IN 4.0

ADAPTATION OF INDUSTRY 4.0 MODEL TO THE NAVAL SECTOR

WP4.3
Maturity level and impact analysis on the top 5 key enable technologies

INDICE DE CONTENIDOS

Introduction 4

1. Chapter 1: Monitoring 7

1.1. Industrial Traceability 7

1.1.1Technologies involved 8

1.1.2 Use Cases 10

1.2. Industrial Information Systems 12

1.2.1. Use Cases 13

1.3. Analyzing Charts 18

Chapter 2: Automation & Robotics 23

2.1 Automation 23

2.2 Particular case: Robotics 24

2.2.1 Robot categories 24

2.3. Use Cases 25

2.4 Analyzing Charts 33

3. Chapter 3: Collaborative Platforms & Data Base 37

3.1. Use Cases 37

3.2 Analyzing Charts 39

4. Chapter 4: Augmented Reality 42

4.1 Use Cases 46

4.2 Analyzing Charts 50

5. Bibliography 53

5.1. Chapter 1: Monitoring 53

5.2. Chapter 2: Automation & Robotics 54

5.3 Chapter 3: Collaborative Platforms 56

5.4 Chapter 4: Augmented Reality 56

Introduction

The aim of this report is to select five technologies, from which an analysis will be made of their maturity, impact on the naval industry and use cases related to the different industrial sectors that are currently using those technologies.

This is based on the W.P.4.2 (Report on the existence of technologies adapted to the particular needs of companies in the naval sector in each of the paradigms of Industry 4.0) which explained the process flow in the ship manufacturing and identified some enabling technologies (KETs). Those are defined as technologies that will allow industries to maintain competitiveness and address new markets, which were grouped into 3 blocks:

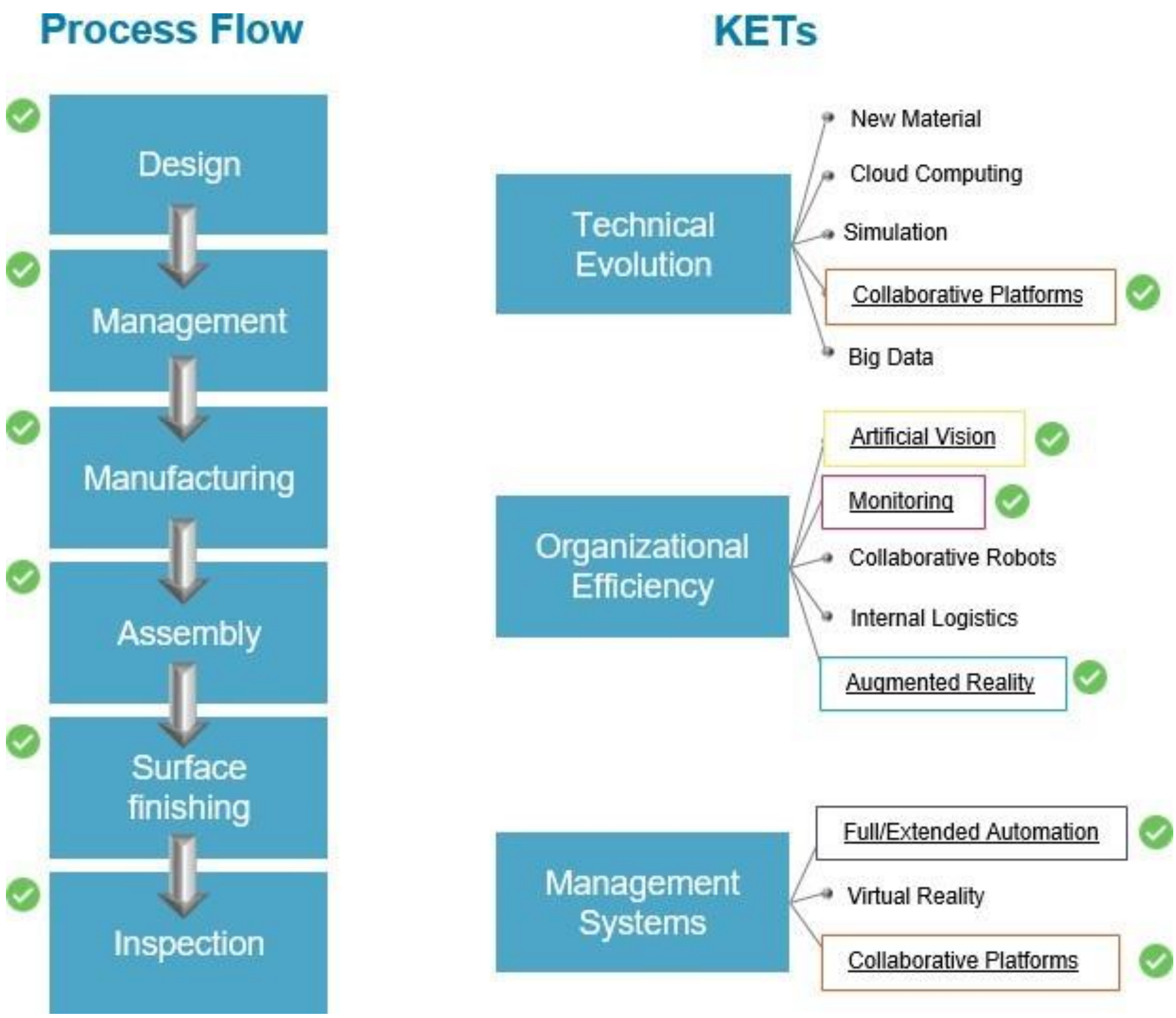
- KETs related to the technical evolution and construction systems.
- KETs related to a more efficient organization of the manufacturing process.
- KETs related to the management systems.

Taking into account the above-mentioned points, the five technologies selected are:

- Artificial Vision
- Monitoring
- Augmented Reality
- Full/Extended Automation
- Collaborative platforms

One of the main reasons to select those technologies was the complex way to manufacturer ships because of involving lots of companies such as auxiliary manufacturers, engineering services, consulting, assembly contractors, technologies providers, and so, all around the shipyards. So it is so important to have a good management and visibility about the information of the process, orders, inventory, ship parts, among others.

The selected technologies will have a good impact in the three blocks identified in the previous W.P.4.2. and therefore this affects all the stages of the process flow.



Thanks to the visit to some enterprise sites from Galician naval cluster, it has been possible to identify different groups of companies involved in the ship manufacturing, based on ASIME 2016 report “Industria naval y marítima”1:

- Type A: Company that build and repair ships like shipyards (Navantia).
- Type B: Companies that produce their own products and deliver them to shipyards where the different parts or blocks are joined. Here are considered: Naval mechanics, engines, propulsion systems and components. Electricity and Electronics. Hydraulics and pneumatics. Boilermaking, machining and industrial piping. Industrial cold. Ship equipment (Industrias Ferri y Ganain).
- Type C: Logistic companies. They do not manufacture an own product, they just plan, implement and control the movement and storage of goods, services or information within a supply chain and between the points of origin and consumption. Here are considered: Industrial supplies and logistics.
- Type D: Service industry that performs specialised activities. Here are considered: Painting, surface treatment and coatings. Quality and inspection (Buqueland, Chorro Naval y Coterena).

Taking these companies into account, a study is carried out about the 5 technologies previously identified, that promote improvement in the sector.

The following document has been divided into 4 chapters in which these five identified technologies will be dealt with. The chapters contain a brief description of the technologies involved. Some use cases related to those technologies, are described to reflect how industrial sectors incorporate them in their process. According to those use cases, some examples show the name of the company because the information is public. But in other cases, due to the privacy of the content, the company names are not identified but the industrial sector. At the end of each chapter, there are illustrative charts like:

- Chart 1 shows the Technologies Maturity, the Adoption Rate of both the Naval Industry and the rest of industries.
- Chart 2 shows the utility of the Technology Applications according to the types of companies identifi

1. Chapter 1: Monitoring

Monitoring is the process of periodic observation and control of the manufacturing process to ensure its effectiveness. Two significant technologies are involved to carry out monitoring is taken into account:

- **Industrial Traceability:** Using different technologies that allow to control where is the product, what kinds of activities were applied into the product such as welding, cutting… Thus, they have completely visibility of the product and the manufacturing process.
- **Industrial Information Systems**: This kind of systems helps to ensure data integration and uniformity, allowing to the company to manage the information.

1.1. Industrial Traceability

Traceability is the composition of prefixed processes that are carried out to determine the various steps and conditions through which a product passes, from its origin to its current situation in the process, making use of the information generated during all or part of the same process. It is possible to distinguish between two types of traceability, namely, internal and external.

As its name suggests, internal traceability refers to the company's internal procedures and takes into account the composition of the product, its handling and other factors. On the other hand, external traceability adds elements that allow the externalization of the information generated in the processes that correspond to internal traceability. In addition, if the company uses products coming from a third party, the traces generated by the different contributors in the manufacture of the product are concatenated.

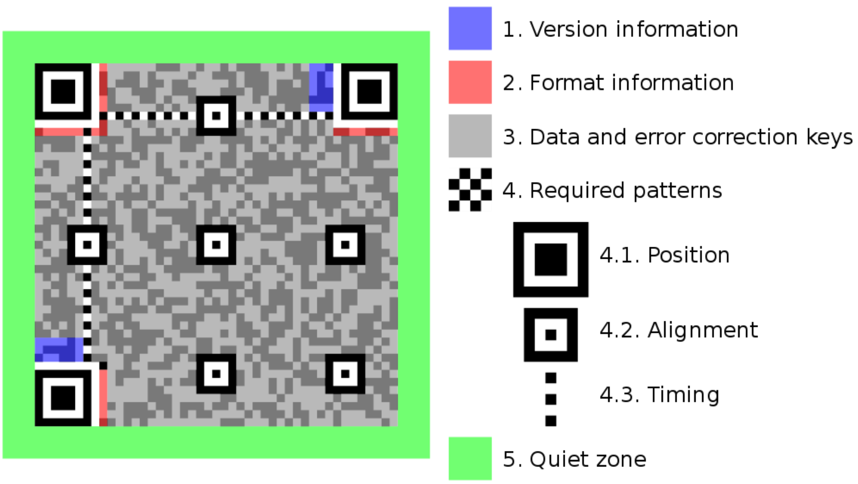
Traceability is therefore an essential and critical part of manufacturing processes, being legally regulated and required in many countries for import.

1.1.1 Technologies involved

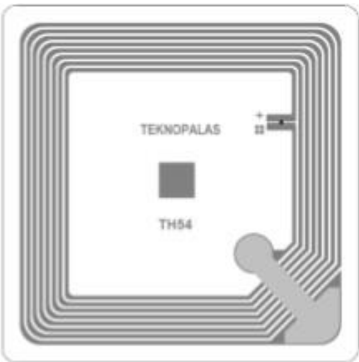
Now, some of the technologies that provide the traceability getting, generating and managing information will be introduced:

Traceability with tags:

- Codification by means of barcodes is a well-known technology aimed at optical data representation that could be interpreted by machines. The data is represented by varying the width and spacing of parallel lines. This kind of barcode is known as unidimensional barcode. There exist some variations for this technology, for instance, the two-dimensional barcode. In this case, no bars are used as a way of information transmission.
- Another technology is the Quick Response code, also known as QR code. It is the trademark for a specific two-dimensional barcode technology and its main characteristic is the high-speed reading capability provided by this type of code.



Radio Frequency Identification, commonly known as RFID, 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 Label and a Reader. Labels are passive actuators where information is stored electronically. These tags collect energy from radio waves emitted by a nearby reader. Unlike barcodes, RFID does not need to be in the reader's line of sight and furthermore, the reader can operate hundreds of meters from the tag.



Information acquisition Technologies:

While the usefulness of the above technologies is to store and read information, other technologies also allow the capture of this information. For example, **Artificial Vision** or **Computer Vision** is an interdisciplinary scientific field aimed at processing images (which therefore include videos) in the way that a human brain would do it but, in this case, carried out by a computer. From the point of view of engineering and industry, it seeks *to automate tasks of various* considerations that are normally carried out by operators. Thus, we distinguish several sub-technologies that are defined by the problem to which they intend to give a solution:

- **Object detection.** It is a sub-technology that focuses on detecting a certain type of objects in an image. In the cases of application, the objective is the detection of the object, no classification is intended.

- **Object recognition**. Unlike Object Detection, Object Recognition intends not only object detection but the classification of the perceived objects. This feature allows Object Recognition to perform more complex tasks in industrial processes.

  Computer vision's uses in traceability may exhibit different levels of specialization. For instance, some techniques have a straightforward application:

- **OCR** (Optical Character Recognition). It is the mechanical or electronic conversion of images of typed, handwritten or printed text into machine-encoded text. This technique is aimed at recording information from objects in its sight-line.

