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Warehouse Management Software Implementation in Osimo's Finished Products Warehouse in Ariston Thermo Group.

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Abstract

The dissertation regards the study of the implementation of a Warehouse Management System (WMS) software and methodologies for finished and semi-finished goods in the Osimo production plant's warehouse of Ariston Thermo Group (ATG), aiming for the improvement of the processes' efficiency in order to reduce stocking, handling and delivery times of the merchandise.

Along the thesis, it is described the working environment in which the speaker is immersed and the general processes and concepts concerning warehousing activities performed in a plant. Some of these, are the main indicators used to measure the efficiency of processes, philosophies and methodologies of work and the concepts behind a WMS software and its main functionalities.

The final analysis as the main core of this work, focuses in the set-up of the SAP WMS software implementation, which includes the remodeling of the warehouse facilities, the process flow of the merchandise and solutions proposed by the speaker to problems that arose during the implementation. It is also analyzed by the speaker the possibility of implementing inside the warehouse, the RFID label tags for the outbound stage of the merchandise as a pilot stage for a future development that has, as a long term objective, its implementation in all the warehouses of the group.

The positive results that are obtained after the WMS implementation, the introduction of new KPIs and the proposed RFID solution is furtherly developed. Future recommendations to continue improving the working site with the objective of motivating future speakers are also introduced.

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Acronyms

1. ATG = Ariston Thermo Group.
2. WCM = World Class Manufacturing.
3. WM = Warehouse Management.
4. WMS = Warehouse Management Software.
5. WH = Warehouse.
6. WCL = World Class Logistics.
7. MES = Manufacturing Execution Systems.
8. MM = Material Management.
9. MRP = Material Resource Planning.
10. HF = High Frequency.
11. UHF = Ultra High Frequency.
12. IM = Inventory Management.
13. 3PL = Third Party Logistics.
14. MMD = Material Master Data.
15. ERP = Enterprise Resource Planning.
16. IRA = Inventory Record Accuracy.
17. KPI = Key Performance Indicator.
18. SqM. = Square meters.
19. AGV = Automatic Guided Vehicle.
20. OFP = Osimo Finished Products Warehouse.
21. RFID = Radio Frequency Identification.
22. REFIX = Replenishment Efficiency.
23. SM = Space Management.
24. PP = Put away Productivity.
25. SC = Scanning Coverage.
26. HD = Handling Damages.
27. TA = Transportation Accuracy
28. PA = Picking Accuracy.
29. OTD = On Time Delivery.

30. RP = Receiving Productivity.
31. REFIX = Replenishment Efficiency.
32. ROF = Rate of Return.
33. PiP= Picking Productivity.
34. OTP = On Time Picking.
35. DTS = Dock to Stock.
36. DC = Distribution Center.
37. DIY = Do it Yourself.
38. OPEX = Operative Expenses.
39. CAPEX = Capital Expenditures.
40. TO = Transfer Order.
41. SN = Serial Number.
42. PBP = Payback Period.
43. PAA = Put Away Accuracy.

Introduction

In this section, it is explained the topic to be boarded. It is presented an overview regarding the specific place and context where the thesis is developed, its object, the main methodologies to be taken into consideration and the theoretical frame.

Purpose of the dissertation

This study regards the implementation of a WMS software module, the possible implementation of Radiofrequency Identification (RFID) label tags and Key Performance Indicators (KPIs), with the objective of raising the efficiency of the different activities performed in the warehouse and their monitoring. These activities are picking, handling, put away, merchandise reception and shipping. The project takes place in the finished products warehouse of Osimo's production Plant from ATG. The scope regards only the internal activities performed in the plant.

Limitations

Solving any kind of problematics from the supply chain management outside the warehouse and distribution Logistics is out of scope. Even more, the distribution processes of the company that are not absolutely inherent to the internal warehousing activities are not to be affected, but given for granted as a basis for the new implementations. Nonetheless, nowadays the areas of the supply chain are very interconnected, so a clear division between them is complex to achieve. This is why in the pages to come, some of these external activities are referenced, but only as a consequence of this tight relationship.

Work structure

Through this paper, the context in which the dissertation takes place is introduced, with a company's and its facilities' description.

Then, the theoretical framework is presented, including relevant definitions regarding Warehousing, Warehouse Management and the most important key performance indicators that are usually used to measure the activities' efficiency. Finally, the different methodologies that are currently employed by the company for constant improvements are introduced.

After this, the Warehousing activities within the plant are explained in order to understand how they are performed today and with the aid of which tools. Then, some different case studies are inserted that state the improvements obtained with the application of WMS within their facilities, along with other technologies.

Furthermore, the problematics motivating this implementation are highlighted and developed, along with the objectives to be achieved.

The previous section is followed by a Benchmarking of the possible solutions that can be applied, where they are analyzed and the best one, is chosen and explained in detail in the next section.

Finally, the outcomes after the Go Live of the project are presented and compared with the initial objectives. This is followed by a results discussion and conclusion, where the speaker shows the benefits that have been obtained and remarks future prospects regarding further improvements that can be boarded in future theses.

Context of the study's object

This work focuses on the Finished Products Warehouse (OFP) of the ATG plant in Osimo. As stated before, the project regards the implementation of a WMS. The company's history, the plant, along with some relevant characteristics and other information within the frame of this development are presented in this section.

Ariston Thermo Group history

The group is initially called Industrie Merloni, founded by Mr. Aristide Merloni (Fig 1) in the year 1930 in Albacine, located in the Marche region of Italy. At the beginning, their business model is focused in the weight scales sales, far away from the idea of thermic comfort. Success comes very fast for the company and it remains for a period of over 20 years, with the consequent result of having more than one third of the market share in the country.

Thirty years later (1960s), the group has grown up to six hundred employees and five production sites. In this moment, the company decides to start diversifying its production and enters in the electric water heaters market, producing as well gas cylinders which are the main component for boilers. It is then when the Ariston brand is born within Industrie Merloni not only with the aim of creating an identity for these new products, but also to position them in the market as a top quality brand in the eyes of the customers. What is more, the company is now producing and selling for third parties, so it is intended that the Ariston brand helps to differentiate products of their own from the rest. The name comes up from the union of the founder's name (Aris) and the Greek word (Ton), which stands for "the best".

Figure 1 Ariston Brand logo (left) and Mr. Aristide Merloni (right). (Source aristonthermo.com).

During the 1970s, the company becomes the absolute leader in Italy regarding water heaters and starts to penetrate in the main markets of Western Europe. At this point, the goal for the years to come is the consolidation in the market at a continental level and to complete its

incursion in the thermic comfort market with a wider variety of products. To achieve this, the production of boilers begins. Also, the weight scales production starts to be left aside, until it eventually disappears.

With the end of the communism in the 1990s decade, a lot of new markets with small or no competitors at all are opened for the Western Europe companies. This gives place to a race among them to enter these markets as fast as possible. ATG starts its expansion not only in Eastern Europe but also in Asia. In this last one, a very important acquisition is done: The Racold group from India, which until the moment, is the biggest enterprise in the water heaters market of this country. Furthermore, the first establishment in China is opened. Like this, the Ariston brand starts achieving a global extension.

The company continues its booming attitude in the 2000s. This is evident as the group starts a very aggressive strategy by acquiring very well-known brands from the heating and burners market such as Chaffoteaux (France), Elco (Switzerland), Cuenod, Rendamax (Fig 2) and Ecoflam (Italy). All of them very important to consolidate the presence in each of their original countries, especially France which today is among the most important markets of the company. Later, in the 2005, a new establishment is opened in Saint Petersburg (Russia).

Figure 2 elco, Chaffoteux, Cuenod, Rendamax. (Source aristonthermo.com).

In the year 2008, Termogamma SA is acquired. Its main products are the heating pumps, which the group isn't consolidated in the market until the moment. The following year, the company name is changed to Ariston Thermo Group. From this year onwards, ATG is among the world leaders in the water and environment heating markets with perhaps the most complete offer in thermal comfort regarding not only products but also services.

In the year 2011, the group acquires Cipag SA and Domotec. Both Swiss companies that help reinforcing the presence to become complete leaders in the water heating market of the country regarding production, distribution and maintenance of the systems.

