figure 17- Barcode*



*Figure 18- QR code*

Barcodes, both one-dimensional and two-dimensional, are commonly used and offer different storage capacities. One-dimensional barcodes consist of parallel spaces and bars that encode data, which can be translated using a barcode scanner and associated system. Two-dimensional barcodes, like QR codes, provide greater memory capacity and allow for the inclusion of additional information such as packaging date, batch number, weight, and nutritional details. RFID tags, on the other hand, offer advanced capabilities with a storage capacity of up to 1 MB.

They enable non-contact and non-line-of-sight data collection in real time and can be electronically loaded and modified. RFID technology provides advantages such as traceability, inventory management, and promoting quality and safety throughout the food supply chain.

**Biometric data** has been used for identification purposes, focusing on measuring individual traits to establish and authenticate unique identities. (Dantcheva et al., 2011) This includes biological traits (e.g., iris, face, fingerprint, DNA), behavioral traits (e.g., gait, voice), and recently adhered traits (e.g., marks, tattoos).

Biometric data offers advantages over possession-based and knowledge-based authentication systems as it establishes a direct correspondence between an individual and their data, providing reliable evidence of identity. AI-driven biometric systems utilize dedicated sensors and pattern recognition algorithms to compare and match biometric traits for identification.

An ideal biometric trait should be universal, distinctive, permanent, easy to collect, perform well in recognition, be socially acceptable, and difficult to spoof. While no single trait meets

all requirements, many biometric traits enhance identity verification processes. Biometric data can be categorized on a continuum from hard to soft. Hard biometric data includes primary traits like fingerprints, DNA, and hand geometry, which are highly distinctive and permanent.

Soft biometric data refers to ancillary traits such as age, gender, race, hair color, eye color, weight, and height. Soft biometric data are derived from hard biometrics and provide additional information about an individual but are less applicable for traditional identification/authentication purposes. However, they are generally less intrusive to collect and easier to understand and label for human interpretation.

The author (**Cheng and Tu, 2019**) says that the results of experiments that happened about the accuracy of fingerprint analysis, shows the fingerprint identification to be suitable to the access control mechanism of warehouse.

Another one crucial theme in the new technologies is the **automation and robots**. Robots have the possibility to make food processing, handling, palletizing and packing. The recent years the robots are numerous in the warehouses of food industry. (**Iqbal et al., 2017**) The robotic in the food industry increased the efficiency and the productivity, the operating costs were reduced (but the cost for the buy of these where high) and the customer service enhanced. The use of robots has increased the last years globally because the warehouses and the industries generally try to modernize increasing the production capacities. (**Luo, 2015**)

The author (**Sell et al., 2019**) says that the term of Industry 4.0 first pushed by the German Government. It was applied to a different and large cases of warehouses and industries. The connection between the real and virtual world came and be increased. The adoption of AVs<sup>9</sup> into the warehouses and industries promises technological revolution. Some of the advantages are:

- Cost efficient: installing of electricity instead of traditional fuels for the Avs
- Digitalization: by use of cloud computing the pickers can drive the Avs and keep control the tracking of products.
- Safety: the tracking and monitoring system in real time is safety because of the Avs
- Sustainable customer service and relationship
- Friendly environment: because of the electricity use than the fuels, the atmosphere is clean and the whole production circle also.

The author (**De Koster, 2018**) said that his research on automated and robotized warehouses is limited, and as new technologies emerge, new questions arise that require further investigation. There is a need for new models to evaluate system performance and provide insights for design and management decisions.

The potential advantages of automation in warehouses include space savings, cost reductions in labor and operational expenses, and improved availability of workforce. However, complete automation of both storage and picking processes has its limitations. It requires significant scale and long-term vision due to high investments that may take time to be recovered. Additionally, automating the picking process remains challenging and manual intervention may still be

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<sup>9</sup> Automated vehicles

necessary. Manual warehouses will continue to exist for now, even in economies with high labor costs, as logistics remains a people-oriented business.

Well-managed warehouses that effectively combine manual and automated processes demonstrate better performance in terms of productivity, process innovation, quality, and safety, as highlighted in studies by De Koster et al. (2011), De Vries et al. (2016), and other relevant literature.

The author (**Plaksina et al., 2018**) said: "In the period from 2017 to 2019, the number of newly installed **industrial robots** is projected to increase by an average of at least 13% per year". He said also that in recent years, there has been significant attention given to integrated solutions for warehouse automation as a part of industrial automation.

Automating warehouse processes offers benefits such as expense optimization and increased production efficiency. Among the effective tools for optimizing warehouse cargo flows, transport robots have gained prominence.

These robots provide flexibility and independence through automated driving, making them more versatile compared to continuous transport conveyors and forklift trucks. Transport robots have demonstrated their effectiveness in intra-shop and inter-operational material handling.

Their use enhances the reliability and efficiency of cargo movement by reducing the need for manual operations and simplifying processes.

The **Big data analytics** is another one important new technology. Big data was a serious and crucial problem for every company, almost 20 years ago. The storage technologies were overwhelmed by the lot of terabytes of big data, in the 2000s. The Information Technology (IT) confront the data crisis. (**P Russom - TDWI, 2011**) Nowadays, every enterprise studies the big data and understand the whole operation of the company, by using analytics tools. Bi, SQL and EDWs (Enterprise Data Warehouses) are some the analytical platforms.