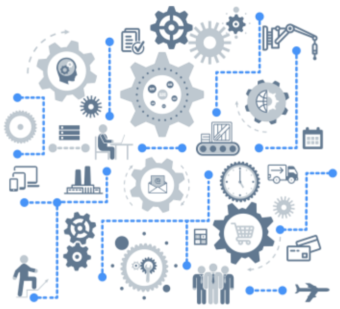
- **OCV** (Optical Character Verification). This technique is based on the same principle that OCR but, in this case, only information contrast is performed.

From the viewpoint of the technology nature, both procedures belong to the group object recognition, however, attending to the developed task, OCR would be classified as an object recognition technique, while OCV would belong to the object detection group. This last case is a little bit unclear, since it uses object classification as a mean to detect objects.

In other cases, more abstract techniques are implemented in a variety of different situations. In these cases, the complexity and the context of the classifications may vary in a wide range, but the scientific foundations remain the same.

Integrated technologies:

Internet of Things, IoT, is a compendium of devices and sensors mutually connected that interact and exchange data and information. This information can be partially obtained by means of the mentioned sensors, which employ different technologies in order to perform their task. In the IoT case, the relevant aspect is the connectivity rather than the specific technology involved in the information acquisition.



1.1.2 Use Cases

Barcodes

•**Nacex**. Nacex is an express parcelling company operating in Spain, Portugal and Andorra. The company belongs to “Grupo Logistica”, the biggest product and proximity services distributor in south Europe.

Problem/Necessity: NACEX has consolidated a large network of franchisees across the different operational regions in order to handle “last mile” deliveries. For this propose, Nacex uses more than 1,500 vehicles that allow franchisees receive parcels from NACEX distribution hubs and then distribute them into vans aimed at their final destination. The reception process is standardized. During this process, NACEX franchisees check if the received parcell is the correct item and then is properly given to the corresponding driver. This process is implemented by means of barcodes.

So far, drivers had used dedicated handheld scanning devices during the checking process. However, these devices presented issues with scan speed, and were also limited in the amount of information they manage during the delivering process.

Solution: Nacex started the development of an Android app based on the Scandit Barcode Scanner SDK mobile data capture platform available to drivers. This platform offers different advantages over handheld scanners. Some of these advantages are, for instance, compatibility with a vast range of Android smartphones, more rapid scanning rates or Effective reading under dark lighting conditions.

RFID

•**Luossavaara-Kiirunavara AB (Swedish Mining Company).** LKAB is a mining company. This company extracts and refines iron ore from deposits in northern Sweden. Its primary products are various types of iron products.

Problem/Necessity: Tracing granular products in a continuous flow in process industry. In this case, the experiment focused on experiments in the distribution chain of iron ore pellets. There exist some processes that are not standardized nor traced, what affects some relevant aspects such as residence time in the distribution chain. For instance, loading and unloading of the product silos do not follow predetermined patterns and the performance of this operation hardly depends on the level in the silos at the time of departure or arrival. These issues have implications in the complexity of traceability initiatives in the distribution chain. Moreover, in case of customer complaints, it is difficult for the company to identify when a product was manufactured and moreover, this procedure is conducted with a great amount of work and vague assumptions.

Solution: An improved traceability in the distribution chain would reduce the described problems and moreover, it would improve the production and the separation customer-specific products. In this case, an RFID system was installed conveyor in each stage of the transporting process.

Computer Vision

•**Western Meat Industries.** Nowadays traceability has gained crucial role in alimentary industry and specifically, in meat industry. Consumers require quality checks that ensure the suitability for human consumption and the welfare of the animals involved within the process.

Problem/Necessity: In industrial slaughterhouses meat cuts are hard to trace once the piece of meat has been cut up from the carcass. Today, most of tracking system are aimed at monitoring secondary systems like boxes or Christmas trees with RFID technology. In meat industry no secondary devices can be attached to the products individually, therefore a batch-level tracking is not possible.

Solution: A vision-based system is proposed in this case of use. An image of the object is captured, which allows the identification of the same object at later point by capturing a new image.

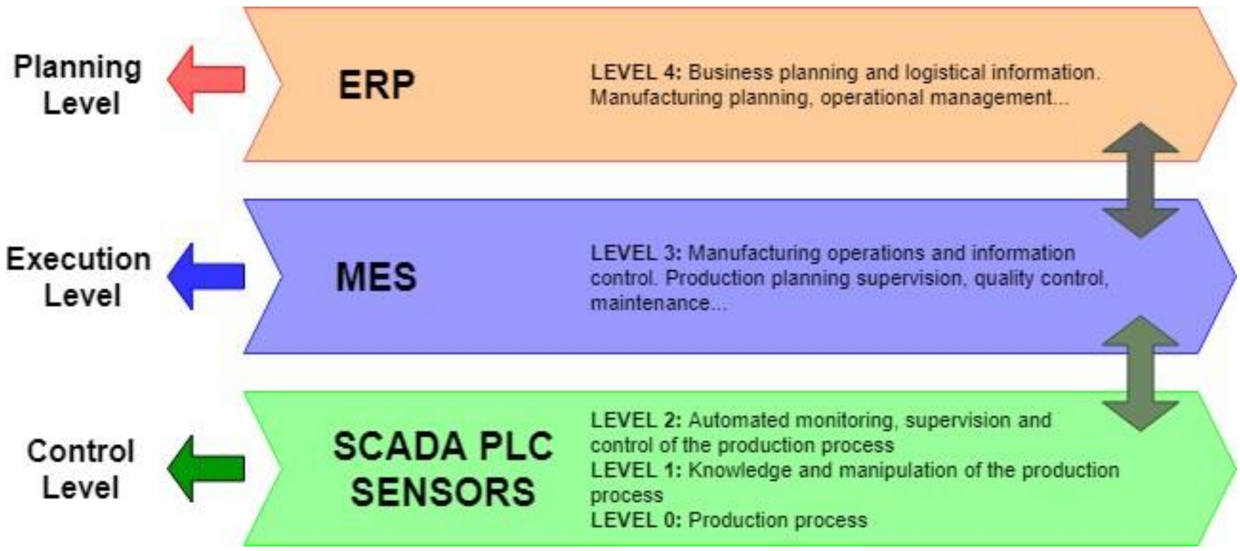
Internet of Things

• **Smart Factory** has arisen as one of the cornerstones of the current industrial revolution (Industry 4.0). As it has been showed along this document, this incoming industrial generation is strongly based on several brand new technologies such as IoT. As one of the main aspects of the production process, Visibility and Traceability are susceptible to be improved by this kind of new technologies. As an example of case of use of IoT in Visibility and Traceability, in the referenced paper, an IoT - enabled Smart Factory Visibility and Traceability Platform is depicted. This platform uses IoT technology in order to identify the target objects. RFID is the technology chosen as data harvester.

1.2. Industrial Information Systems

The Industrial Information Systems have been development with the aim to cover the productive needs of the company, ensuring data integration and uniformity. There are different levels on the Industrial Information Systems, which in ascending order are the following:

- **Manufacturing process machines**, which generate the information that is necessary to manage it.
- **SCADA** (Supervisory Control and Data Acquisition) and PLC (Programmable Logic Controller), they communicate between themselves and receive data from all the equipment of the plant, solving process control requirements and sequences of the machinery.
- **MES (Manufacturing Execution System),** is a software focused on the process control that monitoring and back up the plant management. The aim is to increase the Overall Equipment Effectiveness,(OEE) by detecting reducible costs and rooms for productivity improvement , as well as delivery traceability and quality of production. It can be an intermediate step between strategy and planning processes in a company (Enterprise Resource Planning, ERP) and 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, supply chain, etc. It is a global solution that organizes the information of the company.



1.2.1. Use Cases

- **GKN Driveline**: GKN is the leading automotive driveline technology and systems engineer, more than 50% of the 80 million new cars sold every year contain GKN Driveline technology.

Problem/Necessity: The company desired flexibility to track their process and could manage them correctly. Before introducing the new MES software, GKN used multiple tracking systems that varied by location, from internally created software applications to check sheets on paper. In each process, the drivetrain assembly is tracked with a go-no go determination made at strategically positioned test stations throughout the facility. Nothing can be pallet loaded for shipment to the customer until the product is inspected, checked for conformity with all performance specs, and validated by an operator. Because a variety of systems were in place, this process differed from cell to cell and plant to plant, making it difficult to train operators and to compare metrics across the organization. Without the vertical integration in their systems, assemblies are identified in each operation using barcode or RFID scanning equipment. Quality checking operations are performed at each step, ensuring that faulty parts are quickly identified and stopped before additional costs can be incurred. Every cell validates the correct assembly of the drive shaft components, with tests performed inline to check dimension, seal integrity and other parameters. Each machine controller is connected to Argonaut, so if a part fails at any step in the cell, a quality alert is logged. If the specific machine test is showing an error, that fact is immediately evident, allowing proper corrective action to be taken.

Solution: RedViking, which designs, builds and implements manufacturing and test solutions for difficult manufacturing problems, took all the GKN specs and machine builder data to create a “smart packing sheet” for all operations. Data is collected and tracked in a similar fashion to a conventional SPC system, but since the system is cloud-hosted, the data is instantly accessible from remote locations and remedial actions can be initiated virtually instantaneously. This new software utilizes store-and-forward technology at each production cell, ensuring that production can continue to operate without losing data in the event of an interruption to data transfer. Beyond process and part validation, the RedViking software collects cycle time and machine fault codes with each cycle. This data allows GKN to query for a subset of OEE information and can be gathered for cells throughout the facility.

•One of the world’s largest automotive manufacturer.

Problem/Necessity: The company needed to add more models and styles to their production line without adding floor space. Their assembly line was already overcrowded and the addition of more parts seemed impossible. Operators were becoming frustrated with time wasted searching for parts that led to line interruptions. They needed a partner to design and integrate an inventory management solution to control the delivery of parts and then sequence them with production schedules.

Solution: Large parts such as mufflers, headlines and axles came in several forms and were in various places on the assembly line floor. Valuable time that should have been spent on part assembly was lost finding the correct parts. To solve this problem, RedViking configured a sequencing system for off line part pickers to stagger or reverse order parts before placing them line-side for assembly. Sequencing instructions are automatically updated based on real-time production schedule so parts arrive in time. This solution also included our Error Proofing and Track and Trace applications. Correct part placement is verified before a car moves further down the line. Vision inspection systems check for incorrect or absent parts, like model badges. At each station where off-line pickers are kitting or sequencing parts, RedViking installed light indicators to notify workers of low part inventory or improper bin placement. With the addition of highly accurate error proofing systems, off- line pickers are able to adjust quickly, preventing line shutdowns. Parts are continuously tracked, giving Purchasing better visibility into inventories, so shortfalls and excesses are avoided. A traceable birth history is created for each car to minimize the financial impact of recalls.

•**Tupperware**. Tupperware is the world's leading manufacturer of plastic household products.

Problem/Necessity: The complexity of the product and its manufacture. Tupperware handles up to 52 quality variables so it was difficult to improve the production efficiency. The warehouse did not have the necessary organizational technologies, resulting in many wasted time due to inefficient management of routes and locations. In addition, they needed to organize in an integral way all the processes of a company of its size and characteristics, maintaining for it the previous invoicing system.

Solution: Tupperware Venezuela chooses the ERP software of a famous company called Geinfor, which has a great experience in the manufacturing industry. Tupperware got a better management of the business processes, as well as a better control of traceability and defective products, which has resulted in a decrease of waste and defective products of more than 10%. As a result, claims have fallen by 7%. The better management in the warehouse allowed the company to be more efficient in receiving, locating and managing goods, expediting orders and optimizing delivery routes.

•**TCI Cutting** is an international specialist in the most advanced cutting technologies**.** They have three lines of business: pressurized water cutting systems, laser cutting systems, and plasma cutting systems. The company has distributors all over Europe, America and Asia, having been awarded for being one of the most innovative companies on the Spanish scene.

Problem/Necessity: A company of this size wished operational excellence at the highest level, some of the requirements were:

- It was essential to reduce stocks of raw and semi-finished materials, and that their reliability be 100%.
- A significant reduction in delivery times was necessary, speeding up all shipping processes as much as possible.
- It was vital to keep a precise control of the real manufacturing costs, which at that time were not known exactly.
- In addition, they needed a decision making tool that would make all the information useful and help them make decisions based on data. In other words, they needed a Business Intelligence.

Solution: The company added the ERP designed by Geinfor into their business. The software allows to:

- Manage in a computerized way all their business processes, being of great help to obtain and maintain ISO9001 and ISO14001.
- Have all the information of the company in the same tool, in order to track the different areas of the company, such as sales and accounting reports, production, work queues, unserved orders, unreceived purchases, etc., which has saved a lot of time in all areas of the company.
- Decrease the number of failures and waste of time. Thanks to the data capture in the plant, the data is entered by the team members in the workshop terminals. This allows data to be captured where and when it is produced, a fundamental principle.
- Demand simulations to assess the financial impact of deviations, greatly facilitating business planning, in the short, medium and long term.