In the year 2013, ATG acquires DhE (Italian). This company is an electric resistance's producer for commercial and industrial use. It constitutes a joint venture for the production and commercialization in Uzbekistan for domestic heating systems with a very high electrical efficiency. This strategic acquisition internalizes the production of one of the main components for ATG, bringing a huge competitive advantages for the firm.

To have a visible presence in Netherlands, the group acquires ATAG Heating group, which is a high quality brand in the heating sector. This is not the only big move performed by the ATG in this period. A new plant is also inaugurated in Vietnam with the aim of producing the latest technology in electrical water heaters. Plus, the Heat TechGeysers (South Africa) firm, second greatest player of the country in the water heaters market is bought.

Furthermore, in 2015 the new subsidiary Ariston Thermo Indonesia is opened. Operations also start in the Danish market with the acquisition of Gastech-Energy A/S (Denmark). During the same time period, SPM (France), a company specialized in burners and components related to this product is acquired. To finish an outstanding performance during this year, due to the tenth year of presence in Russia, the group opens a new logistics center in Saint Petersburg.

In 2016, ATG decides to expand to a new market to begin their activities in America. So, NTI (Canada) is bought. This one is a leader in Canada and it is among the top brands in the USA in the condensing heaters market. Some huge advances are also taking place in Italy this year: Osimo and Arcevia production plants are awarded the bronze medals of the World Class Manufacturing (WCM).

During the last year (2017), Ariston Thermo Innovative Technologies investigation center is opened in Agrate (Italy), with the objective of developing the latest technologies for the global thermic comfort market. To continue the expansion in America and to reinforce high efficiency heating solutions, HTP (USA) is acquired.

With this brief description of the company's trajectory along the years, it is noticed that it is a firm completely committed to be the best option in the market regarding the high quality

of its products and to remain as the market leader in the countries where it is already established, while also becoming the one in those that it is starting its incursion. Eighty-five years of continuous commitment in being the best as possible in every way have made ATG become a world reference in the thermic comfort market. Today, ATG (Fig 3) has a total revenue above one and a half billion euros with more than seven million products sold every year, seven thousand employees and a presence in more than one hundred and sixty countries (Ariston Thermo Group, n.d.).

Figure 3 Ariston Thermo current logo. (Source aristonthermo.com).

The Osimo Plant

History and location

The Osimo production plant (Fig. 4) is the most advanced plant of ATG in terms of production levels and one of the top regarding the introduction of technology within its processes.

The total surface of the plant is around 50000 SqM. Which are divided in office rooms, production and warehousing. Today, there are more than three hundred workers in the plant among operators, managers and directors.

Figure 4. Google Maps satellite view Osimo plant (left), front view (right). (Source: Google maps).

The products

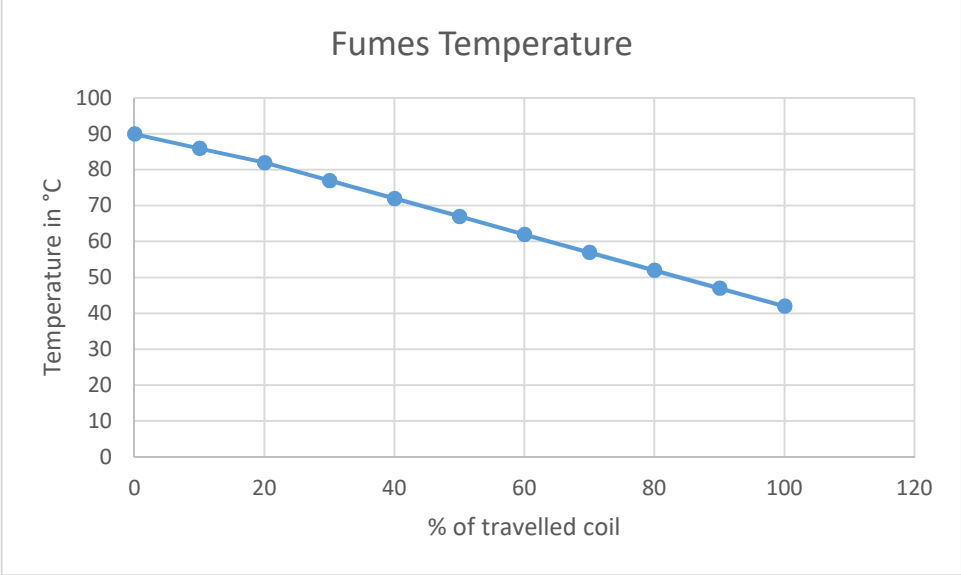
In Osimo plant, wall boilers are produced. These are one of the most important products for the company and are top of the market regarding quality and efficiency. A boiler (Fig 5), such as the ones produced in Osimo's plant, can be found in the market under the following categories: conventional or by condensation.

Figure 5 Boiler. (Source : climando.it)

The difference between them, is the efficiency of the heating process, which is higher for those of condensation. On the other hand, so is the price. The reason is not because the client is getting a higher quality product, but because it is necessary a much bigger coil for the condensation boiler than for the traditional one, which is one of the most expensive accessories.

A boiler of the previous kinds consists in the heating of water through a gas flame. If the water is required for house heating, it might reach up to 80°C. In order to achieve this temperature, the process is as follows:

First, cold water enters through Inlet Port E (Fig 6 and 7). The diverter valve (15) allows the passage of water through the pump (18) where it arrives to a coil that is being heated by convection with the hot air (due to the gas flame fumes). If the boiler is a traditional one, the hot air exits the boiler with high temperature and usable energy within it that is wasted in the process. On the other hand, condensation boilers are designed in such a way that the gases are guided through a chamber in constant heat exchange with the coil transmitting first the heat to the water that is finishing the journey and then to the end of the coil in which cold water is travelling. All along its journey, the gas fumes have been transmitting their energy to the coil (Fig 6) until it arrives to the last portion of it. At this point, fumes condensate with the adequate pressure and temperature conditions and become liquid. During this process, a very important energy exchange has been performed from the condensing gases to the coil. Below, two graphs representing the temperature of the fluids for the condensing boilers case (Fig 6). It is remarked that when the gas is starting to travel along the chamber, it is doing it in the opposite way than the water. So the end of the coil for the water is the beginning for the fumes.



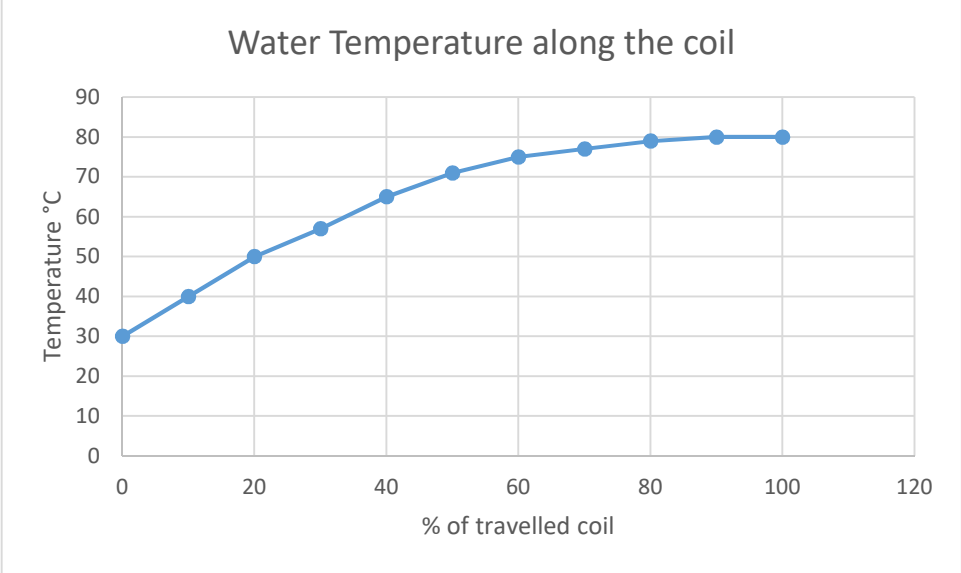


Figure 6. Above, coil temperature, below, the water's

After it passed through all the coil, the water exits through outlet port A and goes to the heaters.

