IN 4.0

ADAPTACIÓN DEL MODELO INDUSTRIAL 4.0 AL SECTOR DE LA CONSTRUCCIÓN NAVAL

WP 6.3 Identification and documentation of successful business innovation processes in other sectors

Contents

Abstract

This report identifies a suit of 4.0 technologies that can have a major impact on the shipping industry and documents related successful business innovation processes in other sectors. To this end, the situation of the naval sector in relation to Industry 4.0 is described first. Thereafter, the 4.0 technologies identified are presented, and their maturity and impact on the shipbuilding industry is analysed. Subsequently, three case studies are discussed, documenting the impact that the development and implementation of 4.0 technologies —which can be applicable to the maritime industry— has had on the growth of companies in other sectors. Finally, the conclusions drawn from the success stories presented are illustrated.

1. Introduction

This section describes the characteristics and current situation of the naval sector in relation to Industry 4.0, based on the document prepared by Xunta de Galicia: "Industry 4.0 Opportunities in Galicia. Sectoral diagnosis: naval" (*Oportunidades Industria 4.0 en Galicia. Diagnóstico sectorial: naval*) [1].

1.1. Naval sector characteristics

The shipping sector is defined as a synthesis industry, manufacturing a unique product, rarely in series, with a high unit value, long manufacturing periods, particularly sensitive to economic cycles, with almost permanent global overcapacity, and strongly subject to international competition. The sector is of great strategic importance in national economies, considering its high technological content, its role as a supplier of essential transportion means in international trade, its research, exploration and energy products extraction purpose, as well as its function as a supplier of military vessels.

The naval sector includes both companies that build, repair and convert commercial and military ships (shipyards) and firms that provide associated products or services (auxiliary industry). Thus, the sector has become a synthesis industry in which shipyards have been specializing to become assembly plants where the hull and basic structures are built and components supplied by the auxiliary industry are integrated. The shipyard has progressively become the coordinator of an overall project, responsible for planning and coordinating a large number of companies activity involved in the design, construction, repair and maintenance or conversion of a vessel. In this way, shipyards are the tractors of an important auxiliary industry. Among the auxiliary activities undertaken by the business network, the following are highlighted:

- Construction and repair services
- Structures
- Hull and deck equipment and accesoies

- Electrical, electronic and automation installations
- Restoration and carpentry of slipways
- Auxiliary machinery
- Surface protection and treatment
- Ship classification society
- Power and propulsion systems
- Vessel’s services
- Suppliers

1.2. Current situation of the naval sector

In recent decades, the EU shipbuilding panorama has changed significantly. The European maritime industry has been strongly affected by high automation in Asian and Eastern European shipyards, combined with low labour costs and subsidy policies in these countries. In addition to the enormous competition, the sector is facing a considerable reduction in market size, i.e., not as many ships are contracted, and therefore more is work associated with repairing and reusing ships for other uses.

The shipbuilding industry is a dynamic and competitive sector, strategic for Europe in terms of its economic and social dimension. Traditionally, mainly due to its operating structure, the shipbuilding industry has lagged behind in the management systems implementation aimed at total control of production operations. For this reason, and given the market characteristics and the difficulties of the sector itself, a major effort is being made by the shipyards —in the strategic, technological and organisational context— to seek specialisation through the manufacture of special non-serial vessels with high added value and to pursue the production costs reduction, as well as the quality and competitiveness enhacement. This requires resources, advanced manufacturing technologies and skilled labour to develop complex vessels while maintaining and/or improving the productivity and competitiveness of the industry. It is therefore essential that companies in the naval sector have access to technological developments that facilitate its technification and technological evolution.

The Industry 4.0 paradigm represents a great opportunity for the maritime industry to gain competitiveness and to turn both the shipyard and auxiliary companies into smarter and more connected, flexible, automated and sustainable factories..

1.3. Naval sector and Industry 4.0

The Fourth Industrial Revolution, also known as Industry 4.0, a term coined by the German Federal Government in the context of its high-tech strategy in 2011, determines changes in the manufacturing domain. The concept refers to a profound digital transformation of value chains, business models, products and services.

Industry 4.0 encompasses the development and integration of innovative information and communication technologies in industry. The main objective is to foster the smart network of products and processes along the value chain, enabling it to make organisational processes and the goods and services creation more efficient in order to improve customer benefit by offering them novel products and services.

Industry 4.0 refers primarily to a shift in production practice from mass to customised production. This results in greater flexibility of production processes and provides means to meet the individual needs of different customers more effectively.

Industry 4.0, through new digital technologies such as Virtual Reality, Augmented Reality, Big Data Analytics, Internet of Things, Additive Manufacturing, Cloud Computing, Smart Sensors, Artificial Intelligence, among others, is revolutionising business rules, as well as the consumer market and, therefore, marketing methods.

Based on these considerations, the shipyard 4.0 must be oriented towards more automated or robotised processes with digitised production control systems, which will make it possible to achieve an improvement in quality and a reduction in costs and lead times. The shipyard 4.0 must also be supported by information technologies (ICT) that manage data comprehensively at all stages, from design to manufacturing, controlling processes using modelling tools, 3D design and MES (Manufacturing Execution System) process simulation, which will help predict and avoid inefficiencies in a highly variable working environment. All this will provide a solution to the naval sector's need to improve its capacity and its production and management system in order to be competitive in a global market, in which differentiation determines the workload of a shipyard, as well as that of its auxiliaries.

The cyber-physical shipyard 4.0, like any other factory 4.0, must develop processes for obtaining its products using the new technologies that have emerged in the current 4.0 revolution. It is necessary to invest in ICT solutions that allow greater control of the production process, thereby reducing delivery times, avoiding rework and, in general, optimising the production process and providing companies with tools that bring greater added value and competitiveness to the industry. To achieve this, a change of mentality is needed in all the stakeholders involved in the sector's value chain, starting with the shipyards, which must act as driving companies, promoting their auxiliary industry.

1.4. Examples of process technologies in Industry 4.0 applicable to the naval sector

This section describes the 4.0 technologies selected in WP4.3, "Maturity level and impact analysis on the top 5 key enable technologies" [2], paying special attention to the solutions developed in the case studies included in this report.

1.4.1. Bar Code / QR Code / Radio Frequency Identification

Bar code (BC) is a well-known technology for the optical representation of data that can be interpreted by machines. The data is represented by varying the width and spacing of the parallel lines. Some variations exist for this technology, e.g. the two-dimensional bar code.

Another technology is the quick response code, also known as QR code. It is the trademark of a specific two-dimensional barcode technology and its main feature is the high-speed reading capability provided by this type of code.

Radio Frequency Identification (RFID)

This technology, developed in the case of Vegalsa and in the case of Cupa (sections 3 and 4 in this report), is a technique for storing and reading information based on the use of electromagnetic fields. The performance of this technology is based on the communication between a Tag and a Reader. Tags are passive actuators where information is stored electronically. These tags collect energy from radio waves emitted by a nearby reader. Unlike the BC and QR code, the RFID does not need to be in the reader's ñome pf sight line. In addition, the reader can operate several meters away from the tag, even if the tag is in motion [3].

Currently, RFID is already being replaced in some logistics processes by computer vision-based recognition systems.

1.4.2. Computer vision

While the usefulness of the above technologies is to store and read information, other technologies also allow the capture of this information. Computer Vision is an interdisciplinary scientific field aimed at processing images and video in the way a human brain would but, in this case, performed by a computer. From an engineering and industry perspective, it seeks to automate tasks of various considerations that are normally performed by operators. Several subtechnologies are distinguished based on the problem they are intended to solve:

- Object detection

- Object recognition
- OCR (Optical Character Reader)
- OCV (Optical Character Verification)

1.4.3. Internet of Things (IoT)

The IoT enables industries and companies to have greater efficiency and reliability in their operations. It is a compendium of mutually connected devices and sensors that interact and exchange data and information. This information can be obtained through sensors or other technologies such as QR codes, RFID or NFC (the most common solutions applied by industry). Although the relevant aspect is connectivity, rather than the specific technology involved in information acquisition.

1.4.4. Industrial Information Systems

The Industrial Information Systems have been developed with the objective of covering the company's productive needs, assuring the data integration and uniformity. There are different levels in the Industrial Information Systems, which in ascending order are the following:

- SCADA (Supervisory Control And Data Acquisition) and PLC (Programmable Logic Controller), communicate with each other and receive data from all plant equipment, solving process control and machinery sequencing requirements.
- MES (Manufacturing Execution System), is a software focused on process control that monitors and supports plant management. The goal is to increase the overall efficiency of the team by detecting reducible costs and gaps to improve productivity, as well as delivery traceability and production quality. It can be an intermediate step between the strategy and planning processes in a company (Enterprise Resource Planning, ERP) and the plant control processes (SCADA, PLCs and sensors).

- ERP (Enterprise Resource Planning) refers to a set of information systems that manage all the business areas of an organization: finance, sales, marketing, production, HR, purchasing, etc. It is a global solution that organizes the company's information.

In addition to these solutions, there are other 4.0 technologies that are part of the Industrial Information Systems. Other solutions that have been developed in the case studies of this report are presented below:

Data capture system

These are systems or technologies capable of performing the data capture process in a completely autonomous way. This technology consists of a hardware, which is directly connected to the machines to extract information through different ways such as digital and analog signals, connection with the machines PLCs, sensors or other elements of the process. After collecting these data, a software is in charge of ordering, categorizing and translating them into information that can be visualized by the plant personnel through any device [4].

These systems allow reliable and real-time information to be obtained on the production process, increasing control over it. Section 2, Partenon's case, shows an example of a data capture system implementation.