•One of the world's largest automotive manufacturers.

Problem/Necessity: They wanted to anticipate and prevent bottlenecks, quickly identify the root source for downtime and design their maintenance schedules to prevent equipment failure.

Solution: RedViking, which designs, builds and implements manufacturing and test solutions for difficult manufacturing problems, implemented a complete OEE/Factory Information System to acquire raw manufacturing data and convert it into usable information to help them reach their goals. Machine and process data is collected from each production station and sent to an on-premise host server database. Once captured, data can be posted overhead on an Andon board, sent via pager to a specific maintenance person, included in a management report, or redirected in virtually any secure configuration. In this case, a third party maintenance notification system was integrated to track maintenance response times. RedViking's OEE/FIS provides extensive manufacturing analytics for process improvement, and can easily integrate third party systems. Equipment reliability data is collected so that preventative maintenance can be scheduled before tools and parts need to be replaced.
The bottom line for the equipment and process monitoring system is improved efficiency. Instead of reacting to equipment failure and line bottlenecks, this automaker now has the data to prevent them through a complete understanding of their own equipment health, life, part quality, process variations and production flow.

•A fast growing automotive battery manufacturer.

Problem/Necessity: A battery manufacturer was opening a new plant in response to fast-growing product demand for automotive lithium-ion batteries. As a critical supplier for electric and hybrid vehicles, they needed to ensure the highest possible quality.
As the market for hybrid and electric vehicles continues to expand, battery manufacturers must make sure that their production quality is not compromised by increased volume.

Solution: RedViking designed and implemented a complete tracking and traceability system that improved quality in materials, processes and final products. At every step throughout production, raw material and work in process is marked and tracked to provide data on time in, time out, machines used and other characteristics integral to production. In this way, if a defect is uncovered, the impacted product can be quickly identified and quarantined. Integrated error proofing quality checks become part of the battery's genealogy and provide the foundation for root cause analysis.
This company added OEE equipment health monitoring to implement better preventive maintenance and minimize unexpected downtime. The combination of traceability and machine health monitoring gives them a complete view of production at any time and helps to refine their plant-wide control plan for quality management. Quality improved, manufacturing costs were reduced and recall impact was minimized.

•One of the world’s largest automotive manufacturer.

Problem/Necessity: The company wanted to have better insight into their manufacturing process and then track quality beyond the plant to create a “life history” for the vehicle. Their ultimate goal was to improve vehicle quality through better data.

Solution: Fully integrated error proofing with track and trace. First, tracking technology was implemented to create awareness of vehicle position throughout the entire production process. Where conveyance is involved, software and controls were used. Where there is no conveyance, a robust method of vehicle identification was put in place such as bar code, RFID or 2D pin stamp marking. Once positional awareness was in place, the next challenge was to interface with the customer’s existing scheduling system so it is possible to generate data about every vehicle’s parts and processes, from engine to keys. Once completed, a user-friendly interface was designed at each station so that the operator could easily understand the requirements for each specific vehicle.
The next use case is not a pure information system, but rather an integrator of various systems at different levels.

•**Altran** develop a system which manages the delegation of tasks and data acquisition (provided by the user). This acquisition process (where defects are examined and part measurements are made) could be performed by sensors instead of an operator (which is how it is conceived right now). The main role for QWALL is the operator.

QWALL allows the flow of information in real time between the different parts involve in a factory and they need that information, even a potential customer e.g. AIRBUS - ALESTIS.

Among its advantages, from the point of view of inspection of parts is the possibility of generating a 3D model which exposes the defects found in the checking stage.

QWALL can be integrated in industry 4.0.

1.3. Analyzing Charts

The chart 1 shows the **maturity of the technologies** considered within this chapter and a comparison between the adoption rate in the shipbuilding industry and some other relevant industries, such us aerospace and defense, energy, automotive or pharmaceutical.

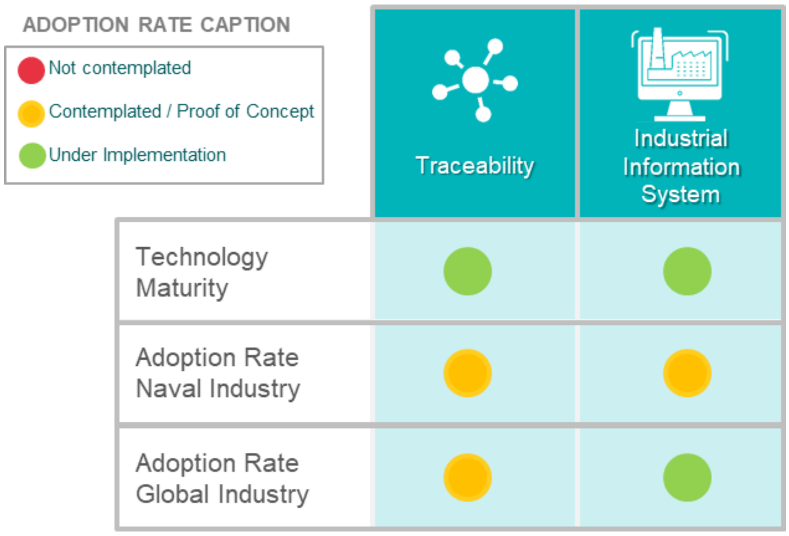


Chart 1: Maturity and adoption rate of the technologies.

Nowadays, both technologies are undergoing a high development process. Indeed, this development process has already yielded useful tools that are currently working out in several contexts. In the very next future, it is expected that these technologies will be going on providing more efficient and specific solutions that will help enterprises from an even wider range of industrial environments.

From the Adoption Rate in the Naval Industry that could be analyzed during the visits, it was concluded that most companies that currently collaborate in the shipbuilding process are not technologically ready in order to introduce this kind of technologies in their processes. However, it was also observed that these companies have the determination to undertake some approaches or, at least, undertaking some proofs of concept as a very first step.

Regarding to the rest of industries, the same lack of traceability can be in general observed. It is well-known that traceablity is a crucial step in any manufacturing context. This is why companies needs to have a perfect control and manage their process or products.

In the case of Industrial Information Systems, the opposite situation is observed. Most of industries already have a vertical or horizontal integration that gives them a vision of the processes and their business, allowing them to better manage the whole

manufactoring procedures involved in their respective contexts. However, the softwares that they usually use are not connected so there is no an automatic data trasference.
In the particular case of Naval Industry they work as isolated constituents, which implies that each constituent company has no vision of the different complamentary stages of the ship-building process (manufacturers, suppliers...).

Chart 2 and Chart 3 represent the technology application impact and how the companies can face those challenges. Color code is used to expose the impact of these applications.

- Transparent: Transparent circles stands for those technologies that do not apply in a concrete company. Those type or group of companies which do not have that application or process.
- Orange: Orange circles are used when the application impact in their company is positive but the priority implementation is low since they are interested in improving other parts of the process.
- Green: The application impact in their company is positive and moreover, the implementation priority is high due to the high interest of the company in the benefits that can be yielde by this kind of technology.

And a circle fill code represents how ready or technological mature are the companies to face those challenges.

Firstly, Chart 2 shows the **Traceability application impact**. Secondly, **how the companies can face those challenges is analyzed bellow.**
The following applications are taking into account:

- Manufacturing process traceability (final product, a ship, or intermediate products like the different blocks or parts of the ship).
- Product traceability, own product of the identified companies.
- Warehouse control (inventories of tools, pipes, materials…) or orders.

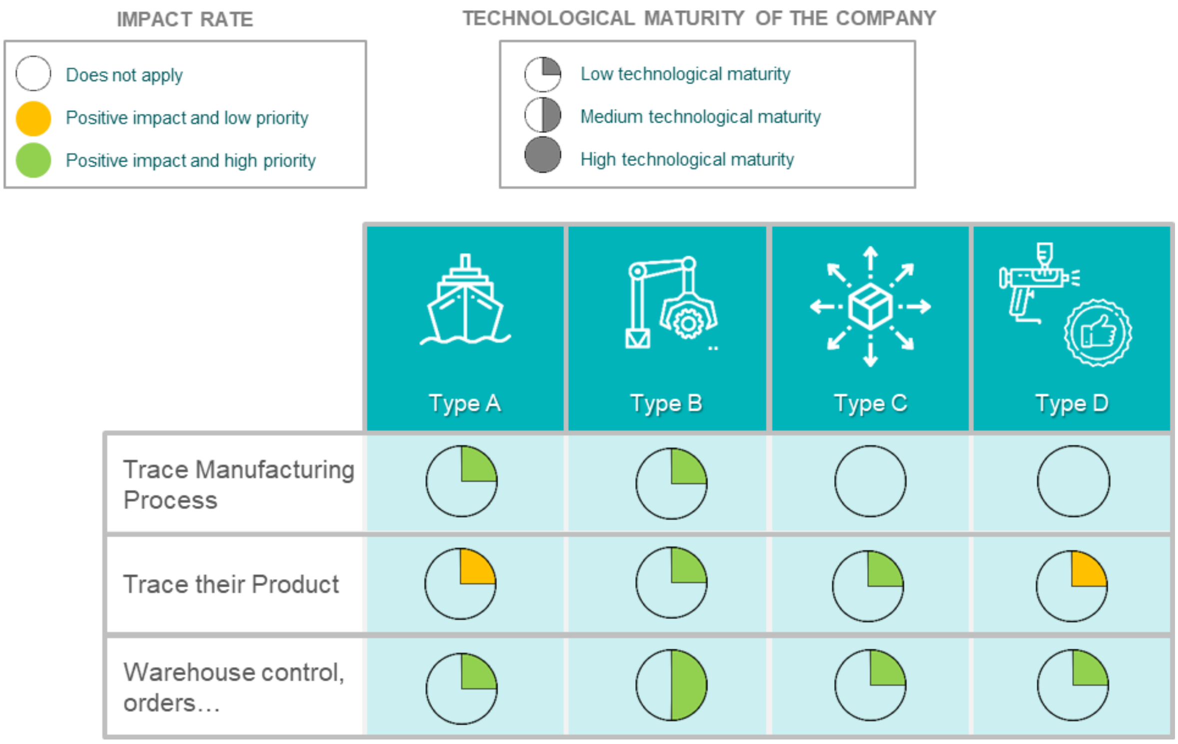


Chart 2: Traceability application impact and technological maturity of the companies.

Type A

The interests of the companies in this group are focused on the warehouse control such as inventory of tools, pipes, materials… and orders with suppliers or costumers. The main reason is the direct impact of that application on the sip assembly. Nowadays, they trace some pipes in a very basic level (do not use RFID or these kinds of technologies). On the other hand, highlight the ability to trace the manufacturing process/assembly due to the importance of the station contol to adjust production times and costs and the possibility to transfer data directly into the virtual twin. Today they do it weekly by entering information manually in an excel.

Type B

For companies that manufacture each part of the ship are very important the three applications detected.

Regarding to warehouse control and orders, it is the one that less effort they have to face. Nowadays they manage it manually using excel files or an isolated software (ERP, ARIBA…) that are not connected to other platforms, so there is no data transference.

Process and product traceability implies a higher effort due to the low automation level of the different stations. This automation level does not exist at all and processes are manually undertaken. However, they highlight that they find interesting tracing products to know which operations were made on them, when they were performed, who did the tasks… all that information can help them when there is any quality problem or just to have a routine monitoring.

Type C

They are logistic companies and they do not manufacture their own product that is why the manufacturing process traceability does not apply in that case.

But product traceability and warehouse and orders control are the two applications with the highest impact on them. They will help to control the order status and make sure that orders arrive on time to their customers. They have a basic stock control but it is necessary to invest in digitization with the proposed technologies.

Type D

Due to the characteristics of these companies (service companies for specialised activities) the manufacturing process traceability does not apply because their core activity is providing a service to shipbuilding.

Besides, tracing their products is not as important as in manufacturers because of the reason aforementioned. Maybe in companies which do activities like surface treatments is important to trace the product to know exactly the processes made on them, the date, the worker who performs it… but it is not highlighted for them as an urgent problem to be solved.

The highest impact is the warehouse and order control application, because they have an enormous necessity to control tools, consumables for the services, which of them are in the client installations, which one are in their factory, etc. In general, this tracking is performed by paper or basic software systems so they have to face a big implementation effort, introducing technologies such as RFID, QR codes, management software for example MES and ERP.

The Chart 3 shows the **Industrial Information System application impact and how the companies can face those challenges** are analyzed bellow.

The following application are taking into account:

- Enterprise Resource Planning, ERP, whose relevant areas are Finance/Accounting, Human Resources, Manufacturing, Supply Chain Management, Project Management and Customer Relationship Management.
- Manufacturing Execution System, MES, whose relevant areas are Maintenance Management, Production Management, Quality Management, Warehouse and Inventory Management.