The author (**Sharma and Parhi, 2017**) says that the usage of **Big Data analytics** in the warehouse operation, will enhance the accessibility and efficiency of the foods. The first thing starts from the farmers where must have to their hands a timely and real time information about the products by a specific technology tool. The data of demand products then will be efficient for the warehousing procedures, and finally the procedure of supply chain will have a normal row. All the big data analytics that are transferred to each other's stages contain information usable about how to produce, how much to store and when to distribute. The Big Data came to play a crucial role to the warehousing improving the accessibility of products targeting the zero-defect supply chain.

In today's global business environment, utilizing data has become essential for improving the efficiency of the food supply chain (FSC). Organizations are constantly searching for new sources of information throughout their supply chain network, from suppliers to end customers. The integration of advanced technological solutions, such as **Big Data (BD)**, at every stage of the food system, is directly linked to enhanced sustainability, traceability, and coordination among participants. (**by the author Abideen et al**) Big Data Analytics (BDA) play a crucial

role in improving supply chain efficiency by identifying new opportunities through processing large volumes of real-time market data and internal historical information the author **(Margaritis et al., 2022)** said.

Supply chain integration and connectivity can be categorized into three main streams: managing uncertainty in the supply chain network, developing social capital to strengthen inter-organizational relationships, and formulating strategies to capitalize on market opportunities. Data acquisition and assimilation across the entire supply chain are highlighted as a higher-order capability that facilitates supply chain integration. This concept is also supported by **Engelseth et al.** through their case study in a complex banana supply chain implying that the capitalization on Big Data is based on accurate information flow and interconnections which are equally significant and related to both II and EI. **(Engelseth et al., 2019)**.

Regarding the food industry, the author **(Tao et al., 2021)** says also that the Big data has wide-ranging potential applications in various aspects of the food industry, including social co-governance, quantitative production, market exploitation, new dishes, take-out services, and precise nutrition and health management.

However, realizing the full potential of big data in these areas requires further research to address technical challenges, social implications, and health and sustainable development concerns. By addressing these issues, the food industry can effectively harness the power of big data to improve operations, meet consumer demands, and promote healthier and more sustainable practices.

#### 4. Research Methodology

The method which is used about the research is the qualitative method. The qualitative method helps to investigate and analyze what are the beliefs, the tendencies and the experiences of a group of individuals. It creates non numerical data.

In this particular thesis, the goal is to investigate which of the new technologies of Industry 4.0 are adopted in the food warehouse management, which will adopted in the future and which are the benefits.

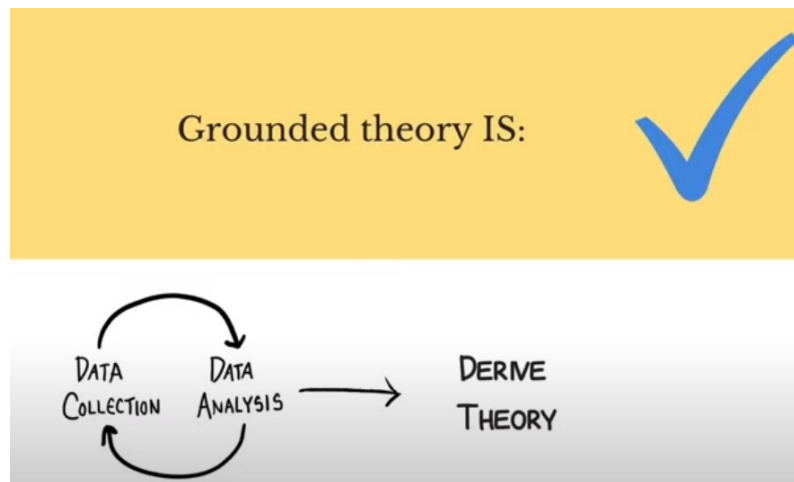
It is addressed to warehouse managers of food Industry. The research is done in dry, frozen and refrigerated warehouses, because it was possible the communication in this branch. The research was carried out through a structured interview, where the managers answered to a form of questionnaire, based on their working experience. The questions carried out, are as follows:

- 1) Do you know about Industry 4.0 and the new technologies which are created from this revolution?
- 2) Which of the new technologies do you use in the warehouse operation?
- 3) Why do you use these technologies and what are the benefits from using them?
- 4) If you do not use them, why you don't use them and which ones would you like to use in the future?
- 5) Do you trust these kinds of technologies?

The interviews to warehouse managers were conducted by telephone. On Chapter 5 are the analytical interviews of them.

The research is included from two parts. The first part is the structured interviews where all the managers answered to the five basic questions inside from a discussion.

The second part of the research is the grounded theory methodology. This methodology means that the researcher collects all the real data based on the interviews that took place before and tries to divide from this data all the important features and key words which needs for analyzing a specific phenomenon or process.



*Figure 19-grounded theory*

"The goal of grounded theory is to generate a theory that accounts for a pattern of behavior which is relevant and problematic for those involved" (**Glaser, 1978**)

Grounded theory (GT) is a qualitative research method that is not limited to any particular discipline, theoretical perspective, or data type. Unlike other approaches, GT generates concepts from empirical data rather than relying on existing literature.

Similar to a detective, GT researchers aim to explain the main concerns of participants in a specific situation and understand how they address or process these concerns. The resulting outcome of GT can be presented as a hypothesis, model, or abstract conceptual theory. The theory revolves around a core category and its related categories.