If water for the sanitary is required, the water passage in outlet port A is blocked by the by pass (9) and goes instead to the sanitary water chamber (7), heating the water entering through inlet port D and exiting through port C.

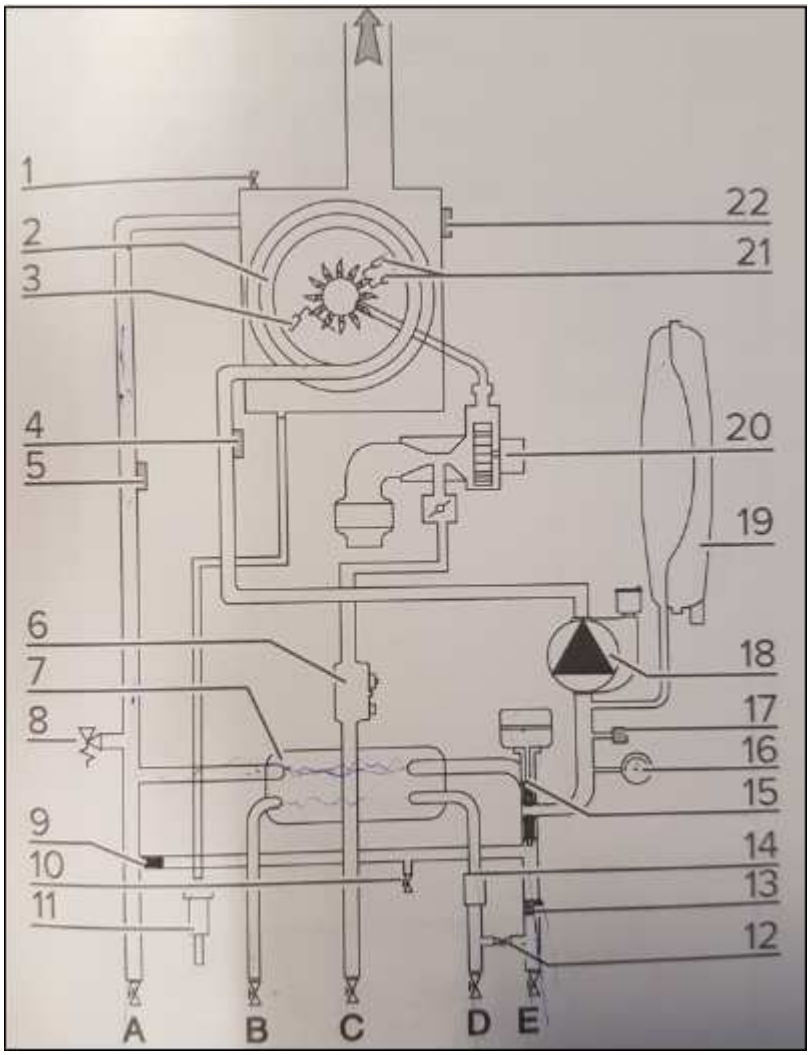


Figure 7 Internal Diagram of a Boiler

1	Air ventilation valve	10	Emptying Faucet	19	Expansion Vessel
2	Primary Exchange	11	Siphon	20	Ventilator
3	Detection Electrode	12	Filling Faucet	21	Ignition Electrodes
4	Ingoing Heating Sensor	13	Heating Circuit Filter	22	Thermal Fuse
5	Delivery Heating Prove	14	Sanitary Flowmeter	A	Plant Delivery
6	Gas Valve	15	Motorized Diverter Valve	B	Hot Sanitary water Outlet
7	Sanitary Water Use Chamber	16	Manometer	C	Gas Inlet
8	3 Bar Security Valve	17	Minimum Pressure Switch	D	Cold water Inlet
9	Automatic by pass	18	Modulating Circulator with Deareator	E	Plant Return

Figure 8 Boiler Internal Diagram References

The function of the ventilator (20) is to provide the combustion chamber with fresh, rich in oxygen air. The detection electrode (3) controls the temperature in the end of the coil in order to control the gas flame. The expansion vessel (19) works as a hydraulic capacitor that reacts

with the pressure changes inside the boiler in order to maintain the pressure. As a safety measure, the boiler also contains a sensor that ensures that gas is consumed only if the flame is present, in order to avoid an explosion.

Warehouse Infrastructure

The total warehouse is composed by an internal building (whose area is divided as shown in fig 9) and two external tendons. The first one is located very close to the production site and has a total surface of around five thousand SqM. The remaining ones (fig 9 right) are around one thousand SqM. each, where one of them is divided in a rack storage area and the other one in ground storage. These tendons have been added in order to expand the total storage area, as the demand grew along time.

In the internal warehouse, accessories and finished products (Osimo's and external production) are stored. While in both external ones, some products from external production and accessories.

Figure 9 Internal Warehouse (left) and one of the external tendons (right)

Theoretical Frame

In this section, main concepts are defined regarding Warehouse Management (WM) and working methodologies within the company's warehouse.

Standard Warehousing Processes

In this section, a short review of the general warehousing activities performed by a company is briefly introduced. In the next ones, these processes are developed in a more detailed way, oriented to Osimo's warehouse.

Generally speaking, warehousing consists in three main processes which are inbound, internal movements and outbound. The first one takes place when a supplier arrives to the warehouse in order to leave its merchandise or either when a production batch is ready for stocking. The second one, only consists in the movement of the merchandise from one storage type to another one within the same warehouse structure, while the third of them, consists in the company being the one who has to hand out the products to the shipping company.

Inbound:

I. Trucks from suppliers reach the warehouse and are parked in the corresponding dock area.
II. An operator downloads the goods from the trucks and leaves them in the staging area.
III. Quality control is performed in order to ensure that the received goods are the correct ones and in the proper conditions. This is very important because after this point, any damage found in the merchandise is exclusively a responsibility of the receiving company and no compensation can then be claimed.
IV. Finally, the products are organized into pallets so as to be carried by the forklift or the operator to their corresponding racks or storage bins.

Outbound:

I. The operators go to the particular racks and pick the items indicated in their picking list and leave them in the packaging area.
II. The goods are packed and organized according to the different orders that are to be shipped in specific trucks.
III. A loader picks the orders and leaves them available in the outbound area, where a quality check is performed in order to confirm that all the products are handed in the proper conditions. This is because, like before, any damaged product up to this stage is warehouse responsibility.
IV. Products are finally loaded in their respective trucks and sent to the final customers.

According to its different technologies and procedures, each warehouse may have more or different steps than the previously listed.

What is Warehouse Management?

WM implies the optimization and control of distribution and warehouse processes (Ten Hompel, 2006). Nowadays, it is a difficult challenge for companies to manage all of their warehouse activities in an efficient way. This is why a deep analysis regarding the current situation and processes needs to be performed in order to produce a satisfactory WM structure (Faber N., 2013).

Warehouse Management Evolution

It is interesting to make a brief recap of the evolution of warehousing processes until today's latest advances.

The first case in history that deals with stocking goods is related to the Egyptian civilization, where crops were stored and rations of it were arranged for its consumption, in order to be prepared in case of famine or whatever natural disaster could arrive. Of course, only papyri and writing could be used to control this "stock". It is interesting to notice that this practice remained practically untouched for thousands of years. It is only in the last century that companies started to pay real attention to warehousing as an opportunity to take a cost advantage with respect to their competitors or even to consider it a client satisfaction factor and so, start investing to improve it.

As every revolution, there is a first technological event or discovery that triggers the events to come. It is during the First World War when hand trucks (Fig 10) are introduced to the warehouse in order to manage larger and heavier quantities of merchandise that are impossible to deal with for humans with bare hands. This increases the performance of employees given that the time implemented in tasks is highly reduced as a consequence of the decrease of total trips required to store the same amount of merchandise as before. At the same time, the amount of goods that are managed in a determined unit of time is much higher. Still, there is too much ground for improvements as the operator's physical strength is required both for picking and put away the goods.