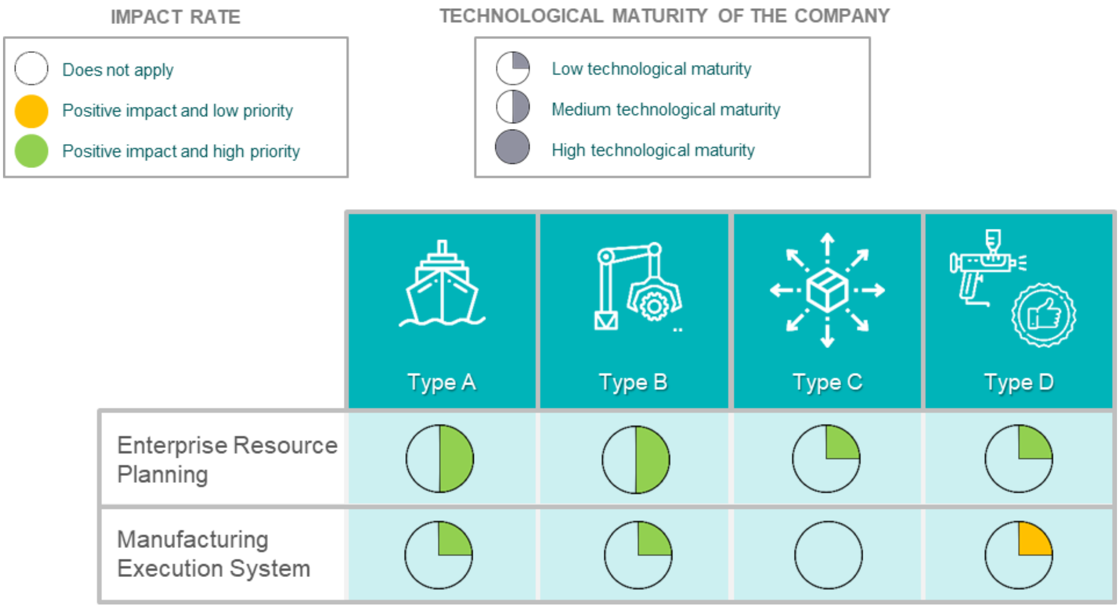


Chart 3 Industrial Transformation System application impact and technological maturity of the companies

Type A
Both of the applications detected have a positive impact for this kind of companies. By means of the control and management of the different areas, they will be able to improve the quality, productivity, business process and also their flexibility. They already use simulation software to analyze the process time and cost, but they are also interested in go a step further.

Type B
Manufacturer companies found important the management and the visibility among the different parts of the company. Some of them already have a basic ERP system controlling the supply chain and manufacturing process, that is why the maturity level is medium. Regarding to the manufacturing execution system they long for having a full control of the stations, products and inventory but nowadays they do not have the necessary previous automation level in the shopfloor. This automation level is determined by, for instance, the amount of sensors to collect the data or the software to treat them.

Type C
These kind of companies do not manufacture their own product so ERP software fits better to them than MES because of the possibility to have a vertical integration of the company and increasing the visibility with orders, human resources, supply chain among others.

Type D
Companies that offer external services to the shipbuilding industry highlighted the neccesity of a vertical integration in their companies, because they consider necessary the implementation of tasks such as list of materials that they have bring to the clientfactory (nowadays it is a manual control), warehouse and inventory control, material request to suppliers and human resources to planificate their workshifts and their routine.

Chapter 2: Automation & Robotics

2.1 Automation

The concept of Automation refers to a process whose performance is developed by itself, with no human supervision. Since no supervision is required, the process can be undertaken every hour along an indefinite time period, with no interruptions. Industrial Processes Automation refers to the automation of processes that take place in the industry. In this context, two different types of automation can be considered, namely, IT automation and OT automation. IT (information technology) refers to those technologies aimed at the information processing, which includes software, hardware or communications. In general, IT does not include technologies that are not information providers. On the other hand, OT (operational technologies) are those technologies that are not specifically aimed at providing information. Thus, these technologies include hardware and software specialized in change detection and generation by means of direct monitoring.

In the context of industry 4.0, the boundary between IT and OT has become fuzzy due to the rising power of the new devices. In this document, OT will be represented as more physical (hardware) and thus it will be explained and developed by means of Robotics in the homonymous section. Thus, automation will stand for all these processes that can be considered as IT.

In a general automation process three stages can be identified. Note that these stages are iterated in a cyclic way while the automated process is taking place. This fact allows the continuous improvement of the designed automation.

- **Data Collecting**: This stage is aimed at the acquisition of information. This information comes to us in the form of data collected by different kind of sensors which harvest the information generated by the different parts of the whole process.
    - A **sensor** is a device conceived to detect events. In these events underlie relevant information which is obtained from the symptomatology predicted by different theoretical principia. This information is then sent to other electronics which will perform some other kind of processes on it.
- **Planning**: This stage focuses on decoding the information harvested in the previous stage. This information processing is performed by entities of different nature, such as PLCs, Scadas or, more generally, computational techniques.
    - On the one hand, Computing refers to a set of techniques aimed at transform the so called raw data (data directly obtained from the sensors) into suitable information for the theoretical models that will be fed with it (Filters, statistical models…).
    - On the other hand, Computing may refer to the implementation of the aforementioned theoretical models. These model yields new

knowledge, which is transmitted to the operator by means of different interfaces.

- A Programmable Logic Controller (PLC) is an industrial computer specially designed for de control of industrial manufacturing processes. Nowadays, these kinds of processes provide a great amount of information by means of sensors strategically allocated. This information flow is managed by the PLC, which interacts with it by means of several signal receptors and emitters.
- Supervisory Control and Data Acquisition (SCADA) is a control system that uses technologies of different nature such as networked communications or computing techniques for process management.

- **Action**: In this stage, a response is generated as a reaction to the received stimuli. This response is aimed at satisfying a particular requirement whose symptomatology has been observed and analyzed in the two previous stages.
    - An **Actuator** is a component designed for moving or controlling a mechanism or system. In order to perform their target tasks, actuators require a control signal and an energy supplier. Actuators execute the actions that have been determined by the corresponding devices in the previous stage.

2.2 Particular case: Robotics

Robotics is the interdisciplinary branch of science aimed at the design, development and creation of the different aspects related to Robots, for instance, control computer systems, sensory feedback, or information processing. A Robot is a machine capable of carrying out a complex task in an autonomous way. A large procedure can be split in smaller tasks, which can be undertaken by robots. Because of this fact, Robots are one of the most popular tools in manufacturing automation since their creation.

Notice that Robotics is not at the same hierarchical level as Automation since Robotics always implies automation but the reciprocal implication is not true in general. However, due to the nature of the task faced in this document, considering Robotics at the same level as Automation has been considered fair enough for our purposes. Moreover, the kind of tasks and jobs that usually take place in a shipyard are suitable for been automated by robots, since several contextual conditions such as danger, repeatability and the need for strength could be easily improved by the use of such technology.

2.2.1 Robot categories

Now, taking into account the observed needs of the shipbuilding industry, we are going to depict the most relevant categories.

- An **industrial Robot** is a robotic system used in industrial manufacturing processes. These types of robots are automated, programmable and they are able to move along three or more axis. Among their most usual applications, Industrial robots often perform welding, painting, assembly or pick a place tasks.
- A **Climbing Robot** is a robot that has the ability to climb vertical surfaces. These robots are able to adjust their centre of mass and adapt themselves in order to reach the proper climbing path. This type of robots may perform pathological tasks as dangerous surfaces inspection or cleaning.
- A **Powered Exoskeleton** is a machine made out of a wearable structure, actuators and a control system. This type of robot allows for performing a great variety of tasks with improved physiological features, such as strength and endurance. It is a system of a low level of automation, in terms of a minimum task decision making that relies in the human operator that wear it, but a high speed and predictive response to the human reactions.
- A **Submarine Robot** is robot that can undertake different kind of tasks underneath the water surface. Some of these tasks are, for instance, ship-surface cleaning.

2.3. Use Cases

Automation:

Problem/Necessity: Network Connectivity Incidents.
Solution: Here a solution provided by Resolve SYSTEMS is presented. This solution is made out of several sub-solutions aimed at solving concrete problems. Namely,
Avoiding waste of time and efforts during false-alarms handling by means of an automatic validation system generated by network management tools.

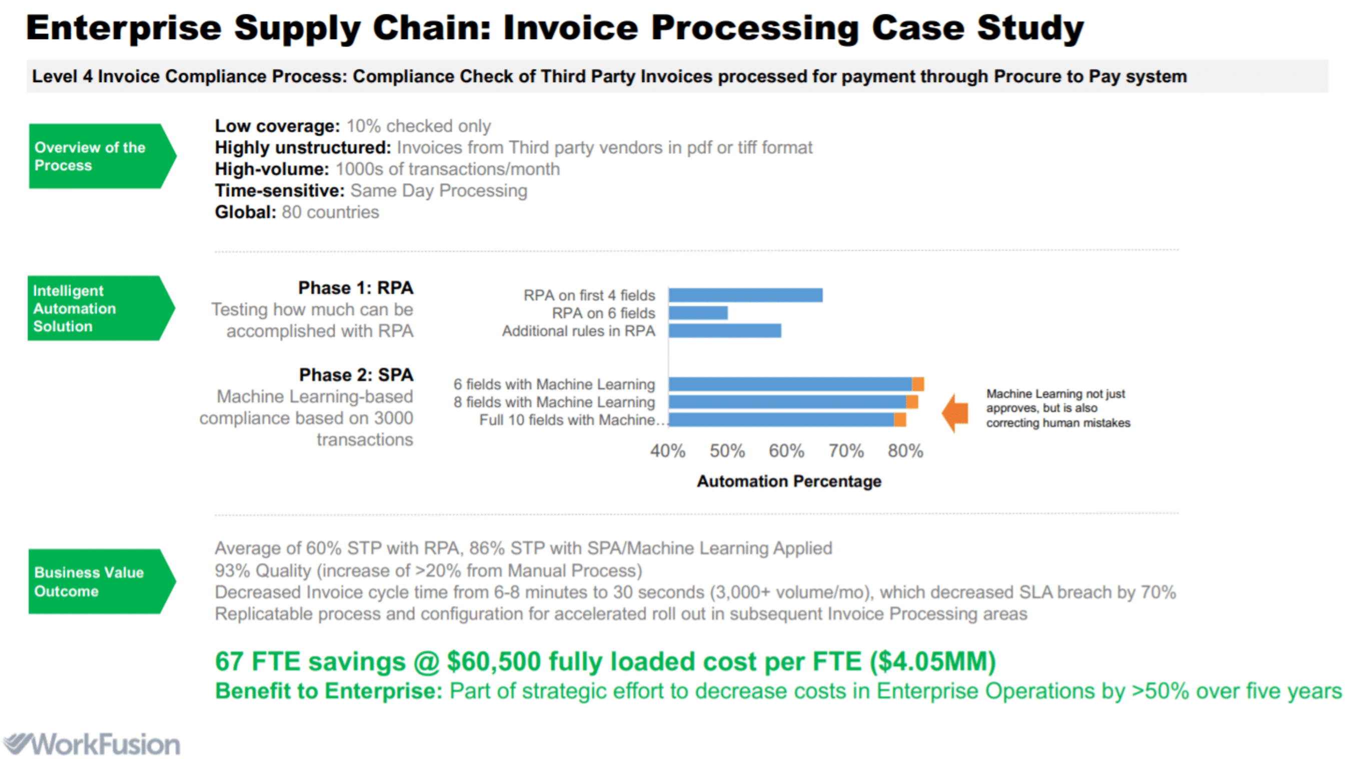
Performing connectivity issues validations and root-cause analysis by testing all possible causes with a set of guided procedures and automation.

Problem/Necessity: Core Service Incidents.
Solution: As in previous case, Resolve SYSTEMS provides a global solution composed by a variety of smaller solutions.
Reducing the validation and diagnose time and resolving core service incidents within web services, databases, email and directory services.
Identifying scope and consequences of an incident, automating the initial troubleshooting, gathering prerequisite information and resolving the incident without any direct interaction.
Accelerating resolution of core service alerts by means of human-guided automations by validating incoming alerts, eliminating false positives, diagnosing affected systems and receiving guidance to help identify pertinent actions in order to solve it.

Problem/Necessity: Quote to Cash. Selling is a critical aspect in every business. Problems in selling may entail a variety of consequences such as complaints or losses.
Solution: The automation of this process reduces the risk of incurring in one of those issues. Moreover, not only these errors will be avoided but the efficiency of the whole process will be increased. Thus, for instance, some other aspects as invoice reception, payments and cash flow will be improved.