Warehouse management system (WMS)

Within this group of 4.0 technologies is also the WMS, developed in the Vegalsa case (section 3). This tool is used to control, coordinate and optimize the movements, processes and operations of a warehouse (product input and output management, stock control, location management, physical movements control of goods, picking, etc.). Typically, these softwares are linked to the company's ERP and are supported by data capture technologies such as RFID, previously presented. These systems application improves management and traceability of stored materials and more efficient planning of resources for warehouse activities [3].

Business Intelligence (BI)

Another of the Industrial Information Systems used in the cases presented (Partenon case, section 2) are BI tools. These tools collect and process large amounts of data from internal and external systems, and analyze them in an automated way. Thus, they provide the user with the necessary information for analysis and decision making [5].

1.4.5. Automation

Three stages can be identified in a general automation process:

- Data collection: the purpose of this phase is the information acquisition. This knowledge comes in data form collected by different types of sensors that gather the information generated in the different stages of the process.

Sensors

A sensor is a device able to detect external actions or stimuli and respond accordingly. These mechanism can transform physical or chemical quantities into electrical signals. In other words, they allow us to capture information from the physical environment around us. Sensors can be used to measure temperature, atmospheric pressure, heart rate or determine geolocation (as shown in Cupa case, section 4), among other magnitudes [6].

- Planning: this phase focuses on decoding the information collected in the previous stage. This information processing is performed by entities of different nature, such as PLCs or SCADAs.

- Action: At this stage a response is generated, in reaction to the stimuli received, by means of an actuator. An actuator is a component designed to move or control a mechanism or system. To perform their target tasks, actuators require a control signal and an energy supplier. Actuators perform the actions that have been determined by the corresponding devices in the previous phase.

1.4.6. Robotics

Robotics is the interdisciplinary branch of science whose objective is the design, development and creation of the different aspects related to Robots, e.g., computer control systems, sensory feedback or information processing. A Robot is a machine capable of performing a complex task autonomously. Due to this fact, robots are one of the most popular tools in manufacturing automation since their inception. The type of tasks and jobs that typically take place in a shipyard are suitable to be automated by robots, as several contextual conditions such as hazard, repeatability and the need for endurance could be easily improved by using such technology.

Considering the observed needs of the shipbuilding industry, the most important robot categories are described below:

- Industrial robot: is a robotic system used in industrial manufacturing processes. Among its most common applications, industrial robots usually perform welding, painting, assembly or picking tasks.
- es un sistema robótico utilizado en procesos de fabricación industrial. Entre sus aplicaciones más habituales, los robots industriales suelen realizar tareas de soldadura, pintura, montaje o picking.

Automatic picking system

This technology presented in the Vegalsa case (section 3 in this report) is included in the category of industrial robots. Automated order picking refers to the application of systems that completely cover order picking tasks. In a fully automated installation, it is common to find the following elements: stacker cranes, roller conveyors and electro-rail conveyors, anthropomorphic robots, control arches, stretch wrappers and automatic labeling. Thanks to these systems/robots it is possible to improve the effective capacity of the picking process and of the storage areas, as well as the working conditions and, therefore, the people's health. The operating efficiency of an automatic picking system is linked to the WMS implementation, as explained in section 1.4.4.

- Climbing robot: a robot that has the ability to climb vertical surfaces. Such robot can perform pathological tasks such as inspection or cleaning of hazardous surfaces.
- Powered Exoequeleton: is a machine made of a portable structure, actuators and a control system. This type of robot can perform a wide variety of tasks with enhanced physiological characteristics, such as strength and endurance. It is a low level automation system that relies on the human operator to carry it, but with high speed and predictive response to human reactions.
- Underwater robot: is a automaton that can perform different tasks below the water surface. Some of these functions are, for example, cleaning the ship's hull.

1.4.7. Collaborative platform

A Collaborative Platform is a virtual space where all the relevant functionalities of one or several companies are integrated. Some functionalities that are integrated in this type of platforms are, e.g., mailing services, databases of different nature, discussion forums, version control software, mass storage or programming services.

The integration of such a large number of services in a common system is extremely useful, not only because of the clear improvement in management capabilities, but also for the simplicity implied by a single common language usage. It is important to note that the companies needs or the companies implementing this system determine the system structure. Thus, according to the needs of the maritime industry, a collaborative platform could aim to provide communication tools, a complete inventory management system for a corporation, version control, etc.

Web platforms

An example of collaborative platforms are web platforms, such as the one presented in the Partenon case, section 2. Web platforms are spaces on the Internet that allow various applications or programs to be run in the same place to meet different business needs. These applications are executed through a web browser, which means that the data or files being worked on are processed and stored within a network. Web applications are closely related to data storage in the cloud, since all the information is permanently stored on web servers —which in addition to hosting such information— send it to our mobile devices or computers whenever it is required [7].

This technology usage improves communication and coordination between the different departments of a company or between different enterprises, allowing centralized, accessible and analyzable information for everyone.

1.4.8. Augmented reality

Augmented reality (AR) connects the physical and virtual worlds. Unlike virtual reality (VR), AR does not create artificial environments to replace the real one with a virtual setting. It superimposes digital content and information on the physical world. AR falls into several categories:

- Recognition-based AR: also known as image recognition. It requires a visual signal, such as a QR code, and a camera to read it. Furthermore, this category comprises location-based or position-based augmented reality, which uses a GPS, a digital compass, a speed meter or an accelerometer that is built into the device to provide data based on its location. With the availability of smartphones, this type of AR generally generates maps, directions, and nearby business information.

Figure 1. Recognition-based AR

Figure 2. Projection-based AR

- Projection-based AR: works by projecting artificial light onto real-world surfaces. Projection-based augmented reality applications allow human interaction on that projected light. Another interesting application of projection-based augmented reality is laser plasma technology usage to project a hologram in the air.

- Overlay-based AR: replaces part or all of an object original view with a newly augmented view of the item. Object recognition plays a vital role because it not only replaces the original view with an augmented one but can also determine which kind of object is the article.

Figure 3. Overlay-based AR

Many modern devices already support augmented reality, from smartphones and tablets to gadgets such as Google Glass or handheld instruments, and these technologies continue to evolve. Some of these include:

- Heads Up Displays (HUDs): transparent digital image that is projected into the user's view.
- Holographic displays: this display generates three-dimensional shapes of objects in real space.
- Smart glasses (optical see through): Microsoft's Hololens, Magic Leap One and Google Glass are recent examples of optical vision through smart glasses.
- Smart glasses (video see through): the HTC Vive VR headset is an example of technology for viewing video through smart glasses.
- Handheld/Smartphone based: the rise of portable AR is the tipping point for the technology to become truly ubiquitous. In portable or mobile AR, all you need is a smartphone.

1.5. Report’s purpose and cases of success

Based on the above considerations about the role that Industry 4.0 can play in the naval sector, in this document a series of technologies have been selected, whose maturity, impact on the maritime industry and related use cases in different industrial sectors will be analyzed, in order to increase the competitiveness of companies in the shipping industry through their production model adaptation to Industry 4.0.

This document seeks to facilitate cross-sector learning and benchmarking with relevant industries (e.g.: retail, textile) considering their innovation processes. For this aim, the impact of successful business innovation processes —which can be applicable to the naval sector— on the companies growth in other industries has been documented, including success stories and case studies.

The selected cases are: Design and development of industrial information systems in Partenon (1), development and implementation of data and automation systems in warehouses: Vegalsa (2) and pallet location in warehouses using RFID Technology in Cupa (3). The cases have been chosen considering their relevance and usefulness for the naval industry. In addition, successful innovation processes in companies of different sectors and sizes have been selected in order to show the technologies applicability in different contexts. In this sense, it is possible to extrapolate the usefulness of the technologies presented to both larger shipbuilding companies (shipyards) and smaller companies in the auxiliary industry.

These cases, framed within the WP4.3 programme (Maturity level and impact analysis on the top 5 key enable technologies), complement the cases prepared by the Cork Institute of Technology (CIT) in Ireland, the Bretagne Pôle Naval (BPN) in France and the High Speed Sustainable Manufacturing Institute (HSSMI) in the United Kingdom.

2. Development and implementation of industrial information systems: PARTENON case

2.1. Introduction

2.1.1. Case of success

Development and implementation of industrial information systems (framed within *Monitoring* technologies) in a textile company. The technologies established have been the following:

- Web platform
- Data capture system using touch screens with Raspberries
- Business Intelligence Tool (*Qlik Sense*)
- Screens with *Work in progress* application

2.1.2. Company overview

Founded in 1958, Sagres S.L. (PARTENON) is a company dedicated to the design, manufacture and marketing of technical clothing for security forces and firefighters. Sagres S.L. encompasses the design, development and production of exclusive garments, person-to-person sizing, personalized delivery and an after-sales service that includes the maintenance and replacement of integral equipment. Recently, due to the coronavirus crisis, Partenon has added to its activity the manufacture of masks and bacteriological protection suits, also for security forces and firefighters. The company's commercial activity extends to 11 European countries, although most of its sales come from Spain, where the firm is the market leader.

Most of the orders received by Sagres S.L. are obtained by public tender, so its manufacturing model is similar to a make-to-order type of manufacturing. This complexity is compounded by the large number of references they sell (380) and the high level of customization of their products.

The company's annual turnover is around €17 million and the workforce consists of 400 employees. The headquarters are located in Redondela (Pontevedra). Partenon also has two warehouses in the Valladares Technological and Logistics Park, in Vigo (Pontevedra), and two of its own tailoring workshops, one in Monçao (Portugal) and the other in Tangiers (Morocco).

2.1.3. Initial situation, original conflicto (overall perspective)

At the time of conduct the change process, the main problem faced by the company was the difficulties in managing information. This resulted in management inefficiencies, complexity in decision making, impossibility to act on incidents due to the lack of knowledge, little control over production-logistic costs and, as a consequence, weak capacity to act on the charges, and poor coordination between departments and, above all, with the tailoring workshops.