With the arrival of forklifts (Fig 10), a great impact takes place. Now, pallet[1] of products are able to be stored not only at ground level and some low level shelves, but also in very high racks. This allows the companies to exploit warehouses in height as now heavy elements can be deposited and removed in higher locations in a safer way than before without the use of ladders. This does not only reduce even more the amount of trips to be done by the operators during handling activities but also provides the warehouse with a huge amount of new storage volume that until the moment could not be exploited due to security reasons and physical impossibility for a human operator.

On the other hand, the stock control strategies still remain unchanged. Books and notes are the only way to keep track of goods locations and quantities. This does not prove to be a limitation for small warehouses, but it is for those companies who start experimenting an exponential growth. As a consequence, the amount of lost, broken and misplaced products

[1] Organizational stock unit consisting of a group of products

increases significantly. This is why the new complications, that were not such previously, demand new solutions. Anyway, the balance between investment and the Return on investment for the firms is sufficiently high.

When the computer's revolution arrives, a place is found for them in every industry that we could think of. Warehouses are not the exception, so software developers start to generate automated programs in order to track the stock availability, inventory, etc. The intention to perfect and improve the functionalities provided by these algorithms and the organization of the warehouse along time gives birth to WMS, which is explained in detail in the sections to come.

Figure 10 Antique hand trucks (up) and forklifts (down).(Sources: hsaforklifts.com.au, powerpalletinc.com, imagenesmy.com, cjvintage.blogspot.com)

Warehouse Management System Software

As a consequence of WMS evolution, different companies have developed this one inside their Enterprise Resource Planning (ERP) software to make its application easier to link with other areas of the supply chain.

Useful concepts

Before getting more into detail, some useful concepts regarding WMS are introduced below:

- Material: A material is every product that a company manages, from raw material until finished goods. It is uniquely identified by a seven-digit code that allows its unique identification in a warehouse.
- Transaction: It is a customized or predefined set of activities performed in the software that allow to interact with the system, handle materials, buy them, etc.
- Warehouse Number: It represents entire or partially the physical plant's warehouse (WH) at a software level. All WMS transactions require a WH number in which the operations are being performed.
- Storage Type: Inside the WH number, its area is divided in these storage types. This division is customizable regarding the user's needs and usually depends in the different products and handling activities required to stock the materials. They are defined with a three-digit code. A storage type can also be divided in storage areas.
- Storage Area: It is an organizational unit within a storage type that is formed by a group of locations (unit cells) that share common characteristics and are used for picking and put away the merchandise. These characteristics are: height, volume capacity and distance to the docking areas.
- Location: It is the smallest volume unit of a warehouse. For each location, it is possible to define a Warehouse Area, Picking Area, Storage Type, Maximum Weight and establish its blocking status to forbid put away or picking of the materials.
- Transfer Order (TO): All material movements from one storage type or location to another one are done through TOs. They are manually done by operators or automatically (if customized) generated by the system when a specific transaction takes place
- Purchase Order: They are created by the system when a purchase is manually done to a client or an internal company of the group. It contains the expected delivery time, quantities, packaging, among others.

- Picking Area: Specifies the areas in which the required products in an TO are to be picked.
- Stock Placement Code: It is used for indicating an operator the storage type in which a material has to be put away into.
- Special Movement Code: Allows the system to address a material to the correct staging area as a first step to start its way to the correct final location. It is only used during inbound and internal handling activities.
- Storage Bin: They divide the area of storage types into smaller spaces with specific characteristics such as bulk storage, high rack, low rack, and dimensions. They can also be called unit cells.
- Mixed Storage: A storage bin is called mixed if it contains more than one material type of quant.
- Quant: A portion of stock that has homogeneous characteristics (same material, plant, storage location) that the software uses as unit of stock.
- Handling Unit: It is constituted by one or more quants[2]. They are uniquely identified in the system by a unique handling unit number made by the system. If it is constituted by different quants, it is a mixed handling unit. Otherwise, it is homogeneous. The advantage of managing a warehouse with these ones is that it is possible to know all the different materials inside it with just the identification of its unique handling unit number. Otherwise, it is necessary to track each material inside the handling unit in a single way, which consumes a lot more time
- Dynamic Storage Locations: These are storage locations generated by the system in order to specify the virtual location of a product that is being received. The name of the location is the number of the goods receipt order, so that it is easy to associate where the material is coming from. As soon as the receipt transaction is verified as completed by the system, the dynamic storage location is destroyed.
- Pallet Data: If a material is palletized in a certain way from production or vendors, the system can be customized so as to receive these values in advance and automatically divide the total receipt order in handling units (or pallets) of the specified quantity.

[2] In the case of this dissertations, handling unit are homogeneous and contain one quant.

For example, if 20 pieces of a material that has a pallet number data of 5, the system automatically knows that four pallets of five units are being received.

- Stock Removal Code: It is used to indicate the WH operators in the TO, in which storage type it is required to pick up the product.
- Put away Strategies: Customized indications for the software to perform an automatic research in order to find the most appropriate location for a material inside a storage type.
- Picking Strategies: Customized indications for the software to perform an automatic research in order to find the most appropriate locations to pick up the required materials to satisfy an order.
- Capacity control code: It is used to allow the system to know that a maximum amount of units can be stored inside a certain location.

WMS software is a set of tools that is complemented and customized with techniques that come in a software application with the objective of assisting a business in the management of their raw materials, semi-finished and finished goods. Depending on the software supplier, its characteristics may be wider, but all the functionalities are quiet the same, allowing to establish automated picking, stocking and handling strategies which help improve the efficiency in the processes by reducing operation times. It also offers the possibility of expanding its functionalities to the transportation management system of the firm, becoming the master of the supply chain. Along the years, WMS has become more and more robust in order to cope with the most complex warehouse structures. Moreover, it has been able to incorporate many technological improvements, such as RFID and Automated Guided Vehicles (AGVs), in order to increase its functionalities. According to their area of interest, some of the main benefits are listed below:

- Production Organization: A higher efficiency regarding raw material's supply is obtained given that when the total amount of daily production is established, the Master Resource Planning[3] (MRP) verifies the stock availability and generates a transfer order in the system. This one contains the list of materials that need to be

[3] A module of the WMS

picked up from the warehouse with its specific origin and destination locations, to be picked/stored in the most efficient order.

If the amount of needed raw materials is higher than the one available in the warehouse, the system advices the user and either re-schedules the job, or accepts it but only for the total goods that can be produced. It also calculates the difference of the required raw materials to satisfy the first production request and makes aware the competent logistics manager of the situation. This is a huge advantage as it avoids the stoppage of the production line for such reason, which is the worst situation that can take place.

Also, when a product exits the line, it is organized in pallets that are then registered in the system thanks to the data read by a program that works through the Manufacturing Execution System (MES) that is called Order Management. This one provides the information to the WMS in order to produce a transfer order indicating how many, where and how to stock these finished goods in the warehouse. The completion of this processes usually requires a confirmation that can be done manually with a computer, or more usual, by radiofrequency transaction by the WH operator. The confirmation is fundamental to certify that the proper action is performed and by whom[4].

- Deliveries and receipts in the docks: Reception and shipping of the merchandise are also in the scope of WMS with the objective of minimizing their duration and managing in advance operator's tasks and required resources. The general cases presented in a warehouse are listed below:
    - Arrival of the merchandise to the warehouse: The software usually allows suppliers to reserve a timing schedule indicating the quantity and type of products that are arriving. It specifies the docks in which the trucks must arrive to the warehouse and discharge its materials. The corresponding storage space for the merchandise to come can be previously checked (usually done) by the system. Then, the software indicates the operators how to store the merchandise according to preset strategies that depend on the product,

[4] Every operator has a personal user with which it performs the transactions.

supplier or any other relevant characteristic desired by the user. After the confirmation of the transaction, the software automatically updates the quantities of materials.