Problem/Necessity: Procure to Pay. This is a complex process that involves some other sub-process. Thus, for example, invoice and payment data from different platforms such as ERP or CRM (Customer Relationship Management) are required. Information provided by these platforms is not always easy to integrate and usually give rise to uneasy tasks that must be undertaken manually.
Solution: Procure to Pay automation might be approached in different ways. One of these ways may be, for instance, using front-end RPA bots that could fill the integration gaps.

Next Image shows an example of Invoice Processing.



With a fully automated procure-to-pay, you can ensure that procurement best practices are followed and there’s a single source of truth for all transactions.

Robotics:

Problem/Necessity: Traditionally, the shipbuilding industry has relied on the labour of a large pool of skilled workers, who faced the prospect of long hours and demanding tasks such as welding, cutting and painting to get large vessels launched. But the industry's workforce has been dwindling in the face of the global downturn and the declining prevalence of shipbuilding in many markets.
As labour pools continue to dry up and shipyards struggle for efficiency gains in an intensely competitive global market, shipbuilders are increasingly relying on greater levels of automation to keep up with their order books.
It's the same story in almost every corner of heavy industry, regardless of labour shortages or economic austerity; employers are recognizing the value of robotics as a driver of efficiency and a method of sparing human workers from monotonous or dangerous tasks.

- **Samsung Heavy Industries' (SHI's) Geoje Shipyard** is the company's largest shipbuilding facility in South Korea, and boasts the world's highest dock turnover rate, launching around 30 ships a year.

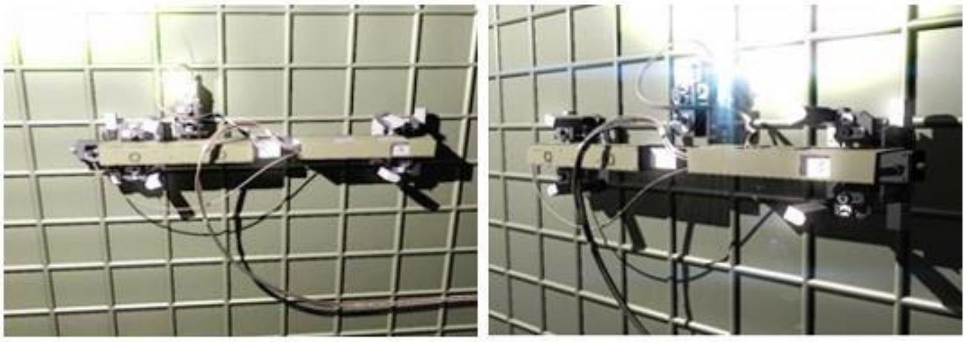
The shipyard's efficiency is partly down to its world-leading automation rate, with 68% of its production processes carried out by robotic systems. Intelligent systems used at the facility include inspection and pipe-cleaning robots, as well as units for welding, one of the first shipbuilding operations to be automated. Some of newest automation improvements that SHI added to their processes are:

- SHI secured **One-Time Setting production technology**, which is capable of securing stable dimensional quality, in order to solve poor dimensional quality and low productivity. SHI established a large-sized structure measuring system by utilizing optical system and automated deformation control of large block.
  It developed a management system that analyzes and integrates dimensional quality.
  The company realized the world-class assembly productivity by applying the two systems to large-sized block for offshore plant.

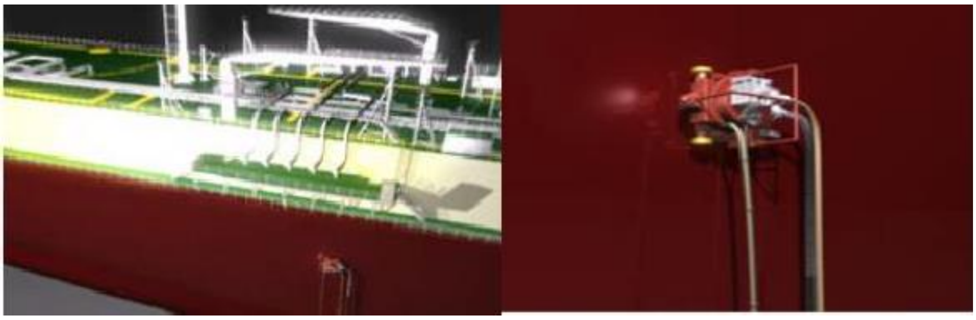
- **Dual Lifting Methodology.** SHI developed Dual Lifting Methodology which connects 8,000 tons and 3,600 tons floating cranes and then operates the two cranes like one floating crane. With Dual Lifting, the company is able to lift, move and erect Terra block with 11,600 tons and secure capability to fabricate and lift the largest block in the world. Block fabrication time and erection cost are saved by applying it to large- sized offshore structure and stability and efficiency are maximized by applying connection system.

- **Smart Yard**. SHI is establishing digitalized and future-oriented Yard where all manufacturing information in the Yard is serviced and managed by connecting with ICT as well as optimized by interlinking each other organically. Through this, SHI expects to build production workshop based on Data, set up process without rework and minimize the amount of stock.

- **Spider Automatic Welding Robot** has developed a spider automatic welding robot system that enables welding works to be performed through free motion on the wall of a cargo tank. Through this system, SHI has eliminated welding faults in the cargo tank within the LNG carrier, and enhanced productivity. The spider robot can move to the desired position with using four-legs step by step and performs welding works automatically.

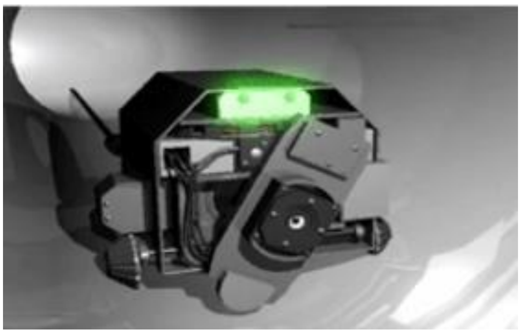


- **Wall-climbing Vacuum Blasting Robot** can move freely across the outer wall of a ship. SHI's vacuum blasting robot, meanwhile, can freely move from all parts of the ship, from the bottom to top and the outer wall. This robot is, in a sense, a showcase of SHI's production automation technology, as it combines the automatic tracking of the welding parts, a wireless communication control system, and automatically controlled vacuum pressure technology. This development has resulted in a seven-fold increase in the speed of blasting work, while enhancing safety, quality, and environmental impact.

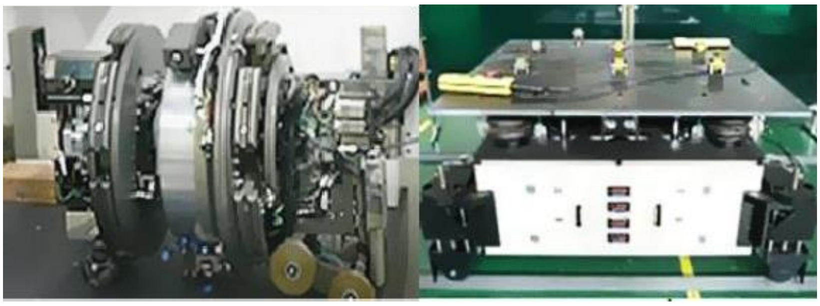


- **Pipe Inspection Automatic Cleaning Robot**. After the welding process to connect the pipes is completed, the result of the welding is inspected, and cleaning work to remove undesired substances is performed if necessary. As the interior of the pipe is very dark and narrow, working inside had been regarded as very difficult. SHI has developed a robot system which conducts inspection and cleaning at the same time. This robot system inspects inside of the pipe using camera system, and cleans the inspected space using brush and suction system. 2 cameras are located on robot's front and rear sides, and 1 camera is attached on the robotic arm. The robotic arm has 360 degree rotating range.

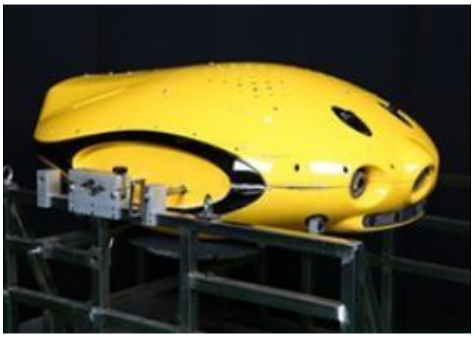
When the robot detects undesired substances, it uses the robotic arm to remove the substance. Thanks to this robot, the quality of the pipe inspection has increased.



- **An Automatic Pipe-Welding Robot**. SHI has developed a robot, which makes all welding spots on the stainless steel pipes the perfect size and shape. This robot precisely and easily connects the stainless steel pipes in the LNG carrier. Before welding the pipes, it corrects any part of the pipe that is distorted, adjusts its roundness, gauges difference and gap using a six-axle motion- robot, and reduces the weight of the 600kg pipes using a weight balancer to allow the robot to operate smoothly. With this robot, welding work is done more precisely and easily than before. It has also shortened the time spent for the welding of the pipes from 3.2 hours to 0.5 hours, significantly improving the competitiveness of shipbuilding work.



- **Underwater hull cleaning robot.** In October 2014, Samsung Heavy Industries completed development of an underwater ship hull cleaning robot able to clean ship surfaces underwater, and successfully completed test runs on actual vessels. The hull cleaning robot, which eliminates the need to re-dock vessels for cleaning before delivery to customers, reduces costs while improving productivity. The new robot is not only an important development in terms of employee safety and cleaning quality, but is also significantly better for the environment thanks to the robot's internal filter, which captures waste materials separated from the hull.



- **Dalian shipyard in China**. General Electric (GE) provided a drive and automation system to Dalian shipyard for the management of a new Goliath crane system, bringing a number of efficiency and energy conservation benefits, especially with its automatic skew control system (ASCS), which allows two 200m gantry sides to safely operate at the same time. GE's technology enables two of these 600t cranes to work simultaneously, enabling the handling of higher loads required for building larger vessels. At the same time, GE's drive system technology saves significant amounts of energy..

Crane operations at Dalian shipyard

- **Welcon A/S, Denmark.** The company manufactures steel components and solutions. It offers products for welded and finished steel constructions. WeldLogic is a robot that replaces the traditional submerged arc welding, which then did require one operator per workstation. Now one operator operates 6 robot systems. The shipyard welding robot that can perform its task 40% faster than a manual welder, with an interface that the company believes is the simplest in the industry.

- **Hyundai Heavy Industries (HHI).** The world's largest shipbuilder and a major robotics manufacturer. HHI showcases its best technology in welding and manufacturing automation. Among its capabilities are fully machine-driven steel-cutting lines and a hot forming automation facility. As the use of robotics in shipbuilding increases and technologies such as sensor systems and artificial intelligence add complexity, there is a gradual move toward customized automation technology to optimize shipyard operations. They introduced mini welding robots to its shipyards. The robot, which measures 50x50x15 cm with its welding arm retracted, is able to operate in areas inaccessible to humans, and HHI believes its six joints can handle almost all welding jobs at a speed comparable to its human counterparts. The robot's magnetised body allows it to stick to panels and ceilings, with a single human operator able to control three of the systems at once to triple productivity. HHI is also working on software for steel cutting, blasting and painting to expand the new robot's capabilities.

Mini welding robots can operate in areas inaccessible to humans. A magnetized body allows them to suspend from panels and ceilings.

As well as remote controlled systems, the miniaturisation of robotic systems is also opening the door to wearable systems that can enhance the user's strength and stamina.
HHI is also using robotics that can curve and weld steel plates for the front and back of vessels through remote connectivity between the machine and design software.
Hyundai expects it will increase productivity by three times compared with manual labour.

- **Estaleiro Atlantico Sul (EAS) shipyard**, the country's largest shipbuilding complex, which has formed a technical partnership with South Korean giant Samsung Heavy Industries (SHI) and introduced four automated plasma cutting machines and one of the largest flat panel production lines in the industry, capable of producing six flat panels a day.

- **Daewoo Shipbuilding and Marine Engineering (DSME**) began in 1973 at Okpo Bay, Geoje Island, on the southeastern tip of the Korean Peninsula. Completed in 1981, DSME has since grown into a premium shipbuilding and offshore contractor specializing in offshore platforms, drilling rigs and FPSO units/floating production units.

    - **Multi welding robot systems,** Most of the welding equipment applied to weld a sub assembly line are semi auto type welding machines, so-called auto carriage. By employing auto carriage to perform welding tasks, there are many merits such as simplicity of operation without any special education for workers, a light weight to handle etc. But, due to certain limitations in the functions of auto carriage, it is nearly impossible to perform an auto tracking of the weld line and round welding which constitute a large portion of welding in shipbuilding. A typical example of this is the DANDY system which is operated by workers to weld a part of the boundaries, then moves to the next welding locations using the overhead gantry crane installed on the ceiling of the shipyard.