2.1.4. Goal/solution reached (overall perspective)

The development and implementation of the aforementioned technologies allowed the firm to considerably improve its information processing capacity. This translates into better control and planning of production, a greater ability to detect and minimize existing inefficiencies, and stronger coordination between the different plants and workshops. In short, the focus on the digitalization of information enabled the company to meet the management needs required to further improve its competitiveness.

2.2. Project

2.2.1. Change process. Why in this moment?

In 2017, there were several aspects that marked a turnaround and raised the need for information management technologies. On the one hand, the company had observed a clear change in business typology. In the last 10 years, the number of units manufactured had multiplied by 5, the reference number marketed had tripled, the number of types and services associated with the product had increased (initially, product customization was only linked to sizing, but nowadays, the company also offers customized shipping, product maintenance, online sales, transmutation, etc.), and the number of small orders was also higher. All this was causing the company to drown in management.

On the other hand, since 2016 the company was immersed in a *Lean Manufacturing* integration project in the plant that required better information management. In addition to these two aspects, there was the concern of the company's managers and the recent emergence of web technology.

2.2.2. Existing problems

The company's main challenges —especially related to information management— at the beginning of the project were the following:

- Completely manual production data capture. This resulted in a lot of resources being devoted to capturing data that was then not analyzed by anyone. Furthermore, manual data capture caused the data collected to be unreliable and made it impossible to obtain information in real time.
- Hard to obtain incorrect indicators and concepts when calculating them. In addition, as a consequence of the above, the values obtained were unreliable.
- Little (or no) accessible information.
- Cause of incidents ignorance (or even unawareness of their existence) and, as a consequence, low capacity to act on them.
- Few control over the tailoring workshops. The productivity of the workshops was unknown, as well as the quality criteria that operated them (no unified quality criteria). This caused non-compliant garments to arrive from the workshops, which increased the reprocessing of parts and had a negative impact on production costs.

2.2.3. Project team

The project team consisted mainly of internal company personnel. It was led by the Production Manager and the R&D and IT Manager. The rest consisted of the R&D and IT department and the heads for each of the areas in which the development and implementation of the proposed technologies was conducted.

Although it could be considered that the Project Team was formed only by internal personnel, it is worth mentioning the role played by two external companies. One of these firms was in charge of advising on the Lean Manufacturing integration and the other was responsible for providing training in the Business Intelligence tool implemented (Qlik Sense).

2.2.4. Internal vs. external development. Implications

The development process of the proposed technologies was exclusively conducted by internal company personnel, specifically by the R&D and IT manager with the collaboration of his team. This allowed for greater adaptation to the firm's needs, given the developers' deeper knowledge of the business model, greater flexibility in reacting to unforeseen events in the system (maintenance, updates, etc.), and higher control over the work schedule.

Moreover, in this entirely internal development, the main disadvantage has been highlighted as the lower level of technological knowledge with respect to companies that are dedicated strictly to the development and implementation of these systems.

2.2.5. Key technologies already in place

At the beginning of the project, the company had implemented an ERP (SAP Business One) for data recording and information processing. The ERP performed a good management of documents; however, the production management and quality data was really tedious and, in addition, the data reliability was quite low. The explanation lies in the fact that the data were manually transferred to Excel sheets from the work reports filled in manually by the employees. The ERP then extracted the data from these Excel sheets. This manual process resulted in a large amount of time spent on data entry and an increase in errors.

2.2.6. Project structure

Although some of the stages mentioned below were conducted in parallel, the project could be structured as follows:

Preliminary phase

Before starting the development and implementation of the proposed technologies, the ERP was parameterized to improve data recording and access.

Development and implementation of the data capture system

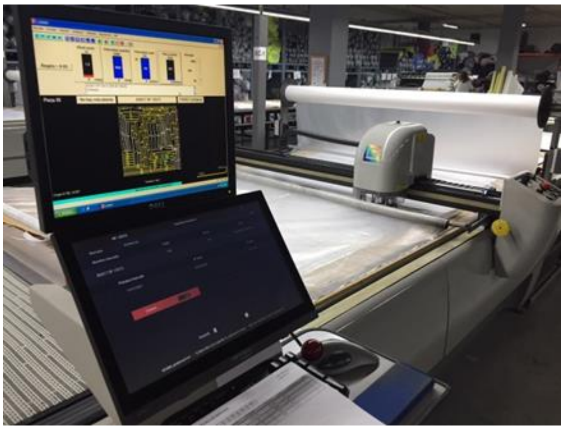

Figure 4. Data capture system. Touch screens with Raspberries

The first action performed was the development and implementation of a data capture system based on touch screens with Raspberries in the cutting process. In this sense, employees could record —in a simple and agile way— the times and causes of line stoppages, having greater control over the production process and reducing the manager's workload, who spent a large part of his day transferring the data from the work reports to Excel sheets. Besides, this allowed to automate the production indicators (mainly the OEE).

Regarding the reasons for this technology choice, the previous use of Raspberries in the bagging process should be highlighted. Moreover, the ease of configuration and upgrading, the ability to integrate with sensors and the low cost were the main motives for choosing this technology.

Subsequently, this system was extended to the ironing process, where parts of the application had to be redone due to the increased automation of the workstations.

Web platform development and implementation

With the data capture system already installed and tested in the cutting process, this system was extended to the tailoring workshops. In parallel to the implementation of this system, a web platform was developed to allow better communication with the workshops and to obtain production information in real time and accessible to all. In addition, the web platform offered the possibility of keeping a data and processes track that were outside the ERP standard and that were hitherto impossible to control.

Once the system was established and the data reliability was high, a capacity analysis of each workshop was conducted. The system was configured to feed back and update as the processing times improved. This would allow for better control and planning of the workload in the workshops.

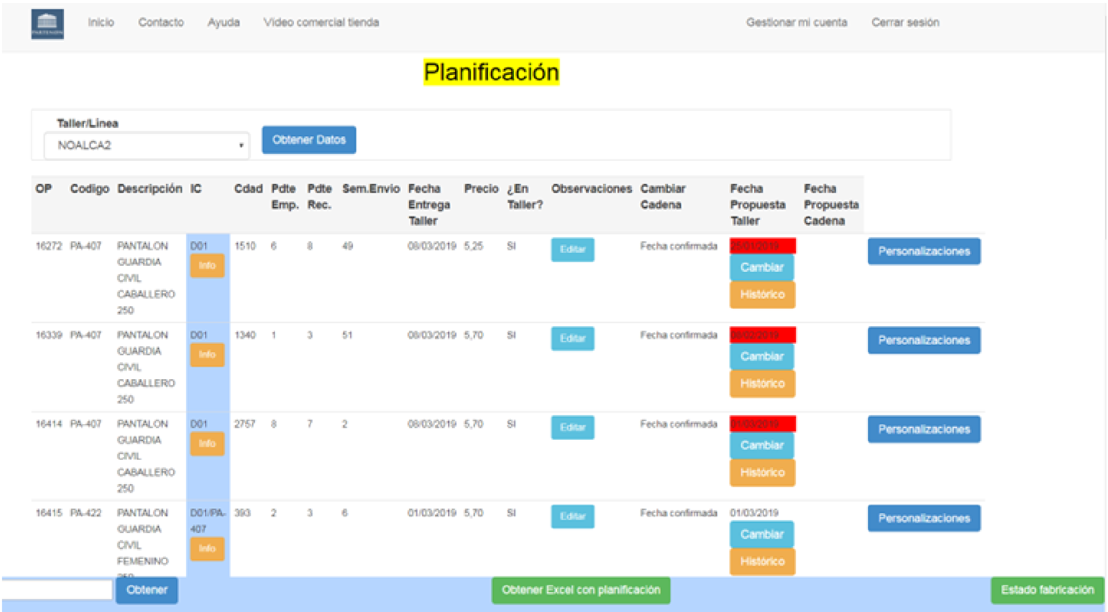

Figure 5. Web platform. Workshop production planning

Furthermore, this moment was used to unify the quality criteria between the tailoring workshops and the Redondela plant (where the final inspection was conducted) and thus avoid having duplicated processes. To this end, the web platform was configured to indicate the inspection points and quality criteria for each of the different workshops.

An incidents classification and the categorization of their causes (where they originate, where they are detected, part and incident type) was also performed. This would prevent defective parts arriving from the workshops and would provide a real-time indicator of workshop incidents with their causes, as well as a unique traceability at the garment level. In addition, the incidents detection at the first stage, the production phase, would have a remarkable impact on the production times reduction by avoiding rework and, consequently, on Lead Time and delivery times.

All the information generated would later be used to evaluate the workshops according to their quality and productivity levels.