The goal of GT is to generate a theory that explains a relevant and significant pattern of behavior for those involved. Conceptualization is a central process in GT, emphasizing its role as a theory-generating method rather than a purely descriptive one. It requires creative and conceptual thinking to generate theory from empirical data. (**"Some thoughts about the literature review in grounded theory studies," 2010**)

Qualitative research offers a valuable approach for studying a theme when it is defined as a subjective experience. By using the qualitative structured interview technique, researchers can capture individuals' own descriptions and perspectives on their role of this theme. This method



allows subjects to express their personal experiences by their own words, providing a deeper understanding of its significance and impact on their lives. (Howe, 1988)

## 5. The Interviews and the results of the research

In this chapter, the four main interviews of warehouse managers have been recorded. The interviews were carried out by telephone and took the form of a discussion. The questions that were asked was five. Below are the recorded interviews, in detail:

### 5.1 Interview A

#### **Warehouse manager in a store of packaged food and vegetables (frozen and refrigerated)**

The manager works in the food company "A" almost 5 years in the frozen and refrigerated warehouse and production. Asking him if he knows what are Industry 4.0 and the new technologies of it, he answered "yes but no analytical". Explaining to him what the new technologies of 4th Revolution is, he understood exactly for what we talking about.

I asked him which of the new technologies he knows and which of them uses for the warehouse operation. He said that he knows the IoT connection and it is one of the technologies which are used in his occasion. Temperatures sensors, scanner RFID and the SAP system are connected with each other wirelessly and they exchange data automatically.

The temperature sensors are the most important devices for him. It controls the temperature (-22 until -25°C) for the frozen foods and the temperature (4°C) for the refrigerated foods. Specifically, the warehouse has a highly system security for the temperature control which is connected wirelessly with manager's mobile phone and tablet. If suddenly, for any reason, the temperatures are not within the permitted limits of the storage, an alarm rang to his mobile phone, so he can control the situation as soon as possible, he said.

Also, an important new technology for him is the scanner for dimensioning of products. After the production, the products are scanned by this scanner. He said that it is a specialized device because they can have by it the dimensional measurements of products automatically, from the device to their computers and tablets. He said "their" which means himself, the warehouse assistants, the outbound department and the marketing team of the company.

The company has a program which name is CRM software, where all the analytical measurements from any item are uploaded automatically after the scanning. The dimensioning scanner gives information about the length, width and height and helps the managers of warehouse firstly to control the inventory management, to check the space optimization and secondly to calculate the shipping. It is important for him, that this scanner require non-contact scanning. It does not require the physical presence of employee because it is a laser with imaging techniques, so this minimizes the risk of product damage because there is not the need of manual handling.

The benefit from this scanner is that the pickers do not waste time to separate the goods by size. There are conveyor belts that automatically lead the products to different spaces

depending on size, so then they can be placed on corresponding pallets by the pickers. The storekeepers do not waste time for separation so it is very useful and productive procedure which leads to a more directly customer service than before and faster delivery of products to the retail stores.

Another one IoT and automatic system which is used in this company is the Packaging system. The manager said that it is so crucial system in the production of items like in cheese. It is used for packaging the sliced cheese. This procedure is a semi-automatic system for his opinion, because the packaging system packages automatically the cheese but before that the employees cut the cheese. However, the system gives to the warehouse operation more productivity ensuring efficiency and consistency in the whole process.



*Figure 20-Autonomous Cleaning Robots*

During the discussion, he said that there are new technologies that the members of the administration of the company want to buy and operate them for the best of the warehouse system. By his opinion, the two needs are the autonomous cleaning robots with sensors and the palletizing system.

The first is an important technology because as a manager believes that the job of warehouse workers is not to clean a warehouse but to undertake all the other procedures within it, which are numerous and time-consuming. Thus, the purchase of such a robot will be efficient and cost-effective for the company over time. The robot will work automatically within the warehouse at times when the warehouse workers will have finished their work. The cleaning process will be more essential since the robot will not encounter obstacles in the whole process, nor the storekeepers will have anxiety and won't be injured in case they are working and the robot is cleaning the space at the same time.

The second device of new technologies that he believes is important for the company's efficiency is the palletizing system. It is an automation technology, where the robot machine



stacks and organizes products onto pallets and then it puts nylon around the products. It is a very time-consuming process for the pickers.



*Figure 21-Palletizing System*

He also said that it would be efficient to have these kinds of technologies in the warehouse but the cost was very high for the company. Even if the administrators had the ability to rent these technologies for a trial period time, this means that they should change all the warehouse operation<sup>10</sup> just for the trial period. This cannot be so easy procedure. So, there is a fear and insecurity in the mind of the businessman and investor, for these challenges. The fear exists because the probability of not depreciation of expenses in the next years, is high.

## 5.2 Interview B

### Warehouse manager in a dry cargo store (food and nonfood)

The warehouse manager "B" works in a multinational logistic company which stores dry cargo. The warehouse has an area 38.000 m<sup>2</sup> and it consists of food (packaged coffee, rice, spaghetti etc.) and no food (detergents, paper goods, cosmetics). It is the central warehouse of the company, where supplies its retail stores which they number in 300 stores, in the whole Greece. The warehouse operates 24/7 and the employees work in three shifts. The number of employees is almost 500 hundred and he has under his supervision 200 employees.