- **'Iron Man' wearable robot**, which is intended to improve worker productivity and reduce the incidence of the musculoskeletal disorders that routinely affect shipyard workers involved in heavy lifting.

- **Kranendonk.** It is a company that offers automation solutions for the naval industry. They have intelligent robots that automate cutting and welding processes throughout the entire manufacturing process. They also have what they call a Pipe shop, a storage chain and pipeline management.

2.4 Analyzing Charts

The Chart 4 shows the **maturity of the technologies** considered within this chapter and a comparison between the **adoption rate in the shipbuilding industry and some other relevant industries** such us aerospace and defense, energy, automotive or pharmaceutical, among others.

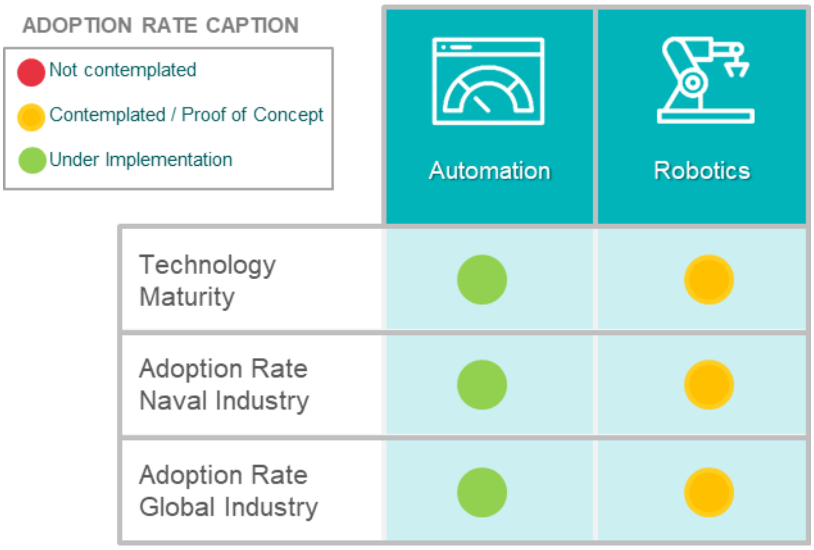


Chart 4 Maturity and adoption rate of the technologies.

The technology maturity of automation is completely developed and validated in industrial processes but new robotics explained above are still in a very conceptual level, because they often rely on several recent technologies to carry out their tasks, and thus, they have not had the chance to be properly tested. For example, the climbing robot used for verification tasks also needs artificial vision to recognize imperfections on the surface or adjust its movement to climb the ship surface or accessing to small or irregular areas. Due to the complexity of their operation these robots are still in process of implementation in most industries.

As it happens in shipbuilding industry, industries in a wide range of contexts have a great implementation of automation in the processes to obtain high quality products.

Chart 5 stands for the technology application impact and how the companies can face those challenges. With colour code the impact of these applications.

- Transparent: Transparent circles stands for those technologies that do not apply in a concrete company. Those type or group of companies which do not have that application or process.
- Orange: Orange circles are used when the application impact in their company is positive but the priority implementation is low since they are interested in improving other parts of the process.
- Green: The application impact in their company is positive and moreover, the implementation priority is high due to the high interest of the company in the benefits that can be yield by this kind of technology.

And a circle fill code represents how ready or technological mature are the companies to face those challenges.

The Chart 5 shows the **Robotic application impact and how the companies can face those challenges** are analyzed bellow.
The following application are taking into account:

- Industrial robot: Traditional robots performing different kind of tasks such as welding, painting, assembly or pick a place tasks.
- Climbing robot: Surfaces inspection or cleaning.
- Exoskeleton: Physiological features, such as strength and endurance and worker ergonomic
- Submarine robot: Ship-surface inspection or cleaning.

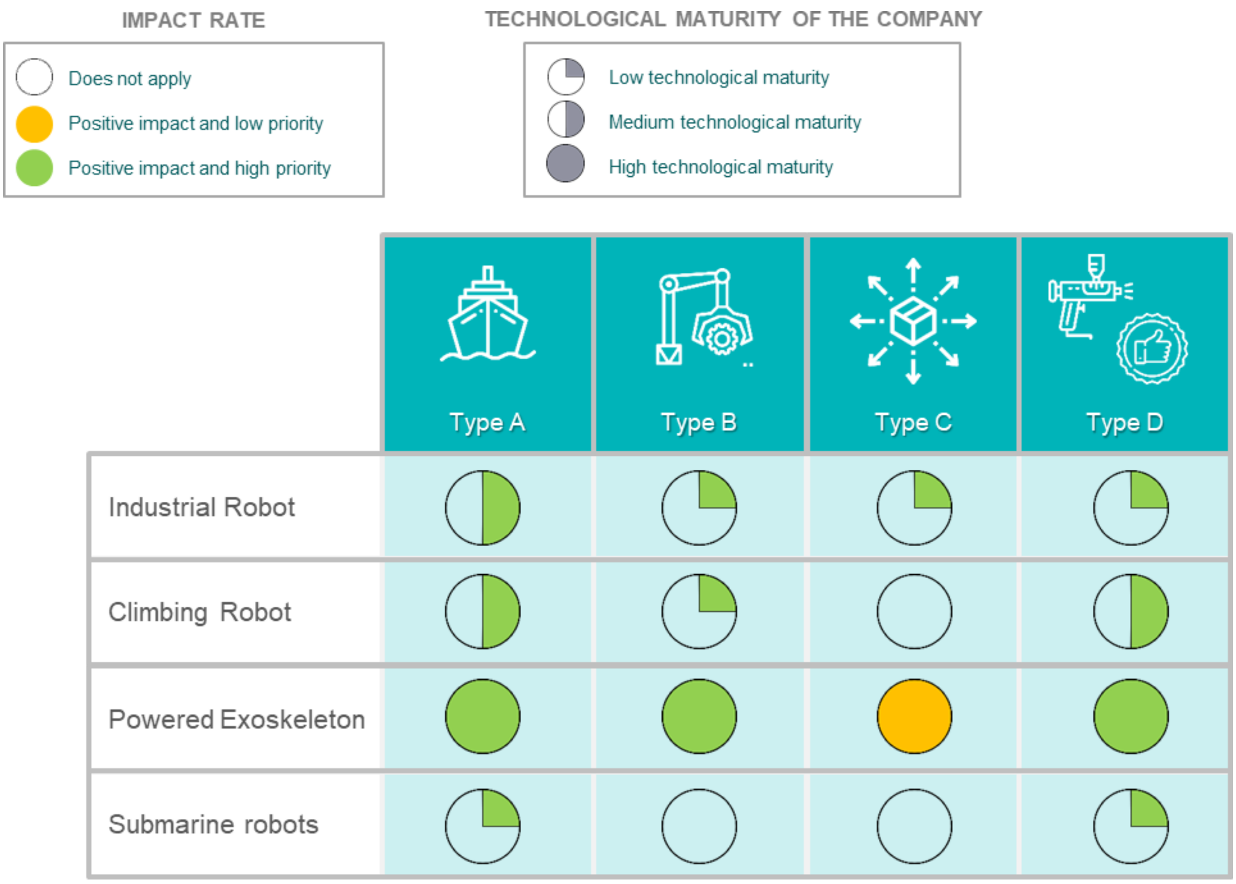


Chart 5. Robotic application impact and technological maturity of the companies.

Type A

The different kind of robots taken into accout on this document have a really good impact in shipbuilds because they will improve the efficiency of the manufacturing processes.
Specially, exoskeleton robots could help correcting worker's postures and with easy implementation.

Type B

Due to the fact that most of the manufacturing and assembly processes in all of these companies take place on the earth' surface, submarine robots are the one with less impact on type B companies.

Exoskeleton robots can help workers doing tasks easily and without hurting themselves carrying heavy objets or difficult postures that take long time.

The rest of the robots have a positive impact but maybe the layout has to suffer some changing to adapt their processes.

Type C

Logistic companies are interested in traditional robots which help them to perform tasks such as pick and place, assembly or dispaching orders.

Due to their main activities, climbing and submarine robots do not apply into them.

Exoskeleton robots can be helpful to move small and heavy boxes or objects during the logistic chain. It does not have high priority because we considered that the most of the objects to dispatch are big and heavy so a worker will not carry them.

Type D

All the robot applications have a positive impact and a high implementation priority because they can make easier the tasks and easily improve the quality of the services, such as exoskeletons applied in activities like painting or climbing robot for quality inspection that allows to access to difficult or small areas for humans.

3. Chapter 3: Collaborative Platforms & Data Base

A **Collaborative Platform** or collaboration system is a virtual space where the set of relevant functionalities of one single or several enterprises are integrated. These relevant functionalities are, for instance, projects or information management, as well as organization management, especially in those cases where the global process is made out of several sub-processes which are undertaken by different members that must be synchronized and share information of different kind.

Some of the functionalities that are integrated in this kind of platforms are, for example, mailing services, Databases of different nature (this nature depends on the kind of information that needs to be accessed), debate forums, version- control software, massive storing and sharing services or scheduling services. Notice that the integration of such a huge amount of services in one common system is extremely useful, not only for the clear improvement of managing capabilities but also for the simplicity implied by using one single common language.

Besides, the term collaborative platform refers to a global concept that includes all the functionalities but, in some cases not all of these functionalities are present at the same time. It is important to note that the needs of the enterprise or enterprises using this kind of systems determine the structure of it. Thus, according to the aforementioned needs, a collaborative platform might be aimed at providing a sort of communication tools, providing a whole inventory management system for a corporation, version control etc.

3.1. Use Cases

•Airbus.

The problem. Airbus Puerto Real collaborates with a fairly big number of partners. These partners provide Airbus with components that will be integrated in the final product at the end of the production process. These components must satisfy several standardized conditions of different nature (design conditions, materials properties, etc.) that are provided by the main manufacturer, which is Airbus in this case. Thus, it is clear that a common channel aimed at managing this huge information flow between the Main Manufacturer and all the partners is necessary.

The solution. In order to afford this challenge, Airbus hosts a collaborative platform within its computer systems. This is a private-access platform where only partners are allowed to go in.
The platform is composed by several apps. Each partner use one or several apps from the platform in order to manage or perform the pertinent tasks. As an example, Altran is on charge of some repair and maintenance tasks, so those Altran operators have access to a repository containing a list of last revisions and repair operations. Altran's operators

also have access to a shared repository where files of interest can be stored and accessed by each part when necessary.
This platform is not only aimed at sharing information, but it also has some other interesting features as tracking and tracing this information. Thus, for instance, given a plan of some particular piece of the plane, one operator can easily access to blueprints corresponding to each integrating component of the piece. Moreover, from one particular component, a list of all pieces containing this component is available to be accessed.
So as it can be seen, this kind of platforms has a variety of tools that are really useful for those enterprises where a lot of constituents are involved.

•Ford, General Motors and Daimler Chrysler:

The Problem. In this occasion the treated problem is the lack of efficiency in inventory and supply chain management by three large enterprises of the automobile industry, namely, General Motors, Ford and Daimler Chrysler. In those days, each constituent was using from three to five different inventory management systems, RFP systems, binding systems and purchasing processes. This fact implied errors such us duplicities or supplying problems.

The solution. Finally, the three automakers collaborated in the creation of Covisint. Covisint is cloud-based platform where suppliers coexist and interact with customers, independently of what client are they working with. Thus, suppliers are given with one single workplace. In addition, the auto makers developed standard EDI, a messaging platform in order to allow the easy information exchange.

•Siemens:

The Problem. In this use case the Siemens B2B consulting, development and production division affords the problem of managing the global knowledge and the search for experts within a corporation with approximately 405000 employees across the world.

LIFERAY
Enterprise. Open Source. For Life.

The solution. In this use case Liferay was the chosen software. This software is an Open Source solution aimed at contents managing. In this case the solution focused on providing the capability of knowledge transfer and communication. This can be achieved by means of web-based work spaces real-time online meetings or streamline communications.

3.2 Analyzing Charts

The Chart 6 shows the **maturity of the technologies** considered within this chapter and a comparison between the adoption rate in the shipbuilding industry and some other relevant industries such us aerospace and defense, energy, automotive or pharmaceutical, among others.

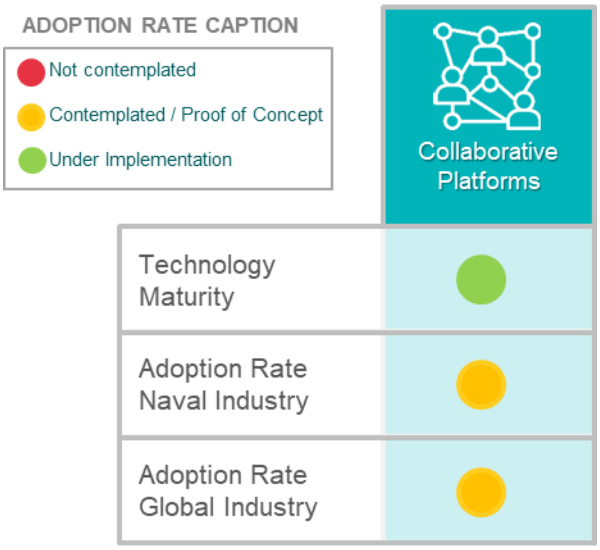


Chart 6. Maturity and adoption rate of the technologies.