- Shipping from the warehouse: The order is performed by a client and it is processed by the system, which checks the availability of the resources not only in real time (currently present in the warehouse) but also taking into consideration blocked stock to be used for future orders in the short term. If all the requirements are met and the order is accepted by the competent authority, a picking list is produced, following a specific order for picking the materials with their specified locations. Once the transaction is completed by the operator, the software automatically updates the quantities of stock.
- Handling of materials inside the warehouse: The system processes the TO and checks the availability of the materials to be removed from the corresponding warehouse type and checks that the destination one is able to stock this product and quantity. It is indicated to the operator the most efficient order to remove the stock and how to order it in the final destination. When the transaction is completed, the system updates the stock values in both warehousing types.
- Sales department: It is linked to the system, that allows them to have a real time control on the sales and stock acquisitions that are taking place in the daily activities of the production plant. It can also be customized to produce the invoices to be sent straight away to the clients. For them, WMS offers a key functionality allowing to check the available stock and the current and future purchase orders. In case the quantities of the purchase orders exceed the actual values of stock, they are responsible of guaranteeing that the most critical ones are satisfied. The software also supports in this task as all the information regarding a client is available here.

RFID Technology

RFID is born as an alternative for barcoding identification. The main advantage of RFID against this technology, is the fact that it is not required a direct vision between the emitter and the receiver.

The architecture of an RFID system, consists in the (Yan Bo, 2008):

- Front end System:
    - Tags: They contain internal circuitry that is excited by an electromagnetic field produced by the reader or transceiver. These are to be applied for pallet identification, warehouse position of merchandise, among others.

      There are many different criteria for their classification and all of them must be taken into account when doing the selection. One of them comes up taking into consideration their power source, which can be passive or active. The first one, uses the energy provided by the reader in order to emit or allow data reception and writing. The active one, contains an internal source, which allows communication without the energy of the reader as it is usually necessary that this tag needs to communicate independently and far away from this one. Also, its range of communication is larger than the passive one (Turck Inc., 2015).

      They can also be classified as Reading only[5], Reading and Write once-Read many, depending on the memory modifications that can be performed inside them.

      According to their working frequency, the most popular ones are low frequency[6], high frequency[7] (HF) or ultra-high frequency[8] (UHF). The working principle of HF consists in an inductive coupling that creates a homogeneous and well defined magnetic field that is quiet immune to interferences. The strength of its signal depends on the distance with the antenna, making them very limited for long distance communications, with a maximum of no more than 70 cm.

[5] The tag is only used for reading its unique internal ID code written during its manufacturing process.
[6] Usual working frequency of 135 KHz
[7] Usual working frequency of 13.56 MHz
[8] Usual working frequency of 860-960 MHz

For UHF, a near and a far field are used. The first one, works with the same principle as the HF one, but with a narrower field of view than the HF antenna's field. Its long range field is accommodated according to its electric field features, making it able to communicate in larger distances, but at the same time much more susceptible to the interferences in the environment and to other close tags due to the fact that its field is not homogeneous. So, it can produce blind gaps or very high power in some areas, exciting other close tags and misreading the information.

  - Fixed antennas in order to receive and magnify low power signals emitted by readers/tags that need to cover big areas in the warehouse. They are also connected to the LAN network by an I/O device in order to communicate the information they read.
  - RFID reader: Obtains and sends information from the tags either by sending automatic or periodic signals when required. Gateways are also used, with different antennas located around it in different angles so that no reading is missed. They are also shielded in order to concentrate inside them all the emitted power and avoid external interferences. In case of HF, the maximum magnitude of the field that is allowed is 400 nano Tesla, while 105 nano Tesla for UHF (Mitton).

- Middleware: Software applications used for managing the connection between the reader's data and the backend. They are used for conditioning the data obtained in such a way that the back end is able to understand it.
- Backend: It consists in the WMS or other firmware that stores, filters and retransmits the data. It is usually the master in the architecture.

Logical vs Physical Warehouse with Warehouse Management System Software

The ideal WMS software represents the warehouse virtually in real time and in the exact same way as it is physically. This is to say that, if someone who usually works in the facilities takes a look in the stock database, he should directly understand where the pieces of stock are located.

The differentiation between Logical and physical warehouses makes reference to the real stock and its position in the warehouse for the case of the physical one. The other one, describes the warehouse at a software level.

A WMS allows, among other things, to map the complete warehouse network of a company. This is done by giving a WH number to each one per plant, or more than one if desired, according to the organization's needs.

Inside each WH, storage types are defined. The classification is done according to the kind of products that are to be stored (high rotation, low rotation, low volume, high volume) or by the storage structure of which it is composed (racks, ground storage, shelves, etc.).

After these are defined, it is possible to map unit cells within each storage type. Their measures come by default but might also be established by the user, as they are completely customizable.

For real time traceability, RFID systems are to be used, as they track in real time the movements of the merchandise in the different warehouse numbers, storage types and if required, in each final unit cell location.

With all these features correctly customized, the probabilities of a high alignment between both (physical and logical) can be achieved

Key performance Indicators

A very typical phrase in business is "We can't improve what we can't measure", (Peter Drucker).

A KPI represents the efficiency of a process. The way it is calculated is stated by the methodologies that a company implements for improving their processes and it aims to analyze specific performances along time. The following list shows some of the currently measured KPIs in ATG and those that are to be proposed by the speaker, ordered according to their area of concern. The majority of them is to be affected positively after the implementations developed in the dissertation.

Currently Monitored KPIs

- Picking Productivity (PiP): It indicates the efficiency of the operators during picking activities. It measures the total amount of minutes that an operator needs for handling one row[9] of stock.

$$PiP = \frac{Time\ Required\ (minutes)}{Amount\ of\ handled\ rows}$$

- Scanning Coverage (SC): Indicates the efficiency regarding the potential traceability of the products sold. Measures the percentage of scanned Serial Numbers (SNs) regarding those that have left the warehouse and the ones that should be scanned.

$$SC = \frac{Scanned\ Serial\ Numbers}{Shipped\ Products(scannable)} * 100$$

- Inventory Record Accuracy (IRA): It measures the alignments between the actual quantities of stock inside the physical warehouse and what is present in the database. To obtain the data for calculation, operators print the list with the total stock (and their locations if they use WMS) and check the presence of each item.

$$IRA = \frac{Absolute\ value\ discrepancies\ in\ pieces\ in\ the\ period}{Total\ stock\ value\ in\ pieces\ at\ the\ end\ of\ the\ period} * 100$$

- Dock to stock (DTS): Indicates the efficiency to stock in time all the products arriving in the warehouse from the dock until they are uploaded in the WMS system and left in their final locations. It measures the percentage of the unloaded products with respect to the total amount of them. The time limit in which the products are considered within the current day is around 16 hours.

[9] Organizational unit of stock within the staging areas.

$$DTS = \frac{Number\ of\ unloaded\ positions\ items\ in\ time}{Number\ of\ total\ position\ items\ to\ be\ unloaded} * 100$$

- Loading or Unloading time (FTL): Indicates the loading and unloading time for each operation. It gives a hint of the productivity of operators regarding these tasks. It decomposes in a sense the previous KPI. At the end of the working day, the missing operations are analyzed and an equivalent of the delayed working hours is obtained in order to incur in penalties.

$$FTL = \frac{Number\ of\ working\ hours}{Total\ operations\ performed}$$

- Picking Accuracy (PA): Indicates the correct picking of the products present in a picking list. It is calculated as the number of pieces in PPM delivered to the client but not accepted or with any other error that is not to be blamed on the provider.

$$PA = \frac{Number\ of\ disputed\ delivered\ pieces}{Total\ number\ of\ picked\ pieces} * 1000000$$

- Transportation Accuracy (TA): It is similar to the previous KPI, but also contemplates external sources of errors. It is measured as the amount of pieces in PPM not delivered not accepted by customers.

$$TA = \frac{Number\ of\ disputed\ delivered\ pieces}{Total\ number\ of\ delivered\ pieces} * 1000000$$

- On Time Picking (OTP): Percentage of shipments picked on time from the warehouse within the required time frame.

$$OTP = \frac{Number\ of\ shipments\ picked\ within\ the\ time\ frame}{Total\ number\ of\ picked\ shipments} * 100$$

- On Time Delivery (OTD): Percentage of shipments received within the daily cut-off with respect to all the ones supposed to arrive.

$$OTD = \frac{Number\ of\ shipments\ delivered\ to\ the\ clients\ within\ the\ contractual\ times}{Total\ number\ of\ shipments\ recevied} * 100$$

- Handling damages (HD): Percentage of damaged handling units with respect to the total number of handling units handled.

$$HD = \frac{Number\ of\ damaged\ handling\ unit}{Total\ number\ of\ handling\ units\ handled} * 1000000$$

Proposed KPIs by the Speaker

Put away

They consist in placing each item in a designated location. Efficiency in this area guarantees a smooth picking process, which leads to time reduction.