My first question in the interview was if he had heard what Industry 4.0 and the new technologies of it were. He said that he knew the 4<sup>th</sup> Industrial Revolution and that the new technologies by this Industry were in a high-tech level. He said that some of these technologies that he had heard were the model Just in Time in the inventory management, the automation in production system, the artificial intelligence in the production system, the IoT and the Big Data analytics (the last only as a term).

<sup>10</sup> Warehouse Management System

My second question was about the new technologies that he might use in the warehouse operation. He analyzed to me that the company used for almost 3 years software which called "DC- Demand and Replenishment Planning System- FnR". The company had run this system in a trial edition for almost 6 years and then run it officially for only 3 years. By this system, the warehouse was making orders daily to their suppliers according to the needs of the retail stores and then the suppliers supplied the warehouse daily with these needs and last the central warehouse supplied all the retail stores. All this procedure was happening automatically and on a daily base.

For example, the automatic feedback of the retail stores is done as follows: when in each retail store the consumers buy, for example, 8 pcs of coffee in one day (the store has inventory 1 box=12 pcs), at the end of this day the cashiers process the history of the total sales and automatically through the FnR program an order is sent to the central warehouse. The next day the retail store receives 1 more box of coffee and automatically the central store makes an order to the coffee supplier to cover the inventory. This procedure happens in all the products and by this way the manager controls the stock in the central warehouse.

The entire process of forecasting and replenishment through the FnR software is done by employees specialized in this program. Their goal is to ensure the availability for the stores orders and to optimize the stock levels.

Nevertheless, the use of this system was discontinued by the company itself for its own internal reasons. But it is worth mentioning the positives and the negatives of its use all these years.

The benefits of using this software were enough. The warehouse manager could schedule the permits of the warehouse workers (200 in number) in the range of 6 weeks period from now. This process was possible because of the forecasts given by the FnR system about the volume of work for the next 6 weeks. Also, an important benefit was the fact that he could schedule the maintenance of the machines, i.e., he was planning the Clarks' services for the next 3 weeks. The technical company schedules with the manager the technical support for the Clarks in the period where the work in the warehouse was not full.

On the other hand, the negative characteristics were more than the benefits ones, he said. Some of them were:

- The software was difficult to use
- The software required a large amount of company's historical sales data to 'run'
- The installation of FnR software in the company's system was very difficult and time-consuming. For this reason, it was implemented in trial edition for about 6 years.
- There were times where the program placed automatically a larger volume of orders to the suppliers than the real and actual demand. This caused serious problems to the capacity of the central warehouse. There were pallets of products out of the place of warehouse because of the full volume in stock. The return of orders to the suppliers was a very difficult process for manager. These situations create serious problems to the reverse logistics.

There were cases where the specialist realized the excessive automatic demand of orders and managed to cancel the extra orders that the system automatically placed. This disadvantage caused a great cost and overtime of workers.

- Another negative feature of this program was noticed during the covid-19 period. The system perceived the increased demand of orders, as an error.

Continuing the interview, he told me that they don't have robotics in the warehouse. It is a very big investment for the Greek companies. It is something very far from the Food warehousing and production. Excluding the investment cost, the robotic arms for example, it is not practical and efficiently in food warehouses. Products like milk, legumes, chewing gums, coffee, vegetables which are diversely, cannot handle from a robotic arm.

Also, AMGs and AVGs are very costly, not useful and no flexible for the storage, he said. The pickers use VNA trucks but he said it is counterproductive.



*Figure 22-Vehicle Narrow Aisle (VNA)*

A very flexible and useful technology that they use to the warehouse is the **reach truck**. The reach truck can be raised up to 10-15 meters high. The shelves of warehouse are 10-12 meters high, so the use of this truck is very productive. It is more productive than the VNA in a standard dry cargo warehouse, like the one where he works. A very positive feature of the reach truck is that the inventory process is carried out on each shelf where the pallet is located. I.e., the pickers perform the inventory control “ascending”. They don't take down each pallet to make the inventory, but they “go up to every shelf” and start the inventory of products.



*Figure 23- Reach Trucks*

The most useful new technology tool in this store is the voice picking. The use of this tool is done via Bluetooth. It is a system that replaces the well-known RF scanner and works with voice commands.

Specifically, the user listens to voice commands (e.g., in which position in the warehouse is the product he/she has to collect) and responds to the system with an “ok”. Voice picking replaces the famous paper of picking list.

It comes from an American company that produces the voice picking. The warehouse manager said that they use this tool in the warehouse almost 10 years and it has many positives characteristics.

The positive aspects from the use of voice picking are (by manager’s opinion):

- It is a very smart device
- User friendly
- Every user creates his/her own profile with account and password.
- It recognizes only the user’s voice. If someone else is near the picker and says “ok”, the voice picking does not recognize his/her voice.
- Pickers have free their hands, so they work comfortable and faster.
- Reduce the delivery time



*Figure 24-Voice Picking*

The negative aspects are (by manager's opinion):

- Spare parts of voice picking are hard to find. The supply of these is very difficult due to the fact that the American company has a monopoly on the production of voice picking.
- There is no technical support representative for this product in Greece.