This technology is completely mature and developed but the most of industries are not technologically prepared for its implementation. This is due to the fact that they would need to adapt a virtual space on which all the parts of a company will depend or even among different companies of the same process chain.

Chart 7 stands for the technology application impact and how the companies can face those challenges. With color code the impact of these applications.

- Transparent: Transparent circles stands for those technologies that do not apply in a concrete company. Those type or group of companies which do not have that application or process.
- Orange: Orange circles are used when the application impact in their company is positive but the priority implementation is low since they are interested in improving other parts of the process.
- Green: The application impact in their company is positive and moreover, the implementation priority is high due to the high interest of the company in the benefits that can be yield by this kind of technology.

And a circle fill code represents how ready or technological mature are the companies to face those challenges.

The Chart 7 shows the Collaborative Platform application impact and how the companies can face those challenges are analyzed bellow.
The following application are taking into account:

- Document management and version control for process traceability, collecting and saving all the information to always have updated documents and accesible for everyone.
- Document transference as a way to transfer files such as drawings, technical characteristics, modifications…instead of using emails or external memories which do not control the lastest version.
- Data base as a safety way to save data.
- Communication focused on logistic management as an automatic way to connect with suppliers to launch orders.

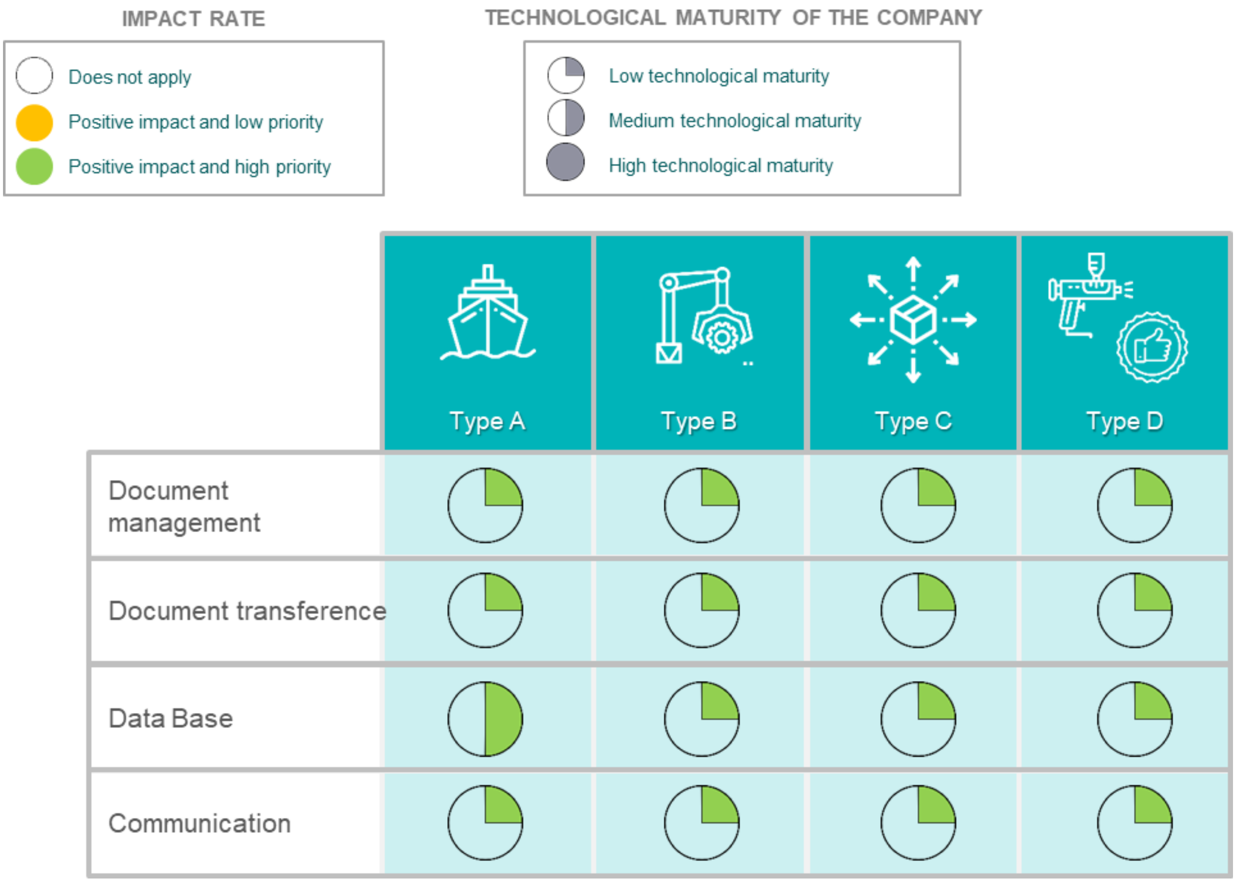


Chart 7. Collaborative platform application impact and technological maturity of the companies.

As it has been previously defined, a collaborative platform cannot be solely applied to one single Type of company all at once. Due to its nature, collaborative platforms must be understood in a holistic way since they deeply impact in the whole process' spectrum, from the supply chain to the final assembling stage, this is why the different types of companies are not going to be explicitly analysed.

In general, all the collaborative platform applications have a good impact on the companies because they will improve the efficiency to manage documentation and save time looking for old documents trying to find the newest version of them, as well as by means of the use of tools allowing better communication in all aspects.

Most companies required a common data base where all the parties could be involved. This would ease the information sharing process and data transference. Besides, the whole workflow is positively affected by collaborative platforms, not only by the explicitly aforementioned technologies but also by the more abstract improved information flow, which directly reduces errors, delays and all sort of common problems due to the lack of communication.

4. Chapter 4: Augmented Reality

Augmented reality is the technology that expands our physical world, adding layers of digital information onto it. Unlike Virtual Reality (VR), AR does not create the whole artificial environments to replace real with a virtual one. AR appears in direct view of an existing environment and adds sounds, videos, and graphics to it.

AR categories

AR is classified into various categories. Each category is having a different use in the different case. The following are major 4 type of Augmented Reality:

- Marker-based AR
- Markerless AR
- Projection-based AR
- Superimposition Based Augmented Reality

Marker-based AR:

Also called Image Recognition or Recognition based AR. It requires a visual marker, such as QR/2D code and a camera to read it, to produce a result only when the marker is sensed by a reader.
In this technology, the position and orientation of the object are calculated first and later the gathered information is overlaid by the marker, on the object.

Marker-based AR:

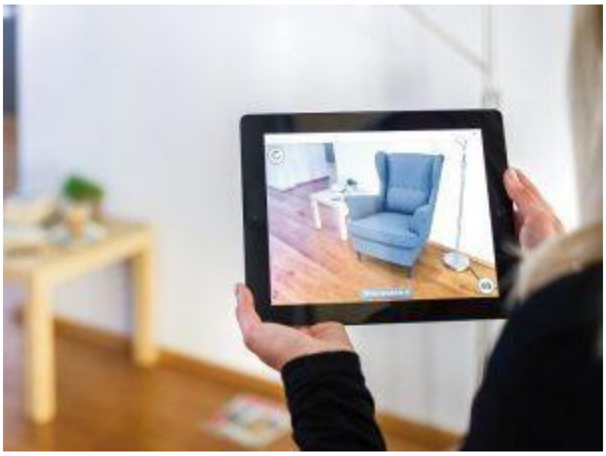
It is also called location-based or position-based augmented reality. It uses a GPS, digital compass, velocity meter, or accelerometer which is embedded in the device to provide data based on your location. With the availability of smartphones this type of AR typically produces maps and directions, nearby businesses info. Applications
include events and information, business ads pop-ups, navigation support.

Projection-based AR:

It works by projecting artificial light onto real world surfaces. Projection based augmented reality applications allow for human interaction by sending light onto a real world surface and then sensing the human interaction (i.e. touch) of that projected light. Detecting the user's interaction is done by differentiating between an expected (or known) projection and the altered projection (caused by the user's interaction). Another interesting application of projection based augmented reality utilizes laser plasma technology to project a hologram into mid-air.

Superimposition based AR:

Superimposition based augmented reality either partially or fully replaces the original view of an object with a newly augmented view of that same object. The object recognition plays a vital role because the application cannot replace the original view with an augmented one if it cannot determine what the object is.



AR devices

Many modern devices already support augmented reality. From smartphones and tablets to gadgets like Google Glass or handheld devices, and these technologies continue to evolve. Some of them are:

- Heads Up Displays (HUDs)
- Holographic displays
- Smart glasses
- Handheld/Smartphone based

Head-Up Displays (HUDs)

It is a digital transparent image that is projected into user's view.

Holographic displays

This type of displays use light diffraction to generate three dimensional forms of objects in real space.

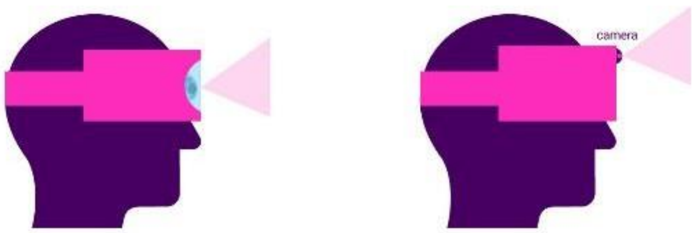
Smart glasses

Optical see through

In Optical see through glasses, the user views reality directly through optical elements such as holographic wave guides and other systems that enable graphical overlay on the real world. Microsoft's Hololens, Magic Leap One and the Google Glass are recent examples of optical see through smart glasses.

Video see through

With this type of smart glasses, the user views reality that is first captured by one or two cameras mounted on the display. These camera views are then combined with computer generated imagery for the user to see. The HTC Vive VR headset has an inbuilt camera which is often used for creating AR experiences on the device.



Optical see through displays   Video see through displays

Many modern devices already support augmented reality. From smartphones and tablets to gadgets like Google Glass or handheld devices, and these technologies continue to evolve. Some of them are:

Handheld/Smartphone based

Although handheld AR is a type of video see through, it deserves special mention. The rise of handheld AR is the tipping point for the technology being truly pervasive. Augmented reality libraries like ARKit, ARCore, MRKit, have enabled sophisticated computer vision algorithms to be available for anyone to use. In handheld or mobile AR, all you need is a smartphone to have access to a host of AR experiences.

4.1Use Cases

•**Ford Motor Company**: It is an American multinational automobile manufacturer.

Problem/Necessity: The company wanted to have a way to design more creative, improve decision making, collaborate better, as well as work quicker.

Solution: Ford's design teams can see potential designs of a car (or its part) overlayed over a physical prototype in real scale with Microsoft HoloLens AR headset.
The information that is crucial to car design comes from multiple sources in Ford, and augmented reality manufacturing has also made it easier for the company to manage it on the spot.
Concurrently, one of the features is the ability to leave comments in AR, so that other team members can access them. Taken that you can operate in AR remotely (this process is called teleoperation), the solution becomes a very powerful and proficient combination.

•**Boeing:** It is an American multinational company that designs, manufactures and sells aircraft, helicopters, missiles and satellites and provides technical service.

Problem/Necessity: Boeing's employees needed to continuously consult a laptop to ensure that numerous wires are correctly assembled. The process caused fatigue in employees and was time-consuming in general.

Solution: With AR headsets, the company's employees now have the same information right before their eyes, making Boeing's wire assembly process faster and more comfortable. They can also issue voice commands conveniently and ask a colleague to join the headset's video stream to assist with complex tasks.
As a result, augmented reality manufacturing reduced Boeing's wire assembly process time by 25 percent and lowered errors to nearly zero percent. More so, the solution significantly improved employee satisfaction and, consequently, employee retention.

•**Lockheed Martin**: It is a global security and aerospace company and is principally engaged in the research, design, development, manufacture, integration and sustainment of advanced technology systems, products and services.

Problem/Necessity: The company wanted to improve the way to teach their workers about manufacturing processes, making it easier and accessible for everyone.

Solution: From engine parts to cables and bolts, the company's engineers use Microsoft HoloLens headsets to view the holographic renderings of an aircraft's parts, as well as the instructions on how to assemble them — right before their eyes. Digitalising the workflow with augmented reality in manufacturing has helped Lockheed Martin increase engineering efficiency to astounding 96 percent, a crucial number for such a demanding industry.