- Put away Productivity (PP)**:** Measures the volume of goods stored per hour by each operator from the staging area until it is loaded in WMS. It helps to complement the DTS and FTL.

$$PP = \frac{Volume\ of\ Stored\ Goods(hour)}{Operators\ Required}$$

- Put Away Accuracy (PAA)**:** Measures the percentage of items that are put away accurately at the destination location. An error is counted when an operator finds in the destination location a product that should not be there.

$$PAA = \frac{Items\ stored\ correctly}{Total\ Items\ to\ be\ stored} * 100$$

Storage

These KPIs are very useful in order to solve inefficiencies regarding the stocking activity such as slow inventory handling.

- Space Management (SM): It measures the efficiency of the warehouse usage. It takes into account the entire volume in stock with regards to the surface.

$$SM = \frac{Volume\ Stocked(M3)}{Warehouse\ Surface\ (M2)}$$

Picking

This activity is of very big importance when it regards lead time.

- Replenishment Efficiency (REFIX): Measures the replenishment efficiency of the products in a warehouse. A low value in this one, implies that a company is failing to supply the demand as a consequence of production forecast errors and/or unavailability of a product which is currently in stock but, for a logistical fault is not available for shipping.

$$REFIX = \frac{Value\ Shipped}{Value\ Requested} * 100$$

Distribution

These KPIs are linked to the outbound activities, with an exclusive participation of the warehouse operators only in at its beginning. Some of them are highly affected by external

factors, but it is useful to track them in order to have a measure of the client service and the external shipping company's performance. In the hypothetical case that these KPIs are below the target and it is certain that the external factors are doing their work properly, it is possible to know in an indirect way, that even if the internal processes have a low impact in this stage, they are failing.

- Rate of Return (ROF): Measures the amount of returned products by the clients as PPM. In order to increase the accuracy of the data obtained, the returns are classified among:
    - Damaged goods.
    - Mistaken Items/Wrong Quantities.

$$ROF = \frac{Units\ Returned}{Units\ Sold} * 1000000$$

Lean Manufacturing and WCM Philosophies, 5s Methodology

A general introduction is done of the different and most relevant warehousing methodologies and improvement philosophies.

Lean Manufacturing

The concept is originated in Japan, after the second world war, due to the fact that only low investments could be done and there was a lack of resources to rebuild installations. Its goal is to be highly responsive to customer's demand, while at the same time reduce wastes without additional resources. The final aim is the production of services and products at the lowest possible cost and as fast as required by the customer. This approach intends to give a competitive advantage against competitors by reducing costs and improving quality and

productivity. It also offers qualitative benefits such as improved employee morale and a more effective communication (Bhamu Jaiprakash, 2014).

In the case of warehousing, it intends to have minimum inventory levels, with a very high stock rotation, requiring the least possible costs regarding warehouse structure and maintenance.

World Class Manufacturing

World Class Manufacturing (WCM) is a series of aims and standards that provide a company with the sufficient tools to be able to solve everyday problems within their production systems. ATG applies this approach in order to keep improving the processes in its plants, which is why it is worth pointing them out.

WCM involves the organization as a whole, independently from its different departments or plants wherever they are in the world. It aims within its field of applications to all the phases of production and distribution. The concept is born in the early 1980s as a collection of best practices like the Just In Time, Toyota Production System and others. Today, it can be said that it is the evolution of Lean Manufacturing. It becomes very well-known around the early 2000s when Fiat Chrysler Automobiles starts to adopt it. WCM consists in a series of 10 technical (Fig 11) and 10 managerial pillars which help structuring its implementation and so dividing it in different areas, each with a pillar leader (Monfreda Stanislao, 2013).

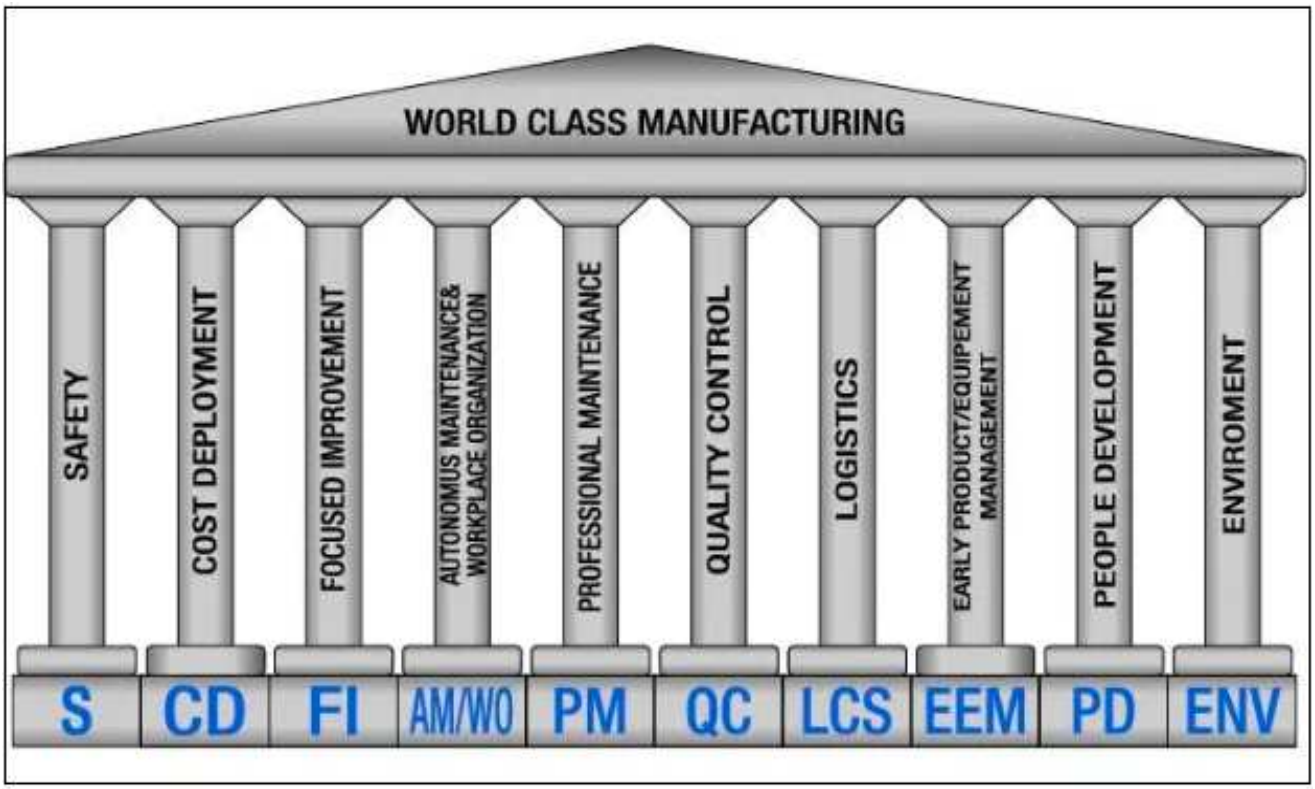


Figure 11 World Class Manufacturing Technical Pillars. (Source: nvlean.com).

The general objective of each pillar is:

- Safety: Ensuring the safety of the operators in the plant by applying specific measures and rules to be strictly respected. The reduction of the number of accidents is the final goal. One of the first and simplest measures usually established within the plant is a pedestrian road to be firmly respected.
- Cost deployment: Analyzes the different costs and losses in the everyday processes and intends to find their reasons and possible solutions by analysis. As a consequence, it pushes the other pillars to go for the development of the projects that bring the highest benefit for the company, as an outcome of their evaluations.
- Focused Improvement: After the Cost Deployment analyses, it classifies the top priorities in order to orient the available resources to solve the most urgent inconveniences.
- Autonomous Maintenance and Workplace Organization: It is the independent maintenance performed by the same operators of the plant instead of dedicated maintenance technicians. So, it counts with the operators performing the simpler, more usual and safer maintenance activities of the machines. Like this, the technical

maintenance is only to be performed if a major issue takes place. The aim of this is to extend the machine working life and to avoid small, easily avoidable issues that force a stoppage in the line.