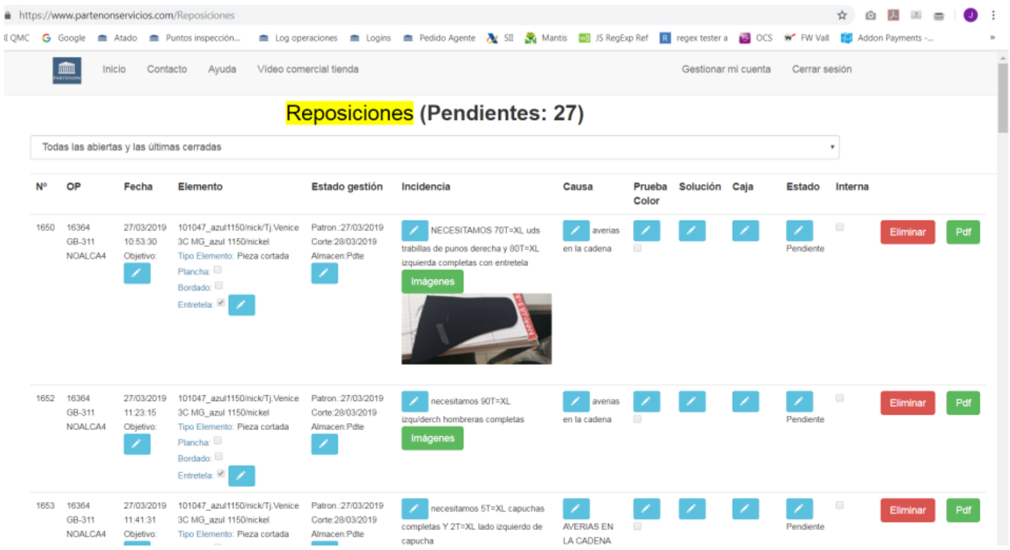

Figure 6. Web platform. Replenishment management

BI Tool Implementation (Qlik Sense)

The next step in the project was the Business Intelligence tool adoption, Qlik Sense. The main objective of the tool implementation was to automate the previously developed indicators and to elaborate a very visual and easy to interpret scorecard. In this way, inefficiencies and points for improvement in the different areas of the supply chain —from garment manufacturing in workshops to customer service— could be quickly detected.

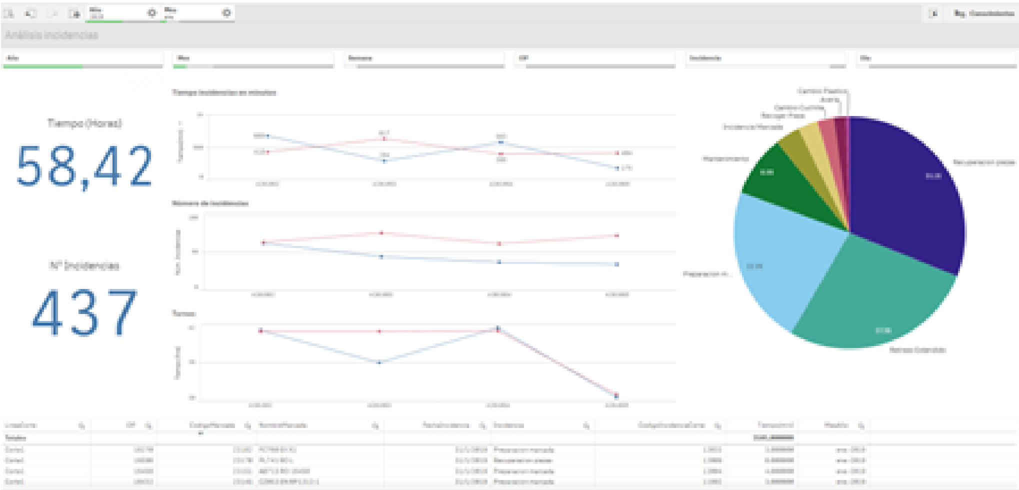

Figure 7. BI tool. Indicator visualization

Implementation of screens with Work in progress application

Continuing with the indicators visualization objectives, screens were gradually implemented to display the production status in real time in each of the company's productive areas (including tailoring workshops). These screens visualize the production information obtained in Qlik Sense.

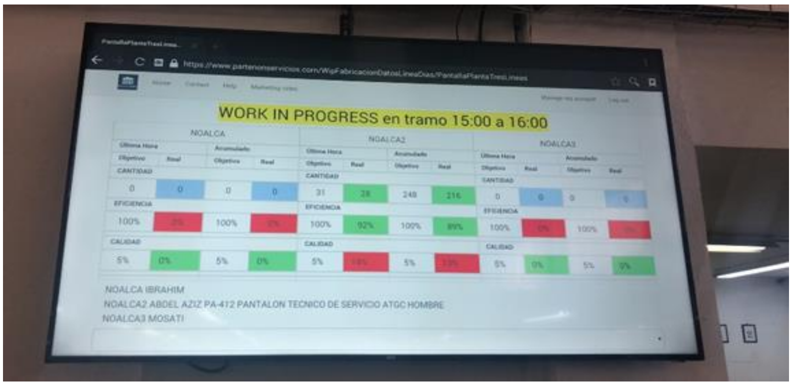

Figure 8. Work in progress screen

Finally, it should be noted that after the implementation of the aforementioned technologies, a systems integration process was installed. In this sense, the information captured through the data capture system would be automatically recorded in the ERP, or in the web platform, and could be monitored and visualized in real time through Qlik Sense and the screens for Work in Progress control.

2.2.7. *Project costs*

The investment made in the development and implementation of the aforementioned technologies includes the following expenses:

- Lean Manufacturing training: 30,000€ – 40,000€
- Development hours: not quantified
- Raspberries: 35€ per unit
- Touch screens: 120€ per unit
- Monitors: 600€ per unit
- Web platform: free software
- *Qlik Sense*: 5,000€ licenses + 5,000€ training

Some expenditure items, such as development hours, have not been quantified as this is an internal development project.

2.2.8. *Critical points*

The following aspects have been highlighted as keys to success in projects of these characteristics:

- Personnel training: both in the technology implemented and in the new work system.
- Integration of staff participation and application development: employee participation is essential to know deeply the divers processes of the company and to be able to configure the different applications based on their requirements.
- Internal development (see section 2.4 of this report) and the role played by the R&D and IT Manager: having a person who can immediately make changes to the system and provide solutions to unforeseen technological and strategic problems is essential for conducting a project of this nature, as it avoids continuous delays in the IT area that slow down the project progress.

- Do not underestimate any improvement idea; any enhacement proposed by the staff can have a great impact on the company.

2.3. Conclusions

2.3.1. Improvements achieved

The implementation of the technologies and the change in the associated methodology and work system have made it possible to achieve the following general enhacements:

1. Improved product traceability
2. Increased negotiating capacity with suppliers and customers
3. Cost reduction in the supply chain
4. Increase in productivity
5. Greater management capacity
6. Improved coordination between departments and with the tailoring workshops
7. Unification of quality criteria among the different plants of the company.

Going into greater detail on each of the technologies implemented, the following improvements were highlighted:

Data capture system (touchscreens with Raspberries)

- Incidents identification and analysis, which led to a reduction in stoppage and changeover times. All this resulted in a 66% increase in productivity and raised the OEE to levels between 85% and 88%, very high values for the sector.
- Greater capacity to react to incidents in the process, given the speed at which they are detected.
- Work standardization

Web platform

- Early detection of incidents and consequent reduction of reprocessing times
- Increased control and workload planning
- Real-time workshop information
- Centralized, accessible and analyzable information for everyone
- Improved communication and coordination with workshops
- Detailed analysis of production process times and waiting times between processes

BI tool (Qlik Sense*)*

- Improved information visibility and accessibility
- Increased capacity for different processes analysis. Identification of improvement opportunities
- Lead Time Reduction
- Scorecard automation
- Greater agility in decision making

Screens with Work in progress application

- Immediate reaction to incidents
- Enhance production efficiency
- Improved internal communication

Thanks to the improvements achieved from the implementation of the above technologies, in 2019, the company managed to increase its turnover without increasing the workforce. In this period, the company did not need to incorporate a second working shift to cover the increase in demand. Moreover, the company has worked a single shift throughout the year, something that had not been possible in previous years. Before, it was always necessary to incorporate a second work shift during the high turnover periods of the year. In short, the comany managed to increase turnover without augmenting or even reducing the resources dedicated to this task.

2.3.2. Outstanding issues

Despite all the work conducted by the company on its path towards the information digitalization, this is an incremental process. For this reason, the firm's next lines of action are as follows:

- Expand the functionalities of the web platform to control the tailoring workshops processes that are not yet controlled.
- Deploy the data capture system based on touch screens with Raspberries in the rest of the company's production processes.
- Implement a WMS to control warehouse processes.
- To value the operations and integrate them into the web platform, in order to analyze the productive capacity of the company.
- Automatically extract information from the machines PLCs and integrate it into the rest of the applications.
- Digitize sewing machines.
- Break down shop floor production PO milestones further and analyze them in more depth through Qlik Sense.

Taking a longer-term perspective, the company is also considering the introduction of artificial intelligence for the optimization of outbound orders, given the numerous restrictions to which they are subject and the continuous changes that occur from the customer. Overall, the company's goal is to complete information control of the entire logistics flow.

2.3.3. Project impacto on the parties involved

The whole technological change process that the company has been undergoing since 2017 has resulted in the staff having a deeper knowledge of the processes. This has resulted in greater staff participation when performing any improvement action, as well as better coordination and collaboration between departments.

2.4. Applicability in the naval sector

2.4.1. Sector adaptation

In spite of the wide differences between the textile industry and the naval sector, the particular case of Sagres S.L. (PARTENON) is quite similar to the typical companies of the shipping industy in terms of manufacturing typology. As previously mentioned, Partenon manufactures on request, which is similar to the manufacturing by project that predominates in the naval sector.

This causes —although there is a wide gap between these companies— both face comparable problems such as the difficulties to establish production standards, to determine with precision the delivery times or even to estimate the demand. For this reason, the case presented —in which technological solutions to the above mentioned problems are proposed— can be highly useful for companies in the naval sector.