For example, he said, a few years ago, it had created a problem in the safety cover of the voice picking battery. Almost all their voice pickings were without safety caps. As a result, the voice pickings did not work. The warehouse manager asked the American company to bring the spare parts as soon as possible but the American company brought the spare parts to the central warehouse after a year!

This event created serious problems in the management of the warehouse and in the whole retail company, like economic damage, reduction of work production, reduction of customer service, non-delivery of products, unreliability towards the customer.

The warehouse manager with the administrative of the company found a temporary solution by creating non-authentic spare parts by the use of 3D print. This was a very smart movement but also with extra cost for the company.

After this financial loss, the company that provides the product, sent to the business new voice picking products with extra spare parts for each, thus preventing possible unexpected losses.

Despite this fact, which caused a strong problem to the warehouse operation and logistic procedures for a year, it is worth mentioning that voice picking increased the company's productivity by 12%-25% in the following years of its use. That is, the pickers were covering a volume of work as if they were working a half shift more. The customer service has greatly increased.

The demand of orders is 24hours, so the voice picking operated efficiently and constructively. It is also worth noting that in terms of time, the trucks left 2-3 hours earlier for the distribution of products due to the use of voice picking.

Hence, the benefits finally were: better lead time, better utilization of storage and better inventory management within warehouse.

Here, it is worth noting that despite the initial economical loss by the problem of voice pickings' battery, in the process the company "B" was positively rewarded by the use of this technology.

The company's ROI<sup>11</sup> became more attractive and increased. New investment possibilities were created and the productivity increased without reducing the human potential. Also, new strategies were created in order to open new points of sale and distribution centers in the future.

The last question from the interview was if he trusts the new technologies and believes to them. He told me that some jobs will be reduced and at the same time new jobs will be created. Also, the rapid evolution of technologies will lead to a lack of prepared human potential to handle the new changes.

For example, in Big Data analytics technology there is no well-trained staff and in 10 years from now the technology will have evolved too much, but the employees will not be already and won't be experienced enough to immediately respond to the challenges of the market.

### 5.3 Interview C

#### Warehouse manager in a dry cargo store (food and nonfood)

The warehouse manager works in a wholesale company in Attica. Throughout Greece there are 20 wholesale stores that serve customers on a 24-hour basis. The company provides to its customers (customers: retail businesses, shops selling various goods, service companies etc.) all kind of products such as food and stationery at wholesale prices.

The capacity of the dry cargo warehouse which be managed by the manager is 12.500 square meters. This is the central warehouse in the whole Greece. The products are distributed from there to the remaining 20 stores in Greece. It is a dry cargo warehouse.

The employees he supervises are 50 in total and their work shifts are equivalent. Regarding new technologies, he told me that he is quite aware of the developments of technologies today and constantly follows the evolutions of logistics science worldwide. But in the kind of company, he works in now, new technologies are not so much required, at least until now.

Regarding IoT technology:

In the warehouse, they use the well-known RF scanner in its most sophisticated form. It is in color and has built-in windows software; it has a touch screen and connects to headphones. The software they use to manage the WMS is called Logistician and to manage the commercial

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<sup>11</sup> ROI = Return on Investment

It is a performance measure which evaluates the efficiency and profitability of an investment. It can also compare the efficiency of different investments.

The calculation of ROI is: 
$$ROI = \frac{CURRENT\ VALUE\ OF\ INVESTMENT - COST\ OF\ INVESTMENT}{COST\ OF\ INVESTMENT}$$



process is SAP. The “bridge” between WMS and SAP which processes and transfers the data is “live”. This does not happen in all companies and especially in companies that have a large amount of data. They have a large amount of data, so it is impossible technically to create a “live bridge”. For this reason, they do manual import their data every night. As a result, any errors and any changes that occur (in WMS) or in the orders taking (in SAP) are noticed the next day.

However, in the warehouse where he works, the bridge is updated automatically (live) and thus errors are corrected immediately.

For example, in the past, it had invoiced a customer with products of 20.000 pcs instead of 2.000 pcs and the payable amount was €10.000 instead of €1.000. Due to the “live bridge”, the problem was immediately detected and the invoice was canceled. A new invoice was reissued with the correct amount before the information reached the customer.

In other companies, however, which do not work with live bridge between ERP and WMS, because the installation is difficult, time-consuming and expensive, they face the problems the next day, where the orders already are to the customers.

Regarding the automation:

The company uses reach trucks (specifically the side reach trucks), because they are more practical to use, according to the manager.



*Figure 25-Side Reach Trucks*

Also, he uses electric pallet trucks. They are not new technologies; they are tools that have been used for many years in the warehouses. He believes that the tools that are used in this warehouse are sufficient, if we take into account the volume of work and distribution of orders.





*Figure 26- Electric Pallet Truck*

Regarding the new technologies of Industry 4.0, something that would increase productivity in picking and packing warehouses, is the AR smart glasses for “voice picking”. These glasses are like sunglasses and have a cross(laser) in the center. The glasses scan the product which the picker is looking at, i.e., where the cross (laser) “touches”.

While the manager believes that it would increase the productivity, on the other hand he considers that it is very extreme tool for this warehouse and he called it “gadget”.

Its cost is so high that the company would not make this purchase.