- Professional Maintenance: Its final aim is to achieve zero breakdowns within the machinery in the production plant. For this, it provides a set of tools to make a deep analysis into the problems that may arise before they take place in order to identify their root and eliminate them.
- Quality Control: Its aim is to guarantee the quality requirements demanded by the market. The final goal is the production with zero defects to avoid discarding products.
- Logistics: Aims for a more effective management of supply chains, reducing material storage and ongoing production, reducing logistics costs, integrating logistics networks (suppliers, co-operators, producers), better usage of means of transport and of the warehouse facilities among others.
- Early Product/Equipment Management: Aims at reducing the start-up times for newly installed production machinery and its lifecycle costs. To achieve this, consideration is taken regarding the outcome to be obtained.
- People Development: The objective is to constantly raise the knowledge and competences of the professionals of the company thanks to an organized training program developed for each area.
- Environment: This pillar regards to the environmental impact that is done by the company. The goal is to reduce it to its minimum possible and to respect the local laws. This is done by reducing energy consumption and wastes after production.

The final objective of WCM applications are the following ones:

- Zero inventory.
- Zero defects.
- Zero breakdowns.
- Zero waste.

The WCM gives a punctuation to each plant according to their performance in each pillar. The recognitions start with Bronze, then Silver and finally Gold medal.

Today, the Osimo plant is currently at the bronze level.

5s Methodologies

Almost exclusively focused in warehousing. These methodologies impact directly in the workforce, as they intend to order and discipline the company's warehousing activities and ensuring the surveillance of even the smallest details. 5s focuses on effective work place organization, simplifying the working environment and reducing wastes while improving the operator's safety and quality. Its simple intrinsic methodological approach, makes it easy to be applied by every company, disregarding its level of complexity (5S activities and its application at a sample company, 2009). Its name comes from the first letter of each word that represents its stages, which are expressed by five Japanese words:

- Seiri: Sort and separate unnecessary materials. Whatever is useless must be eliminated from the working place.
- Seiton: Set in order. Organize working place efficiently.
- Seiso: Sweep. Increase working place's level of cleanness.
- Seiketsu: Standardize. Prevent the appearance of new disorder scenarios by establishing fixed procedures and rules.
- Shitsuke: Self Discipline. Motivate workforce to maintain this new aim.

Warehousing activities within Osimo plant and different case studies

In this section, an overview of the processes taking place in Osimo's warehouse is firstly presented. This is followed by different case studies, with the aim of showing the general tendencies around the subject.

Warehouse activities in Osimo

At Osimo plant, product's storage is composed both of finished products and raw materials. These are in charge of different areas.

In the Osimo's finished products (OFP) warehouse, activities are executed by a 3PL (Third party Logistics). This are logistics decisions taken by companies, that consider that. even if this option implies a higher direct cost and loss of activities control, several advantages are obtained. Some of them, are the following ones:

- Allows the company to focus in its core business while paying for the know-how of the 3PL who is supposed to be an expert in the area. This saves a lot of time and resources.
- Higher flexibility regarding any changes in the warehouse location (which happens very often) such as no employees under the company's responsibility. The only limiting factor is a short term fixed time contract with the 3PL.
- All the assets (like forklifts or hand trucks) that are required for the shipping or handling activities do not require any structure to be maintained by the group as it is of the 3PL property.

In order to ensure that the 3PL performs its activities correctly, the hiring company states the quality standards that must be achieved and respected, using as an indicator some of the previously named KPIs[10]. The intention with these is to reduce the presence of any defects in the shipped and received merchandise and a very strict delay policy in shipping and handling

[10] Which depend on each company's policies

times of the stocked and shipped products. In case these standards are not successfully complied, economical fines are applied to the 3PL.

Considering that the 3PL complies with every requirement in the contract, so no problems emerge regarding quality and shipping delays, the main inconvenience that comes out from such a structure, is the lack of control over the company's stock. This is because once the products exit the production line as finished goods, they are picked up by the 3PL and stocked in their corresponding locations in the warehouses, but under full control of the 3PL (fig 12).

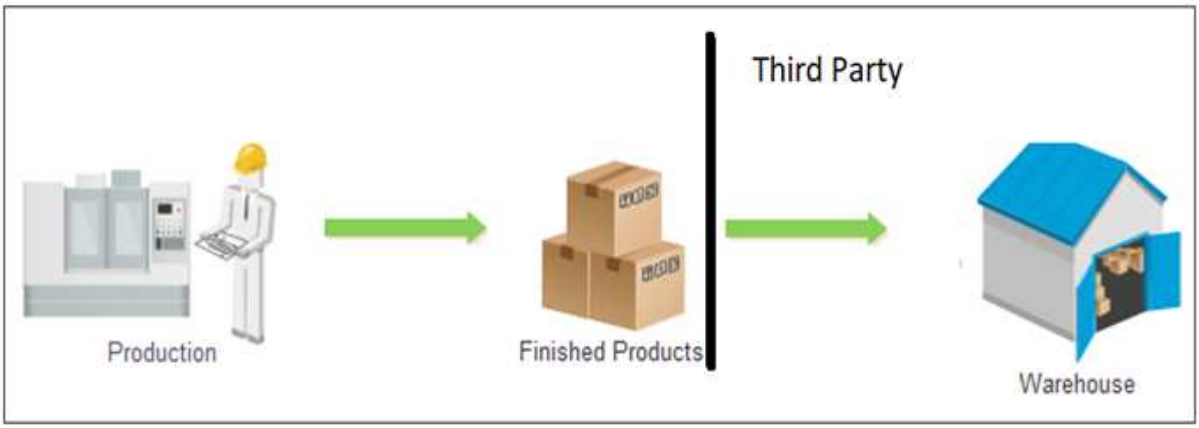


Figure 12 Simplified flow of finished goods. (Source: financesonline.com)

One of the consequences of this is mainly the lack of certainty of responsibility regarding a difference in Inventory. If materials are missing, is it the 3PL's fault or the company's production operators? How is this black border determined? Also, if stock is under control of the 3PL, there are difficulties to cope with the clients' purchase orders regarding the stock availability. To handle this, features of the Material Management (MM) module are used. This one, allows the company to keep count of their stock and materials, among other benefits.

MM: Stock Manager

This is a software module that allows a company to take care of plenty of activities regarding IM (Inventory Management) such as the supply of the raw materials, manufacturing, stocking

and shipping of products (SAP, 1997). It is the base for WMS, as this one uses MM to perform many tasks, but with a very constrained repertory of its functionalities.

As a general basis, MM consists of different modules (Fig 14), being the most used ones the ones that follow:

1. Purchasing: Allows a company to manage how and when to make an acquisition to a predetermined supplier. The purchase orders are usually born with the MRP. When production requests are launched, the MRP makes a consumption of the stock of the products that are employed to supply the request in a specific warehouse and if a certain limit is reached (this function requires customization), a purchase requisition is automatically done by the system to the predetermined supplier with the sufficient quantities for replenishment, within a certain limit of expenses. If this one exceeds the maximum value, it is put in hold to be approved by the logistics responsible in charge that has to check the viability of the purchase.

   Once approved, it is officially transformed into a purchase order and the supplier is communicated, so he prepares for the delivery. An invoice receipt is generated through the system once the goods are received into the warehouse. The period to pay the invoice and the corresponding discounts depend in the relationship with the supplier and this can be as well customized. The process is represented in figure 13:

Figure 13 Purchasing process in MM. (Source: guru99.com)

2. Inventory Management (IM): This component supports the transactions performing virtual movements of the inventory in a company within the same plant or different ones, from suppliers and to clients. To do so, many different software transactions and parameters (that can be fixed or customized) are defined with the objective of indicating the purpose of the goods movements such as returns of damaged goods, delivery of merchandise from a plant to another, among others.