2.4.2. Points for improvement

The following are improvement opportunities for companies in the naval sector that can be addressed by implementing the proposed technologies with a strategy similar to the one developed in the project by Partenon:

- Improved production planning: know at all times thework progress level (breakdown by milestones), the task being performed by each worker, process incidents or even the deviations that are occurring with respect to the deadlines for each milestone and in the total of the work
- Real-time information management: both from the different areas of the organization and from the companies that make up the entire supply chain
- Optimization of manufacturing and maintenance process times, as well as failures reduction and their causal analysis
- Optimal resource planning and allocation

- Bottleneck identification
- Quality improvement: detection and incidents reduction, as well as their causal analysis.
- Automation of production, quality, service, supplier evaluation indicators, etc. Design of a visual and easy-to-interpret scorecard.
- Improved customer service: more reliable delivery times, non-conformity rate reduction, etc.
- Increased knowledge of each customer
- More precise costs control (especially those associated with production)

2.5. Appendix: Photo taken during the visit

3. Development of data and automation systems in warehouses: VEGALSA-EROSKI case

3.1. Introduction

3.1.1. Case of success

This case revolves around the improvements obtained in processes developed at the logistic platform of one of the main consumer goods industry distributors in Spain. To that end, the company has integrated different Communications and Information Technologies, along with various levels of automation. Specifically, the technologies adopted were the following:

- Automated system for order preparation through storage boxes.
- Automated pallet storage system.
- Warehouse management system (WMS).
- Mobile RF (Radio Frequency) terminals with code readers.

3.1.2. Company overview

Vegalsa-Eroski enterprise have its origins in 1935 with the launch of a specialist butcher's stand in the O Calvario Market located in Vigo led by Mr. Ventura González Prieto. Since that date and until nowadays, the company has been growing and developing its activity in a sustainable way and it is now one of the market leaders in the Spanish large-scale retail sector thanks to the strategic partnership with Eroski Group in 1998.

In 2019, the company achieved a turnover of more than 1,100 million euros and employed over 6,000 people. Vegalsa-Eroski had an expanded sale point network of 266 supermarkets and hypermarkets displayed across the entire north-western Iberian Peninsula (Galicia, Asturias and Castilla-Leon region).

This supermarket and hypermarket net is established with different names or commercial brands (Eroski Center, Familia, Cash Record, Aliprox, Eroski City and Rapid) in order to adapt to different contexts and meet the needs of million costumers per day.

Logistically, the firm comprises two large platforms, one base in A Grela industrial park (A Coruña) specialized in fresh products and the other in Sigüeiro industrial estate near Santiago de Compostela and dedicated to dry products.

Additionally, the company has two trans-shipping centers in Vigo and Ourense, combined with an external platform for frozen goods located in O Porriño –close to Vigo– that operates through a logistic provider. The product distribution to the sale point is performed for a fleet of 150 trucks. The logistics field employs 700 people, 500 of those in logistic platforms and in the company's own warehouses and the other 200 workers are employed in the transport branch.

This particular case focuses on Salgüeiro company's platform, specialized in the logistic management of over 16,000 dry product references, i.e., goods that do not require specific temperature control (positive or negative) for conservation or operation.

In this platform of 37,000 m2 surface works more than 300 people, and it is devoted to reception processes, warehousing, picking and dispatching activities. On a daily basis, around 5,000 pallets are received from the suppliers and this same amount is distributed to the sale points.

3.1.3. Initial situation, original conflict (overall perspective)

After years of improvement and adaptation in the processes developed in the logistics platform and in its associated establishments and infrastructures, the company is now facing the dilemma of how to tackle new logistic challenges shaped by the supermarket and hypermarket network. In particular, the threats related to an increase in the number of references to be managed and how to handle the stock reduction in the supply chain —including the sale points and the logistic platforms.

This situation calls for valuing the possibility to partially automatize the picking procedure to increase global efficiency for warehousing processes, especially, those related to order preparation.

3.1.4. Goal/solution reached (overall perspective)

In view of the before mentioned situation —the large increase in the number of references— the company implemented an automated system for the order preparation based on box or container storage. This system copes with the traditional and also named manual procedure for order preparation, i.e., routing the picking positions with pallet trucks along the aisle and shelves. Besides, the system also cohabits with other warehouse processes, including the traditional and automated pallet storage.

Naturally, this new technology incorporation is associated with the need for integrating it in the overall platform processes, affecting the specific data system that coordinates all systems (WMS or Warehouse Management System).

3.2. Project

3.2.1. Change process. Why in this moment?

This platform was one of the first Galician logistic centers that opted for automatize certain activities through an automated pallet storage system, practically corresponding with the platform inauguration in 2001. The automated structure of 5,000 gaps has coexisted by now with the remaining traditional or manual infrastructures, such as conventional shelves —with 17,000 storage gaps and in which ground level, picking activities are carried out— cross docking actions and loading or unloading operations. Figure 1 shows pictures of these areas located at the platform.

Concurrently, this platform had also adopted, almost since its beginnings, a WMS linked to the company principal ERP (in-house developed and based on AS400 system) and RF connected to forklift terminals that serves to manage and locate pallets in different areas inside the platform. These forklift terminals incorporate code bar readers that read tags of pallets and boxes.

Thus, physical material flows are synchronized in time with associate data flows. Consequently, the platform possesses data in real time, not only about the stock available, but also where the stock is located and in which processes the goods are being use.

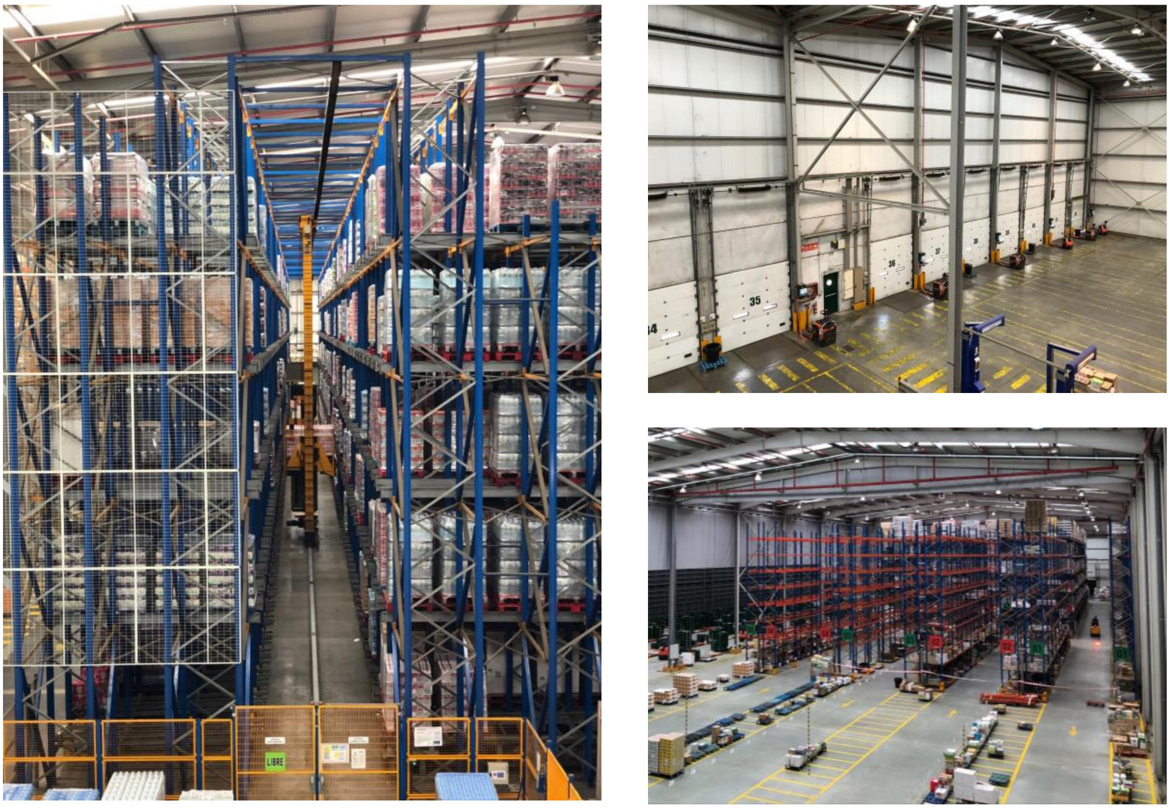

Figure 9. Detail of platform areas. On the left, automated pallet storage system; in the upper right side, loading and unloading bays area; in the bottom right the conventional storage and cross docking areas

Both initiatives (the automated pallet storage system and the WMS) were implemented and developed by the same supplier. The reason for this coincidence was inspired by the need to facilitate the understanding between the new storage system automaton and the WMS.

Nevertheless, the previous situation forced some adaptation in how the warehouse processes were managed in order to respond to WMS and automatism requirements.

After years achieving successful operation because of the implemented systems (considering the necessary updates) the global platform efficiency and productivity has started to suffer. Hereafter, various reasons to explain this situation:

- On one side, the number of references was increased. For instance, between 2008 and 2016 the references were almost 7,900 to over 14,500, and today the numbre already exceed the 16,000 references.
- On the other side, there is a need to accompany the stock reduction global strategy into the sale points, generating more frequent orders and even smaller quantities to furnish.
- Finally, the gradual staff aging also constrains the productivity of some processes—particularly, picking and order processing activities— that require intensive physical effort.

Any of the criteria mentioned above, would justified the adoption of specific measures, but the three of them combined imply a sort of “perfect storm” that has to be addressed urgently, since the installation capacity and flexibility is limited.

In this regard, picking process had become a critical factor. The increase in the number of references and orders is most frequent and intensifies the routes and manipulation during the order preparation. Simultaneously, the platform also adopts measures to reduce stock in the supply chain, in particular, through the increase of frequency in placing orders with suppliers including the use of cross docking (provisions without having to keep stock). The problem with this cross docking method is that extra surface is needed to be managed efficiently, an installation surface where space is at a premium.