Another one technology which may be useful but also expensive is the RFID Tracking technology. He said that it will be useful in the wholesale’s stores and not inside the central warehouse. This technology is used to big e-shops companies on abroad, yet. It is a system which is put in the exit of the stores. When the customers leave from the store, their purchasing products passes from this system. Automatically the RFID tracking recognizes the products (e.g., 3 pallets of olive oil, 1 pallet of boxes of snacks etc.) and the WMS is updated. By this way the warehouse managers can control the tracking of products.

The company, he said, is open to new changes, as long as their implementation and their cost to be realistic.

## **5.4 Interview D**

### **Warehouse manager in a store of packaged frozen food**

Here, the warehouse manager works in a warehouse of frozen products with a temperature (app. -22°C to -26°C) and area of the storehouse 7.000 m<sup>2</sup>. The company produces and freezes products such as cheese pies, ham cheese pies and spinach pies. The number of employees

within the warehouse is 15 pickers and, in the production, department are 50 workers. These are distributed in retail stores, mini markets, and bakeries, canteens both at home and abroad.

He manages the warehousing and is responsible for both the timetables and the pickers' shifts. Asking him if he knows what Industry 4.0 is and what new technologies are derived from it, he told me that he has little knowledge about it.

The technologies which are already installed in the existing warehouse for a few years, he told me that in terms of IoT technology, they use:

✓ Temperature sensors

The warehouse has moving aisles and shelves where they move by sensors. In each moving aisle there is an electronic panel that monitors the temperature of the products. The temperature must be between -22 and -26 °C strictly. If the temperature drops below the permissible limits or rises above the permissible limits, an alarm sound. The alarm application is connected wirelessly to the manager's tablet and mobile phone, so that he can be updated immediately.

✓ Biometrics

The company has implemented the biometrics system both for the entry and exit of the pickers from the warehouse, as well as for the entry and exit of the workers in the production department. The biometric system they use is the “fingerprint”. In this way, they control the workers' schedules as well as the safety in the production and storage areas, in case an event or accident occurs due to human intervention.

- ✓ In terms of product picking, the company uses the classic RF scanner that works wirelessly. What they would like to change is the use of this tool with another one, such as vision picking. It is a wearable technology. The warehouse manager believes that the use of this system will help a lot, because human errors are thus eliminated. It is a system that guides the picker through light signals. In his opinion, this technology will improve customer service, because the lead times will decrease and the just in time (JIT) will automatically be improved.



*Figure 27-Smart glasses for Vision Picking*

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Also, he states that picking and palletizing orders constitutes 70% of the warehouse’s activity. Therefore, if this work of the storekeeper is carried out in half a shift because of the new technology like vision picking, then what will he/she do? There will definitely be some extra work to do within his/her 8-hour workday, manager says. In the future, there will be fewer jobs and he doesn’t like this as an idea.

In terms of automation, the manager says that:

- ✓ In the warehouse they use reach trucks. Both he and the storekeepers are happy with the use of these, and for this type of warehouse the manager considers that something more sophisticated is not necessary. Mentioning AMG and AVG to him, he told me that such a thing would not facilitate the procedures inside the warehouse. The configuration of the warehouse space does not support this type of technology. In such a case, it would be necessary to completely change the layout of the warehouse, so that the new trucks can be used in the operation of the store.

He said also, it would be crucial the company to buy VNA Forklift, which was high tech and useful but there was an important problem in that case. The use of VNA is not recommended because the warehouse has mobile racks installed. Therefore, the use of it would require a total change in the layout of the warehouse and this implies an increase in costs and a long delay in the current logistics processes. So, this will also cause damage.

Another one useful technology in the already existing warehouse would be the robotic arms, specifically, in the production department. After the production follows the palletizing, this is quite time-consuming for the worker. So, robotic arms are a very useful tool for this purpose.



*Figure 28-VNA Forklift*

Regarding the Big data analytics:

The business manages its data volume through a program called "Power Bi". Through this program, the warehouse manager has access to the statistics of the company's data, specifically to the stock, sales and defective product information. Also, through this data, he makes a forecasting in production of products and stock of them (weekly, monthly and yearly forecasting) according to the needs of the customers. Also, he controls the receipt of raw materials.

His goal is to predict what quantity needs to be produced that does not exceed the needs of the customers but also the capacity of the warehouse for stock.

The new technologies create some insecurity for some warehouse managers, and also to him. The high cost from the purchase of these technologies and the question of amortization of money, the difficulty of adapting the workers to the new changes, the need for required training of the workers, the total change of the warehouse facilities for the new changes, are some of the issues of concern the manager. Nevertheless, he said that the company is open to new changes and would like to attempt it.

## 5.5 Results of the research

After the detailed interview which was given by each manager, the main and most important elements from each interview were collected.

In the tables below, it is recorded each question and the answer of each manager in direct speech, exactly as they were asked.

Do you know about Industry 4.0 and the new technologies which are created from this revolution?
A) He said: "Yes, I know what does Industry 4.0 mean, but I haven't study analytical about it and as well as the new technologies."
B) He said: "Yes, I am informed about Industry 4.0. The new technologies which are derived are in a high-tech level"
C) He said: "I am quite aware of it and I "follow" the evolutions of logistics science"
D) He said: "I have heard about it, but I have a little knowledge"

*Table 1- Results of question 1*

Which of the new technologies do you use in the warehouse operation?
A) He said: "I am informed about the IoT connection. We use this kind of technology. Specifically, we use temperature sensors and RFID scanner, which are connected automatically with the SAP software system. Also, we use scanner for dimensioning of products and autonomous packaging system".