•**Magna:** It is one of the well-known global Automotive supplier

Problem/Necessity: A quality inspection process ensures that a supplied product to a customer meets all required specifications. Traditionally, this is done with the help of a checklist set of a large number of checkpoints. So, a quality inspector needs to fill out this checklist before allowing (or, rejecting) the product for final delivery. Thus, the final product quality, that the customer receives, depends not only on the quality of product manufacturing but also on the accuracy of the inspection process.

Solution: Magna using the AR headset, like Microsoft HoloLens allows them to have an interactive platform to perform the complex task easily and in a more efficient way. Magna with the help of the Holo-Light has developed a software solution for the quality control process. The program is useful for inspecting a car for potential defects with the help of Microsoft HoloLens. Whenever, a quality inspector wearing his HoloLens looks toward the car, the software highlights only the parts to be inspected. Additionally, the inspector is also guided through a step-by-step procedure for inspection. The below YouTube video demonstrates the Augmented reality assisted quality control at Magna

•**Caterpillar**: One of the world's famous heavy equipment manufacturers

Problem/Necessity: The maintenance of equipment related to the manufacturing industry is more complex than your household goods.
And, it requires a thorough knowledge of each and every corner of the equipment in terms of construction and function both. Additionally, the technician must refer a service manual with several hundreds of pages consisting technical diagrams and relevant information.

Solution: Caterpillar is effectively utilizing augmented reality for the maintenance and repair work. They have developed their own service AR App.
This application can be run on a smartphone, tablet or even on an AR headset. Whenever, the user points its device towards specific equipment, the application guides the user through the interactive visual step-by-step procedure to perform the maintenance or repair work. Additionally, the user can also snap step wise pictures of the whole process. Nevertheless, voice-controlled futuristic AR glasses allow hands to be free while performing the task.

Other possible applications:

•**Collaborative tasks**: AR systems can be used to create unique collaborative experiences because this technology allows users to view and interact in real time with virtual images seamlessly superimposed over the real world. For example, co-located users can see shared 3D virtual objects that they interact with, or a user can annotate the live video view of a remote worker, enabling them to collaborate at a distance. The overall goal is to augment the face-to-face collaborative experience, or to enable remote people to feel that they are virtually co- located.

•**Geo-referenced notes around the factory**: Virtual sticky notes which can be used for information exchange within an augmented reality environment. These virtual sticky notes represent static maintenance information, dynamic maintenance information and recurring maintenance tasks. As a user interface, mobile devices such as tablet PCs or smart phones are used. These are integrated into a platform for a context sensitive services, which support access to real-time production data and indoor location.

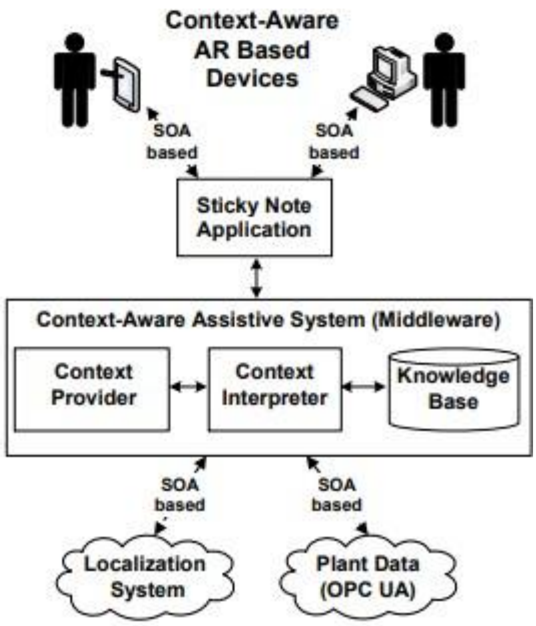


Fig. 1. System Architecture of Context-Aware System

•**Remote assistance for welding processes:** The welders working conditions are improved by augmenting the visual information before and during welding. An online quality assistant is available during welding, suggesting the correction of the gun position or pointing out welding errors, by analyzing the electrical welding parameters. An assembly advisor will suggest the assembly sequence, by displaying the type and the position of the following piece into the actual ensemble. In addition, an available online documentation of the welding process gives an opportunity to reduce the effort of post process quality assurance which often uses expensive x-ray investigations.

•**Marketing and sales**: AR demos are usually really attractive when showing other people, a certain scenario or the capabilities of a product. Therefore, AR has the ability to transform the customer experience, enabling the inclusion of different parameters, options, setting or configurations. Moreover, an improved customer experience is able to reduce the levels of uncertainty about their choices shortening the sales cycle. Furthermore, it can also be used to collect data about product preferences. A good marketing and sales example was created by BMW for a campaign for selling its latest electric vehicles.

•**Wharehouse tasks**: AR can enhance the efficiency of the picking process in warehouse by providing an indoor guidance system. That picking items represents from 55-65 % of the total cost of warehousing operations, which are still mostly carried out through a pick-by-paper approach. Thus, AR can give instructions to the workers and guide them using the best route.

•**Quick access to information systems such as ERP or PLM,** as well as presentation of information on the spot and on site. ERP systems are one of the cornerstones of the current entrepreneurial architecture. However, these systems usually tend to be cryptic and cumbersome, which implies difficulties of different nature when the time comes for the operator to use it. In the context of 4.0 industry, new technologies are pointing out the path to be followed in order to revamp the global industry and, in particular, information systems. Information systems involve several difficulties such as data volume and velocity or the demand for accurate up-to-date information. In this context, Microsoft arises as an example of ERP and AR integrator. With Microsoft's HoloLens ERP app, an operator could receive details of different orders coming from the ERP system right in their field of view (keeping their hands free) meanwhile this same operator keeps on paying attention to his/her current task. Moreover, HoloLens can give him directions of interest (inventory, warehouse) and allow him or her to relay information to the ERP system with a simple flick of their finger. This implies the avoiding of cumbersome scanners and all sort of instruments.

4.2 Analyzing Charts

The Chart 8 shows the maturity of the technologies considered within this chapter and a comparison between the adoption rate in the shipbuilding industry and some other relevant industries such as aerospace and defence, energy, automotive or pharmaceutical, among others.

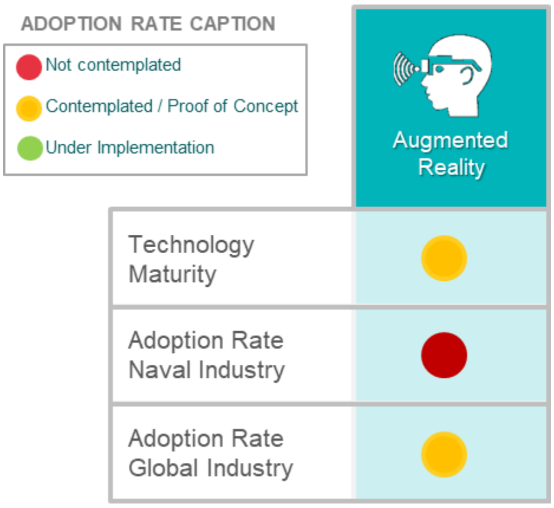


Chart 8. Maturity and adoption rate of the technologies.

Chart 9 stands for the technology application impact and how the companies can face those challenges. With colour code the impact of these applications.

- Transparent: Transparent circles stands for those technologies that do not apply in a concrete company. Those type or group of companies which do not have that application or process.
- Orange: Orange circles are used when the application impact in their company is positive but the priority implementation is low since they are interested in improving other parts of the process.
- Green: The application impact in their company is positive and moreover, the implementation priority is high due to the high interest of the company in the benefits that can be yield by this kind of technology.

And a circle fill code represents how ready or technological mature are the companies to face those challenges.

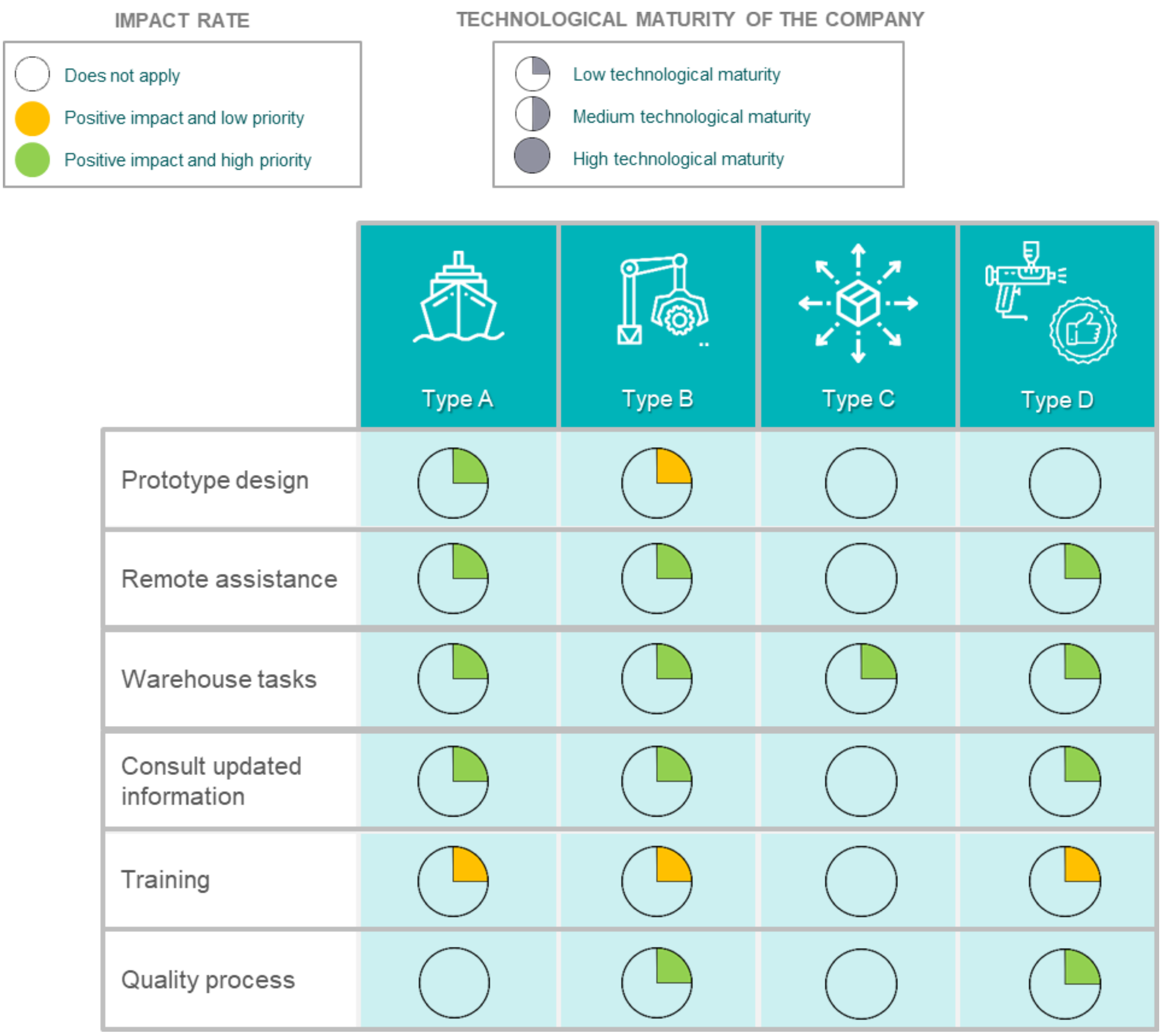


Chart 9. Augmented Reality application impact and technological maturity of the companies.

In general, the technological mature of the companies is very low because Augmented Reality is a new technology that is still with improving their devices or applications.

Type A

Shipbuildngs find interesting some augmented reality applications such as showing a virtual prototype of the final product to the customers or a virtual mokup to make some design changes easily (prototype design), control inventories (warehouse tasks), the necessity of locating tools in the shopfloor, interactive ship drawings, normatives...(AR device to consult updated information) and remote assistance for workers who can be guided through a step-by-step procedure.

Training is not one of their priorities because they do not have constant staff turnover.

Type B

On the one hand, the activities identified with positive impact and high priority can solve current problems like remote reparations, access to piece drawings or another updated information in any part of the factory, workers guided step- by-step, stock management (controlling the existence of necessary tools for the process), verifying some processing (weldding) and tasks planification.

On the other hand, the applications identified with low priority are the training debido a que buscan empleados con gran especialización en las tareas lo cual conlleva muchos años de aprendizaje.

Type C

Logistic companies are focused on how they can manage better and easily the warehouse, helping their workers to perform tasks faster and decreasing mistakes.

Type D

Highligthing the remote assistance, for example in quality verifyications when the worker has some quiestions can be guided by an expert, warehouse tasks like inventory control, bring the opportunity to workers to have the flexibnility to consult documentation whenever they need it in the shopfloor and quality verification or assembly processes.

In that case, training is also low due to the neccessity of very high qualificated workers for that job.

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