In view of this situation, two where the alternative measures:

- Extend the picking area, increasing the employees dedicated to this task. This measure with a cost associated (augmenting the staff) facilitates the company's growth but does not tackle the productivity losses (increase manipulations and more routes), the current aging and the future of the staff decicated to physical activities. Moreover, the expansion level of this picking area come into conflict with the developing needs of other platform areas, such us the cross docking surface.
- Partially automate the picking processes. This measure has an associated investment cost, however, allows bettering combine the growing needs of other areas without significantly increasing the picking staff.

After a strategic analysis and the assessment of the pros and cons, this last measure (automation) is the one finally developed.

3.2.2. Existing problems

The main existing issues, acting as a preliminary requirement in the new automated picking design, were the following:

- Flexibility and agility in actual and future processes developed by the new system.
- Integration with other platform systems and processes.
- Platform total cost reduction.

An additional problem that had to be considered when addressing the possible solution was the incoming platform needs, such as changes in the working methods and processes. So far, these solutions were expensive and not very flexible in the existing WMS.

3.2.3. Project team

The Project team consisted of platform and new system supplier employees. In the in-house team were, among others, the platform manager and system technicians assigned to the logistics field. The personnel of the supplier integrated in the project team operates in the automation line and in the new WMS adaptation.

The project team was led and coordinated by the Logistics Directorate of Vegalsa-Eroski.

3.2.4. Key technologies already in place

As stated above, at the beginning of the project the platform had already implemented an automated pallet storage system and a WMS RF connected to the forklift terminals that in turn had code bar readers. This WMS system already monitored the warehouse operating through related processes, the warehouse map and the ins and outs algorithms of each area.

3.2.5. Project structure

Although some of the stages below mentioned were conducted in parallel, the project can be structured as follows:

Preliminary phase. Design requirements

In this stage, the new system design requirements were identified by the in-house project team at the end of 2016. Conceptually, the below options were formulated:

- Seek an automation solution through the current supplier (automated pallet storage system) that had also implemented the initial WMS system.
- Find an alternative supplier to the automated system capable of integrating the initial WMS.
- Search for a new supplier for the automatism and in parallel, look for an alternative WMS which supplements the initial component.

Under no circumstances substituting the current WMS was regarded due to financial and provisional cost of disposal that would arise from this decision and that it would include how to control the automated pallet storage system. The initial WMS properly worked with the current processes, but may not be well-prepared for incorporating new processes and needs.

Search and selection of suppliers

The choices of suppliers that were considered in this selection phase conducted between the end of 2016 and April 2017 deepened in the before mentioned options:

- Automated picking system provided by the same supplier of the automated pallet systems. The main advantage in this case is that the integration of the new automaton with the WMS is simple because it will function similarly to the automated pallet system. Furthermore, there will be a single interlocutor during the entire process (the suppliers' personnel). The major drawback if the proposal is adopted may be the persistence of adaptation problems and the initial WMS cost in response to changes and improvements needs in the processes.
- Automated picking system provided by a new supplier equipped, with an integrated control system for the automaton and the new WMS. The main problem with this option is that it complicates all systems' integration. In addition, the number of interlocutors to ensure that all systems work as a whole increases. Logically, this new supplier could led to a greater flexibility and an optimized cost in light of new requirements, although this flexibility may decrease since the management and the automation layers are integrated, such as the current system have already suffered.
- Automated picking system provided a new supplier that also delivers the control of the automaton. However, the system management layer is independent of the automaton layer, as it was a new WMS that complements the initial one. The main obstacle relies on the complexity for integrating all the systems and also the number of interlocutors increases. The major benefit apart from the potential flexibility and a lower cost is that if the integration is done right, the platform will have an alternative new system where to develop changes and improvements without depending on the initial WMS and its inflexibility.

Finally, the last option was selected after taking into account the before mentioned alternatives of different providers. This final decision has been significantly influenced by the investment total cost, as well as by the fact that the supplier itself provides a WMS solution independent to the automaton layer, and through a partner with whom he usually works. This would simplify the number of interlocutors in the project.

Detailed design and new system implementation

The adopted solution for the picking process —that supplements the manual/traditional picking area— is an automated container storage space of reusable plastic boxes based in the use of micro shuttles to accommodate over 17,000 containers. These shuttles are connected to an order preparation system (pick to order) for preparing the sales point orders from the storage products of this area.

The picking in this new system is integrated with the other picking activities consisting on manually preparing the products in other platform areas prior to departure to the sale points. More specifically, the new system comprises the following parts (figure 2 and 3 show pictures of the new automated system):

- Automated strorage with micro shuttles (17,424 locations and capacity to transport around 588 boxes)
- 4 stations for picking (since the boxes leave the system, the staff in these stations will draw the units for preparing the order).
- Box transport system.
- Induction and extraction line.
- Extraction of empty tub line.
- Period for adjusting the different speeds of the system parts.
- Control system (automated layer).
- Management system (management layer, new WMS).

Figure 10. General overview of the new automated box storage system.

The detailed design of the new automated system and its installation were conducted between May 2017 and April 2018. Once installed, the overhaul of the system took place between May and June 2018. In this stage, the reference feasibility was tested in order to determine which products should enter in the automated system, along with other design settings (number of staff, order inflow volume…). All this, to improve the system's overall productivity (orders, boxes or units per hour) using its technical capacity.

Thereby, if the initial idea was filling the system with products of low turnover, in practice, it was observed that if the manipulation strategy was followed, the induction augmented without benefiting from micro shuttles and the extraction capacity. So, the unproductive period of employees increased during picking activities since the products were extracted at a greater speed in comparison with the filling rapidity capacity of the new system. This means that global productivity of the new system decreased in terms of orders per hours.

At the other end, if the filling strategy of high turnover products continued, the productivity increased, but the feed line may collapse at the product entry (few orders and the system will rapidly run out of stock).

After the tune-up, it was decided to locate intermediate turnover products with a better balanced level among the automated system parts, achieving a greater overall productivity. Logically, this reference settings in the new automated system should be dynamic, since each product's relative importance may vary over the year according to seasonality, tendencies, special offers, etc.

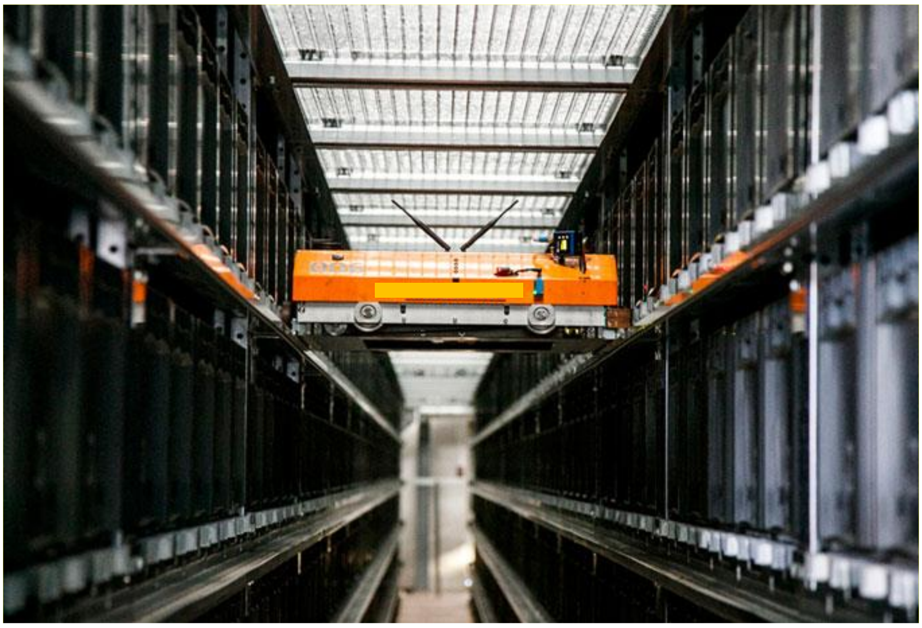

Figure 11. Details of the handling micro shuttle in a box storage as the one installed.

From the data system point of view, the order references involved with the new WMS —that is coordinated with the new installation automaton— is integrated through the corporate ERP with the initial WMS, as the references were a product particularly shape for that order. In this sense, autonomy to design the processes independently is acquired, improving flexibility. The below figure 4 synthetically shows the relation between the different data information and the automatons.