B) He said: "the company install a new program which names is FnR. It belongs to IoT connections, like RF scanner. Also, we have for the picking VNA trucks, Reach trucks and Voice picking".
C) He said: "We use the IoT technology, like RF scanner but in modernized edition. It operates by windows, it has colorful screen and it works with headphones, if the pickers want it. Also, there is a "live bridge" between SAP system and WMS. It's a very useful and smart project. In automation part, we have side reach trucks and electric pallet trucks".
D) He told: "We use the IoT connections and mainly the temperature sensors the Biometrics, the traditional RF scanner and last in the automation part, we have the reach trucks and in the technology of Big Data Analytics we use the program Power Bi".

*Table 2- Results of question 2*

**Why do you use these technologies and what are the benefits from using them?**

A) He said: "I use them because we can exchange data automatically (between the departments), we feel safer in the procedures inside the warehouse (me and the pickers). E.g. the temperatures sensors make me feel safer than before, because the sensors control the temperature 24/7 inside the warehouse fridge and if something happens the alarm ring. The benefits for me, are: safety, reduce of waste time, productivity, efficiency and automated control of the all processes".
B) He answered: "I like the evolution and I like to test new things in my work life. By using the new technologies, it is easier (for me, for the pickers and the distributors) the work life in the warehouse than before. For example, as a manager, I can make from now schedules (weekly, monthly etc.) for the shifts and permits of pickers. The benefits for me are the right inventory management by the use of new techs, the speed of working and the safety".
C) He said: "We don't use new technologies so much. We have some kind of them as I have mentioned before. The benefits are mainly the safety and the efficiency.
D) He said: "the new technologies that we have, like temperature sensors and Biometrics, help me very much in my work. The automated alarms from the sensors of temperature, the automated check of the entrance and exit of employees in the warehouse by the Biometric, reduced me the spending time about the use of these. I have the time to focus in other necessary parts in the warehouse".

*Table 3- Results of question 3*

**If you do not use technologies, why you don't use them and which ones would you like to use in the future?**

A) He said: "I use the new technologies in the warehouse operation. We can't work without technology. There are some technological tools that I prefer to see in the warehouse in the near future, like the autonomous cleaning robots with sensors and the palletizing system. They help in the efficiency and in the right performance of the shifts. The reasons that I don't use them are two: the high cost and the need of workforce training and adaptation".
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B) He said: "Of course the technology exists in our warehouse, as I answered before, because without technology, we cannot manage a warehouse nowadays. I believe that we have the necessary tools until now, so maybe I don't have something to say about the future technologies in the warehouse."
C) He said: "We don't have the choice not to use technologies. Of course, we use. Some technological tools that I have seen in expeditions that I have gone in Germany and I would love to test them practical in the food warehouse, are the AR smart glasses for "voice picking and the RFID Tracking.". The administration of the company is open to new changes and tests, but the problem is the extremely high cost of them. E.g., the smart glasses costs app. 12.500 €/ per pcs".
D) He said: "As I am not fully aware of the available technologies and their potential, the new technologies that we have after the industry 4.0 are important and useful. Every company has nowadays. After a searching, the administration considers that the VNA Forklift and the robotic arms in the production department will be useful and crucial. Also, the vision picking instead of RF scanning will be an important investment. The brake on investment is the high purchasing costs, the costs of training the employees and may the whole change of the construction of warehouse is another one extra cost.

*Table 4- Results of question 4*

<b>Do you trust these kinds of technologies?</b>
A) He said: "I cannot say with confidence 100% that I trust the new technologies. I trust some of them like the IoT, but the automation like robotics arms and AI robotics in the production, I cannot say yet that it is a good choice in a food warehouse. If there was a proven track record of reliability and performance in the food supply in our country, may it will be easier to test it. The high purchase cost and the cost of installation of these technological tools in the already existing warehouse are 2 important things which need thinking"
B) He said: "Yes, I trust these technologies and the administration trust also. We already proved this by our actions. The FnR system that we replaced years ago in the company, it was new and trial system. We changed all the previous system just to go some steps more up. The company wants to invest in new changes for the better functioning of the whole business, and they want to keep a hybrid working system".
C) He said: "Even if the technologies that we use now are sufficient, the company trust the new techs. The administration is open to something new, which gives an evolution to the warehouse, as long as the new tools be compatible with a certain infrastructure. On the contrary, the costs are very high and our company would not be able to invest in something like this."
D) He said: "As I told before, I am not fully aware of the available technologies and their benefits. This happens because the busy operational environment leaves me little time for research and exploration. For this reason, may I say first that I don't trust them because of the ignorance about the theme. I need time to search with the administration department, to see exhibitions on abroad and to observe what positive impacts the techs have in the logistics world."

*Table 5- Results of question 5*

## 6. DISCUSSIONS

### 6.1 Findings

Overall, the key questions above indicate that technologies such as IoT, temperature sensors, dimensioning scanners, conveyor belts, voice picking, and software systems have been adopted in some warehouses, improving the efficiency, the inventory management, the lead time and the customer service.

The interviews did not provide explicit information about the warehouse managers' knowledge or familiarity with big data analytics. The interviews focused more on the technologies and practices implemented in the warehouses, rather than discussing specific data analytics tools or techniques. While Interview B mentioned "Big Data analytics" as one of the technologies associated with Industry 4.0, it did not elaborate on the managers' understanding or usage of such analytics in their warehouses.