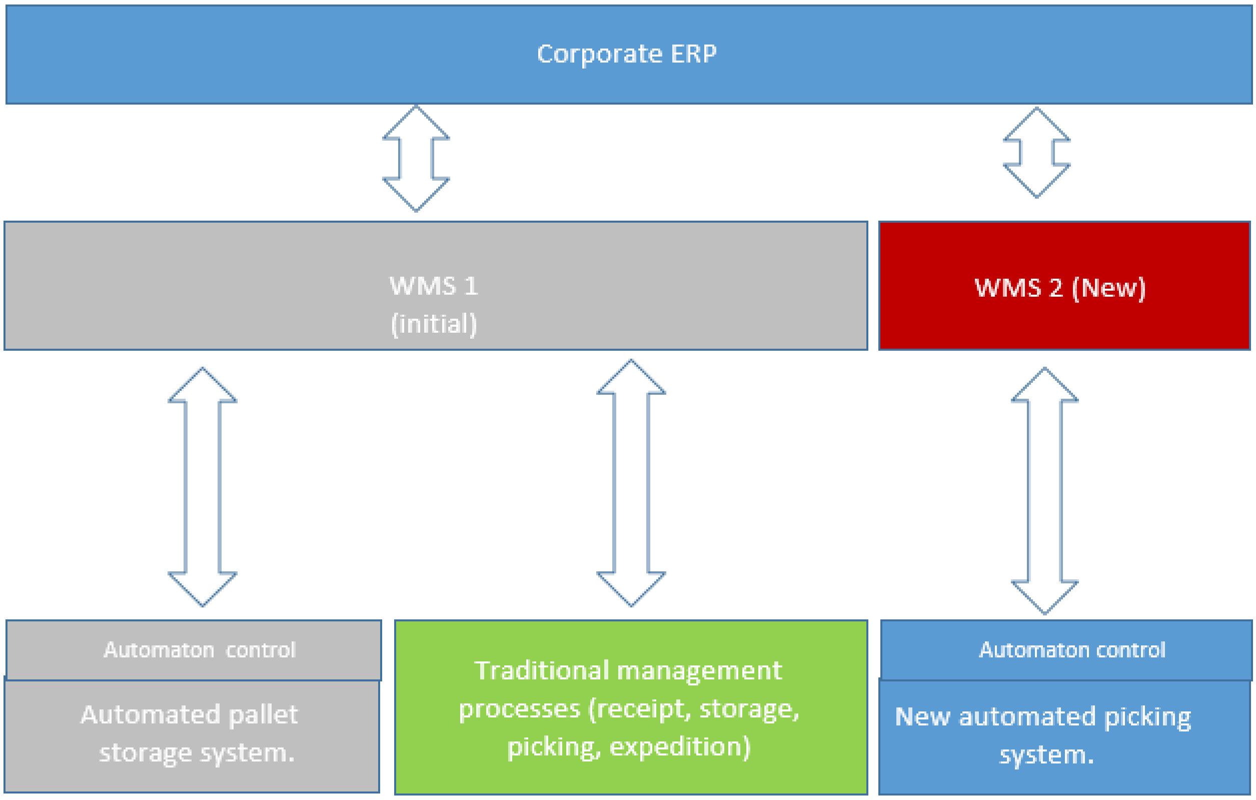

Figure 12. Final scheme of data systmem and automatons integration.

3.2.6. Project cost

The investment made for developing and implementing the technologies mentioned includes the following points:

- 2.5 million euros investment for the new automated picking system.
- Design and internal monitoring hours (no additional cost in this case).
- Design, adaptation and integration hours for the initial WMS (no additional cost in this case).
- Plastic containers for 17,000 storage positions (no additional cost in this case).
- Supplementary, an over 100,000 euros cost for the new system maintenace.

3.2.7. Critical points

The following aspects were highlighted as keys to success in projects with similar characteristics:

- Do not focus on what the system (in an automatism or management level) may do, but on the processes and operations that objectively request "Go to the Gemba" in Lean Management terms.
- Avoid dependence on a sole technological supplier for automation and data system, in order to achieve greater flexibility and better financial performance.
- Without limiting the foregoing, search for mix solutions that ensure systems' integration, reducing the number of interlocutors in the implementation process.
- In any case, properly guarantee this flexibility and the possibility to increase and modify processes and the system contractually.
- To have a contingency plan for the implementation and tuning to respond to uncertainties or changes in the design requirements.
- Thus, in dynamic environments (such us the large-scale retail sector but also the maritime industry) the adopted storage system (at the automatism and management level) should be flexible and dynamic.
- Consider the total costs involved when financially evaluating different alternatives (pros and cons), without ignoring significant costs.

3.3. Conclusions

3.3.1. Improvements achieved

The new automated picking system implemented and integrated with the other platform processes (manual or automated) through another WMS supplementary development has represented the following general progresses:

- Global productivity improvement of the platform. The combined process of automated and manual picking generates positive synergies in the overall processes in the platform.
- Reduction of costs linked to picking process.
- Platform flexibility improvement at a system level. Implementing the new WMS that is coordinated with the initial WMS generates room for maneuver in designing and implementing changes and improvements in the processes, without creating a lot of financial and deadline dependence compared to the initial dependence.
- Labor conditions improvement and consequently enhancement in people's health (reducing injuries related to physical effort now, and in the future).

More specifically, the new system implementation improves productivity in the conventional shelves' storage area because:

- Releases picking locations mainly at the ground level. This improves effective picking capacity in the conventional shelves' area.
- Picking processes are more productive (shorter route) and reduces repositions (from the upper storage spaces to picking positions, primarily at the ground level).
- Additionally, more space is generated in the stock positions (upper spaces) facilitating the goods location and consequently, the effective storage capacity in conventional shelves is improved.

3.3.2. Outstanding issues

Despite all the progress made by the company in order to improve the platforms functioning via data and automated system integration, there are some aspect to ameliorate and an analysis to examine. Among these aspects are:

- The solution adopted by Sigüeiro platform of dry products is kind of different compared to the company's other important platform in A Grela specialized in fresh products. The WMS version differs even when is conducted by the same supplier, neither has A Grela platform an automated system. In this context, could it be the substitution of the initial WMS for the new WMS (more flexible a priori) a solution to this platform?

- In the Sigüeiro platform two coordinated systems coexist. In this sense, this platform is more flexible when adapting to future changes in processes not constrained by the initial system stiffness that derives from a traditional management approach, i.e., the preparation per store with stock in a conventional warehouse. This approach is more flexible and permits provide support to future processes improvements.
- Inside the automated picking system, the understanding of how it works before certain settings changes could be improved (particularly, referring to references type, number of staff, types of inflow orders…). This knowledge may be acquired using simulation techniques, without risking the own system real time functioning.
- Currently, the automated data collection referred to physical movements in the warehouse has mainly been done through code bar readings in pallets and boxes thanks to the forklift terminal. There is the possibility to explore other data collection alternatives, for instance the RFID tags. These tags are already being use in the large-scale retail sector (in the textile and fashion industry, for example), but this system is also integrated in other industrial fields as it shows the supplementary CUPA case, section 4. Moreover, RFID is being replaced in some logistic processes by recognition systems based on artificial vision.
- With a longer-term perspective, the company could consider using artificial intelligence and employing the existing movement data to rationalize, prevent and anticipate certain good moves inside the platform and make them even more efficient.

3.3.3. Project impact on the parties involved

The entire technological shift that is being implemented in the company since 2017 meant a great control of the staff in the developed processes in the platform. The situation implies that the platform management staff has greater visibility and criteria to redesign objectively adjusting parameters in each system individually, but also to act concertedly with the overall system.

All this results in agility and flexibility improvement of the platform in order to adapt to new point of sale requirements and, in general, to the market.

3.4. Applicability in the naval sector

3.4.1. Sector adaptation

In spite of the important differences between the retail and the naval sector, the particular Vegalsa-Eroski case may be interesting to companies of the naval industry when addressing the management and material location needs referred to warehouses and material, components or blocks storage location (in outdoor areas or in the vessel under construction itself) through a WMS.

3.4.2. Improvement aspects

Below, improvement opportunities for companies of naval sector are shown. These enterprises may carry out the implementation of the new technologies before mentioned through a similar strategy developed in the Vegalsa-Eroski project. The benefits are the following:

- Improve traceability and knowledge of the material location in each company, area and step of a vessel construction.
- Synchronize material and data inflows in order to make decisions “in real time”. This synchronization may be based on data collection technologies (RFID tags or code bar tags) and on moving forklift terminals, as the supplementary CUPA case shows in section 4.
- In line with this previous point, improve the planning production, since the knowledge in terms of progress or construction stage may be associated with location changes of certain materials, components or blocks.

- Consider the automation of storage or picking processes for certain materials or consumables of small volume to increase productivity and efficiency in the logistic activities.
- Planning and measure more efficiently the resources destined to storage activities.

3.5. Appendix: Photo taken during the visit to VEGALSA

4. Pallet location in mixed warehouses (outdoor and indoor) using RFID Technology: CUPA case

4.1. Case of success

In this case —supplementary to VEGALSA situation— the integration of a slate pallet localization system for CUPA's central warehouse is presented. This system is not only capable of showing the pallet location inside a mixed warehouse (outdoor and indoor), but also indicates the route of each forklift in order to provide services to this warehouse.

4.2. Company overview

Cupa Group is a multinational enterprise shape by 65 companies with direct presence in 9 countries, 22 quarries and an exploitation level that reaches more than 70 nations of the 5 continents. Moreover, Cupa employs over 2,100 people. The group has two principal business lines that are: Cupa Pizzarras —global leader in production and commercialization of natural slates— and Cupa Stone —experts in natural stone.

Currently, Cupa Pizarras has 16 quarries and 22 processing facilities in Spain. The headquarters are located in A Medua, Ourense (Spain), where the following project is developed.

4.3. Initial situation, original conflict

In its headquarters, the company has a centralized slate warehouse where all pallets produced in the enterprise units are stored. In this centralized warehouse, the pallets are tagged and registered in the ERP system when entering. This circumstance makes the storage management complex. A human error could lead to a change in the default location of a pallet outside its section making its search an extremely difficult task. Similarly, if the details of the different locations according the pallets types are unknown, find the selling goods may be complicated, even if these goods are well located.

4.4. Project structure

4.4.1. Preliminary phase

In this preliminary phase, the general variables are the following: Placement, Identification and Height. Furthermore, the pallet search is carried out by the use of the identification number already set in the pallet tag. In addition, the optimal forklift selected for this case is the warehouse clerk's forklift.

4.4.2. Design and implementation of the system

In order to reach this project goal, a number of sensors, readers and tags are provided. These devices are capable of furnishing with the variables needed for the warehouse optimal management. The sensors used were the following:

- ✓ For forklift geolocalitation:

  I. **GNSS Base-Station**: A system that receives and estimates corrections for the position calculation using kinetic navigation in real time or RTK. The GNSS Base-Station knows the real placement where itself is installed and thanks to the position data received from GLONASS and Galileo satellite network, the GNSS Base-Station calculates the corrections needed to determine the location of a moving object with sub-meter accurancy. The siting chosen for the GNSS antenna installation was the warehouse transmission tower. After making satellite coverage measurements, this place was appointed as optimal. It was installed on a certain height and encapsulated in order to protect the device against the weather and at the same time, obtain an interference-free connection.

Figure 13. GNSS base-station

  II. **Mini Router**: this router serves as an interface between the Reach receptor and the local network located in A Medua storage place. This router provides security mechanisms for the access to the GNSS Base-Station software interface since the Base-Station does not have means for that. The Mini Router was installed next to the transmission tower and the GNSS Base-Station, both interlinked.

III. **Bluetooth Beacons:** these hardware modules are responsible for transmitting signals in indoor locations. The beacons operate autonomously through batteries and have a lifespan of around 5 years. The signal given by these beacons is collected by a receptor that obtains its position in real time based on a multilateration calculation in spots where the GNSS signal is unavailable. These devices were employ to localize the pallets in roofed-over areas, where the satellite has no signal entailing a blind spot.

Figure 14. Beacons

IV. **Reciever Module:** In order to obtain the forklift position, a receiver module was installed. It uses the corrections of the GNSS Base-Station to locate its position with a resolution of less 15 mm. Besides, this module has been modified to deliver the data required for indoor positioning via Bluetooth + Wi-Fi.

V. **Fork Lift Sensor:** this component provides the height at which the forklift forks have been lifted.

Figure 15. Ultrasonic Fork Sensor.

✓ For pallet reading:

VI. **RFID Tags:** these tags provide a unique electronic code to each pallet for its identification. Its range is up to 4 m.

VII. **RFID Antenna:** detects the RFID tags from the forklift position.

VIII. **RFID Reader Module:** when it is connected to the antenna, it reads the RFID tag data. Its read range goes from 1 m up to 6 m as long as the vehicle speed does not exceed 80 km/h, in which case the reading accuracy would be affected.

- ✓ For pallet identification:

IX. **Bar Code Reader:** a 2D optic bar code reader. This tool reads the code bar that appears in the current tags at CUPA.

X. **Desktop RFID UHF Reader:** a RFID tags reader. Its reading exploration range reaches up to 30 cm.

4.4.3. Results

The entire system implemented through the above mentioned sensors can be summarized graphically in the following figure:

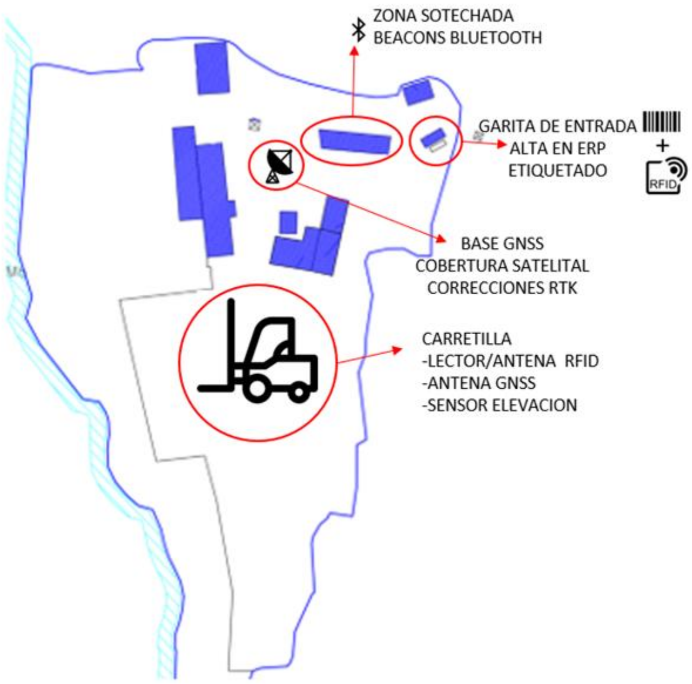

Figure 16. Central warehoouse system in A Medua.

The forklift onboard computer receives the following data throughout the whole route:

- ✓ Forklift position: receives constant information about the forklift spatial situation via satellite connection and Bluetooth (in roofed areas).
- ✓ Pallet cargo: the RFID reader antenna reads the pallet cargo tags while in the forklift at all times. When the forklift releases the pallet, the device ceases to read.
- ✓ Forks height: the lift sensor allows us to know the forks height at any time.

Thanks to all this computer data it is possible to know the pallet location at all time. Thus, the forklift operator shall have the capacity to search a pallet with the Tablet located inside the forklift that shows the below presented interface:

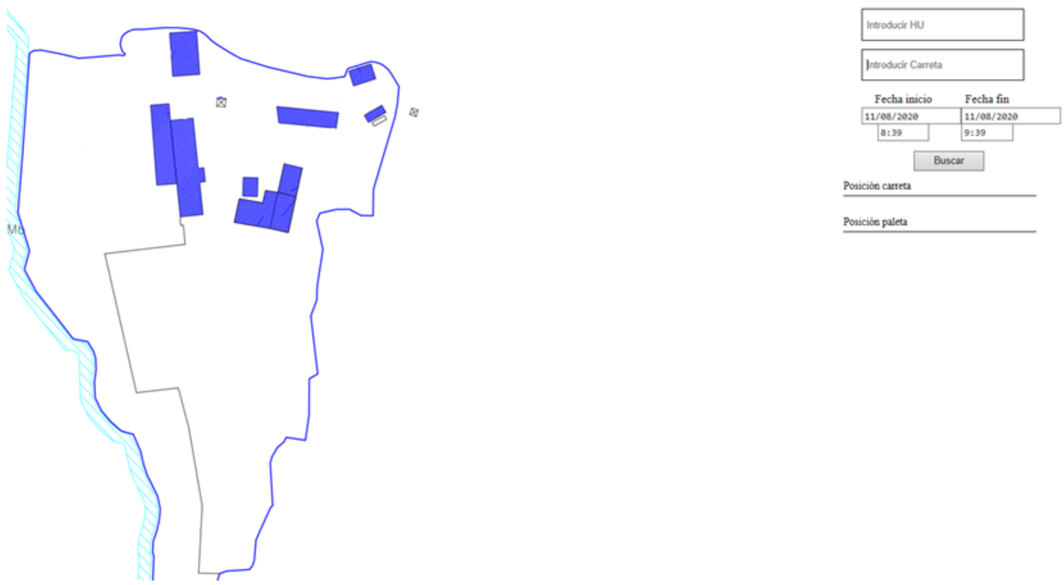

Figure 17. Werehousing interface

4.5. Applicability in naval sector

Despite the significant differences between the slate sector and the maritime industry, the case of CUPA can be useful to enterprises in the naval sector when addressing management and materials location requirements, both in indoor or outdoor warehouses. Hereafter, improvement opportunities for naval sector are shown. These are the improvement possibilities that can be obtained thanks to the implementation of location systems based on RFID through a strategy similar to CUPA project:

- Real-time management of the material location data (positioning and height) in outdoor and indoor areas. In this way, it is possible to optimize time and movements in the pursuit of materials improving process reliability.
- Knowledge about the material movement record in the warehouse and the means of maintenance that transported these materials.
- Greater reliability and agility in the identification process. In contrast with other systems, a RFID reader detects RFID tags at a distance of 4 meters without needing a direct view

of the tag.

- Effective monitoring of warehouse ins and outs, thanks to the fast detection of materials using RFID tags. In doing so, a greater control of the stock can be appreciated.
- Efficient planning of resources devoted to warehouse activities.
- Better traceability of the different materials that constitute a vessel.

5. Conclusiones

The technological diagnoses conducted in the shipbuilding field show the sectorial need to incorporate new manufacturing technologies in order to improve the competitiveness of shipyards and auxiliary industries. Among the wide range of possibilities available to boost competitiveness enhacement through 4.0 technologies, this report presents related success cases in relevant industrial sectors that can have a great impact on the shipbuilding industry. Among the 4.0 technologies developed in the cases presented we find:

- **In-plant data capture system** based on touch screens with Raspberries, for data capture at the Partenon cutting line.
- **Radio Frequency Identification (RFID),** for pallet identification in Cupa's central warehouse.
- **Geolocation sensors,** used for the gelocalization of pallets in Cupa's central warehouse.
- **Business Intelligence (BI) tool,** specifically Qlik Sense, used for the development of a fully automated scorecard of the different areas of the company Partenon**.**
- **Warehouse Management System (WMS),** developed for the control of Vegalsa's warehouse processes and operations.
- **Automatic picking system,** to improve the effective capacity of the picking process and storage areas, as well as the working conditions and, therefore, the health of workers in the Vegalsa warehouse.
- **Web platform,** developed to improve communication, control and workload planning in Partenon's production workshops.

In addition to the technologies presented, depending on the characteristics of the services or products developed, other 4.0 tools such as augmented reality, robotics or artificial intelligence, among others, could be used in the shipbuilding industry. The adoption and integration of technologies framed within Industry 4.0 is a strategic decision that will allow companies in the naval sector to become, both shipyards and auxiliary companies, more intelligent, connected, flexible, automated and sustainable factories. This will provide a solution to the naval sector's need to improve its capacity and its production and management system in order to be competitive in a global market.

5.1. Aspects to consider in the implementation of 4.0 technologies

For the successful implementation and use of the different 4.0 technologies, it is necessary to take into account a series of aspects that are described below:

- Integration of the different tools: it is not enough just to implement the technologies; it is necessary to integrate the different tools so that they communicate properly and use a single, updated and common information for all of them.
- Staff training, both in the technologies implemented and in the new work system.
- Personnel participation in the development of applications: it is essential to know in depth the company different processes and to be able to configure the different 4.0 tools based on their requirements.
- Focus not only on what the system (at the automation or management level) can do, but also on what the processes and operations objectively demand.
- Avoid dependence on a single technology supplier to gain flexibility and better economic performance.
- Adequately ensure this flexibility and ability to grow and modify processes and systems on a contractual basis.

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