Therefore, based on the provided information, it cannot be definitively concluded whether the warehouse managers do or do not know about big data analytics.

However, challenges such as cost, implementation difficulties and the need for trained personnel are mentioned as potential barriers to the widespread adoption of these technologies.

Based on the information provided, it is difficult to determine the exact sentiment of warehouse managers towards new technologies.

Therefore, we observe that the managers have a general understanding of what Industry 4.0 is and the new technologies that stem from this concept. Some may not be as well-informed, but they have at least some knowledge.

Regarding the technologies used in warehouse management, we would say that there are several, but it is noticed that the technologies implemented in these warehouses do not belong to the latest generation.

In other words, each company has installed RFID scanners, temperature sensors, biometric fingerprint systems, ERP or SAP software systems, VNA trucks, and electric pallet trucks. However, these devices and tools do not belong to the new advanced technologies. Manager B mentions the use of voice picking, which is considered a truly cutting-edge tool. Technological means such as AMG, AGV, and palletizing systems are not mentioned by any manager.

All four managers emphasize the significant importance of technological means in warehouse management for achieving goals and process efficiency. However, the use of new technologies is not yet feasible according to their statements. Some desire it, but the financial risk is significant, and the possibility of future expenses not being recovered causes them great uncertainty. Other managers want to conduct their research first to confirm that these technologies have positive outcomes in other warehouses. Some do not want to risk investing in a new technology because it may require a reconfiguration of the entire warehouse, resulting in higher costs. Additionally, one manager expresses a desire for a Hybrid system to be maintained.



Overall, the responses from the interviews suggest a mix of attitudes towards new technologies in warehouses. Some managers appear to be open and willing to embrace new technologies, while others may be more cautious or hesitant due to factors such as cost, disruption, or fear of the unknown. It's important to note that individual attitudes may vary, and further investigation or surveys specifically targeting warehouse managers' perceptions and concerns would provide a more comprehensive understanding.

## 6.2 Limitations

During the research there were some limitations worth mentioning:

Finding the warehouse managers to conduct the interviews was not a very easy process. For this reason, only 4 interviews have been analyzed in the thesis. Unfortunately, this fact has not been very helpful in achieving qualitative research large enough to draw meaningful conclusions.

There was an inability to gather detailed information, due to the fact that the managers couldn't give a lot of data and information about the company where they work. For this reason, also, the name of each company is not listed.

Perhaps, if it were possible to expand the topic beyond the food industry, i.e., to the pharmaceutical industry or spares industry, then finding more managers would be easier. On the other hand, the volume of information would increase beyond reasonable limits.

## 6.3 Future Research Directions

Some more future research directions about the adoption of new technologies from the warehouse managers in Greece, may are:

- *Factors Influencing Adoption:* Investigation the specific factors that influence the adoption of new technologies in Greek warehouses, such as organizational size, industry sector, location, and managerial mindset. Analysis how these factors impact the decision-making process and the rate of technology adoption
- *Performance and Efficiency Impacts:* Assess the impact of adopting new technologies on warehouse performance and efficiency metrics in the Greek context. Measurement the key indicators such as order processing time, inventory accuracy, fulfillment rates, labor productivity, and customer satisfaction to evaluate the effectiveness of technology adoption.
- *Sustainability and Green Technologies:* Exploration the adoption and impact of green technologies in Greek warehouses. Investigation how technologies such as renewable energy systems, energy-efficient equipment, and sustainable packaging solutions are being adopted and integrated into warehouse operations to reduce environmental impact.
- *Human-Machine Interaction:* Examination the interaction and collaboration between humans and machines in technologically advanced warehouses in Greece. Exploration how the integration of robotics, automation, and artificial intelligence affects job roles, task allocation, and human-machine interfaces. Investigation the implications for workforce training and skills development

- *Risk and Security Considerations:* Assess the risks and security challenges associated with the adoption of new technologies in Greek warehouses. Investigate potential vulnerabilities in systems, data privacy concerns, and the need for robust cybersecurity measures. Develop frameworks and guidelines for mitigating risks and ensuring the secure implementation of technology solutions.
- *Policy and Regulatory Frameworks:* Explore the policy and regulatory frameworks that support or hinder the adoption of new technologies in Greek warehouses. Assess the role of government initiatives, incentives, and regulations in promoting technology adoption. Identify areas for policy improvement and recommend measures to foster technological innovation in the warehouse sector.

These research directions can contribute to a deeper understanding of the adoption of new technologies in warehouses in Greece and provide valuable insights for industry stakeholders, policymakers, and researchers.

## 7. Conclusion

From the above, it can be concluded that the Greek economy and Greek businesses are not yet ready to embrace the new technologies arising from Industry 4.0. Adoption of certain technologies in logistics warehouses has been taking place for several years (according to the aforementioned research), but not all of them fall under the new technologies of Industry 4.0.

We cannot definitively determine whether the low digitization of warehouses is primarily due to the economic risk associated with each company or the lack of information, knowledge, and research on these technologies.

There are several questions arising in our era regarding these new technologies. Their existence will ultimately assist humans and truly improve their work-life with an ideal hybrid work system, or will it fundamentally change warehouse management, gradually eliminating the human factor?

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