It is very important when developing the customization, that every transaction movement created counts as well with its opposite one, which is capable to cancel its effects as the system is configured to work this way. There is not always simple cancelling of a mistaken movement for security reasons. This is very important to have present when a new implementation is introduced as it tends to happen that the necessary movement is created, but its opposite one does not come into consideration given that it is not involved in any apparent scenario. An example of this, is creating a movement that generates a new piece of stock to correct and error. The destruction of one piece should also be programmed so as to guarantee that, in case the operator manually inserts a higher number of products than the real one, it can be corrected.

3. Master Data: Stores all the data that may be required in order to perform every transaction. Every module (CRM, ERP, HR, etc.) gets its information from here. In the case of ERP, where MM is contained, some examples of this data are stock, Bill of Materials (obtained from material master data), suppliers (vendor master data), distributors, clients (customer master data financially oriented) and pricing master data among others. Below, a brief explanation of each of them:
    a. Material Master Data (MMD): It is the logical description of a material type produced or acquired by the firm. It consists of two "anagrafic" views where each field[11] has to be completed. Whenever a transaction that involves a material is performed, the necessary data to be used is collected from the MMD. As a consequence, it is vital for the firm to maintain all the information up to date. Some of the main characteristics of a product are:
        i. Material types: They can be classified in Finished Product with the use of the FERT code, Semi-finished Products with HALB, Trading Goods using HAWA and Raw Materials as ROH. In the case of warehousing, these predetermined values can indicate the final stocking area of a material.
        ii. Material Group: This is a flexible criterion that is established by the company according to its requirements. There are some of them

[11] The fields are the data to be stored.

already predetermined by the system but they can also be inserted by customization of a new parameter.

Its final goal is to allow the classification of products in different groups according to the purposes needed. It can be according to family products, materials required for the production process, transport services, etc.

b. Customer Master Data: Each customer and its relevant data are stored here. This data is composed by:

c. Vendor Master Data: Contains the vendors from the company. It works in the same way as the Customer master data.

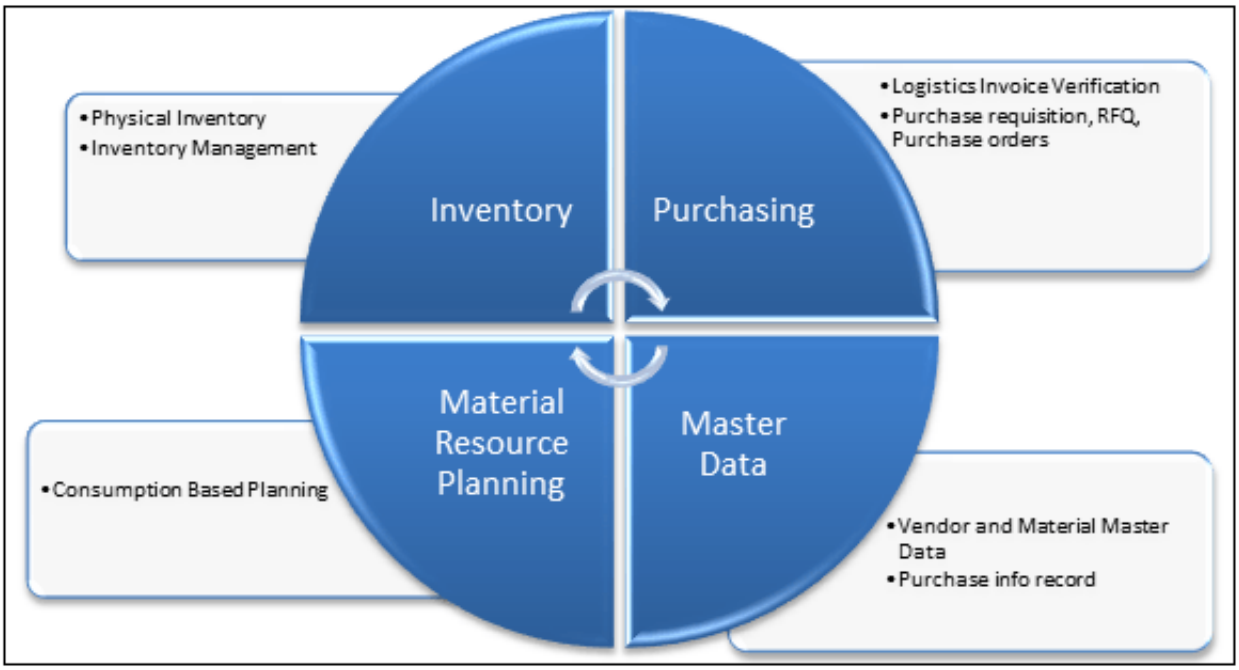


Figura 14: Main MM modules. (Source guru99.com)

MM solutions the 3PL stock control

When a product leaves the production line of Osimo's plant, it continues its way through a tape that automatically leaves it with the other units of the batch in the warehouse area.

Then, warehouse operators pick them up with a forklift and proceed to stock them. Between the warehouse and the production site, there is a physical division that when the products pass through it, the barcoded serial number is read and automatically becomes a finished product registered in the MES. After this point, it is certain that the read products are effectively under the control of the 3PL. During this process, products are also uploaded into the ERP system (in the MMD) with an automatic transaction that identifies which kind of material (7-digit code) it belongs to, so the stock is updated. As a result, this automatic transaction represents the physical displacement of the finished products from the production line, to the warehouse with no manual labor involved, so it is exactly known by both parts who is responsible for any material loss using these scans as a judge.

Every internally or externally produced material that enters in the company has a unique and specific code assigned to it with which it is identified in the database (7-code digit mentioned before). Each warehouse of the company and each division within it are also identified in the software with a certain coded number. All this data is required when a material movement is to be performed. In order to accomplish the outbound and inbound movements of products, the operators from the 3PL log on in their MM accounts and execute the corresponding transactions. Their confirmation is performed either through a desktop computer or by special bar code scanner pistols linked to the software.

The database containing the stock quantities is automatically updated, according to each implemented movement, which is fundamental for every company's sales department and logistics for having the up to date stock, allowing them to efficiently schedule sales requests to be done.

Summarizing, thanks to MM, it is possible to track the amounts and type of stock under the control of the 3PL, but there are no details regarding where and how the merchandise is being organized within the warehouse.

The Osimo warehouse as a logistics key point

In the chapter nine of the book "The Handbook of Logistics and Warehouse Management" (Rushton Alan, 2010), the approach of the logistics network planning that a company should

perform is established. It shows both ends of how the distribution center should work for the best possible client satisfaction and for the best interests of the company.

According to this source, regarding the client's best interests, there should be a DC (Distribution Center) as close to him as possible and contain the exact goods that the client requires in the specific moment that he needs them. This is of course, a very expensive solution as high costs arise from the truck deliveries (Secondary distribution) and a huge number of DCs are required in many places, leading to high employee and facility maintenance costs.

On the other hand, the company's best interest is to have as few DCs as possible and send the merchandise only when the request from the DCs lead to a full truck load. This is the cheapest solution for the firm but the worst for the customer, and eventually leads to losing the final client. A compromise needs to be found between both of this extremes.

As a general basis, the solution consists in positioning DCs strategically to supply diverse areas. These ones are supplied by a main headquarter/s with large primary vehicles that are doing long distances. Then, these DCs supply the final customer with smaller vehicles and shorter distances. According to (Rushton Alan, 2010), there are different kind of DCs for different purposes:

- Finished goods DCs for warehousing: They are the ones that normally store the merchandise.
- Regional or National DCs that also hold finished goods: Same functionality as the previous ones, but supply larger surfaces.
- Seasonal Stock Holding Sites: In seasonal businesses, these ones are only used when the demand rises to its peaks.
- Overstock Sites: Only used when the regular warehouses are at maximum capacity.
- Transshipment sites or Cross Docking: They don't stock any merchandise. Products leave the warehouse as soon as they arrive. They are just changed of vehicle.

The cost of primary and secondary transportation varies according to the amount of DCs that the company has. While more DCs, secondary transportation costs are reduced, but primary ones arise. On the other hand, few DCs increase secondary transportation costs but reduces the primary ones (Fig 15).

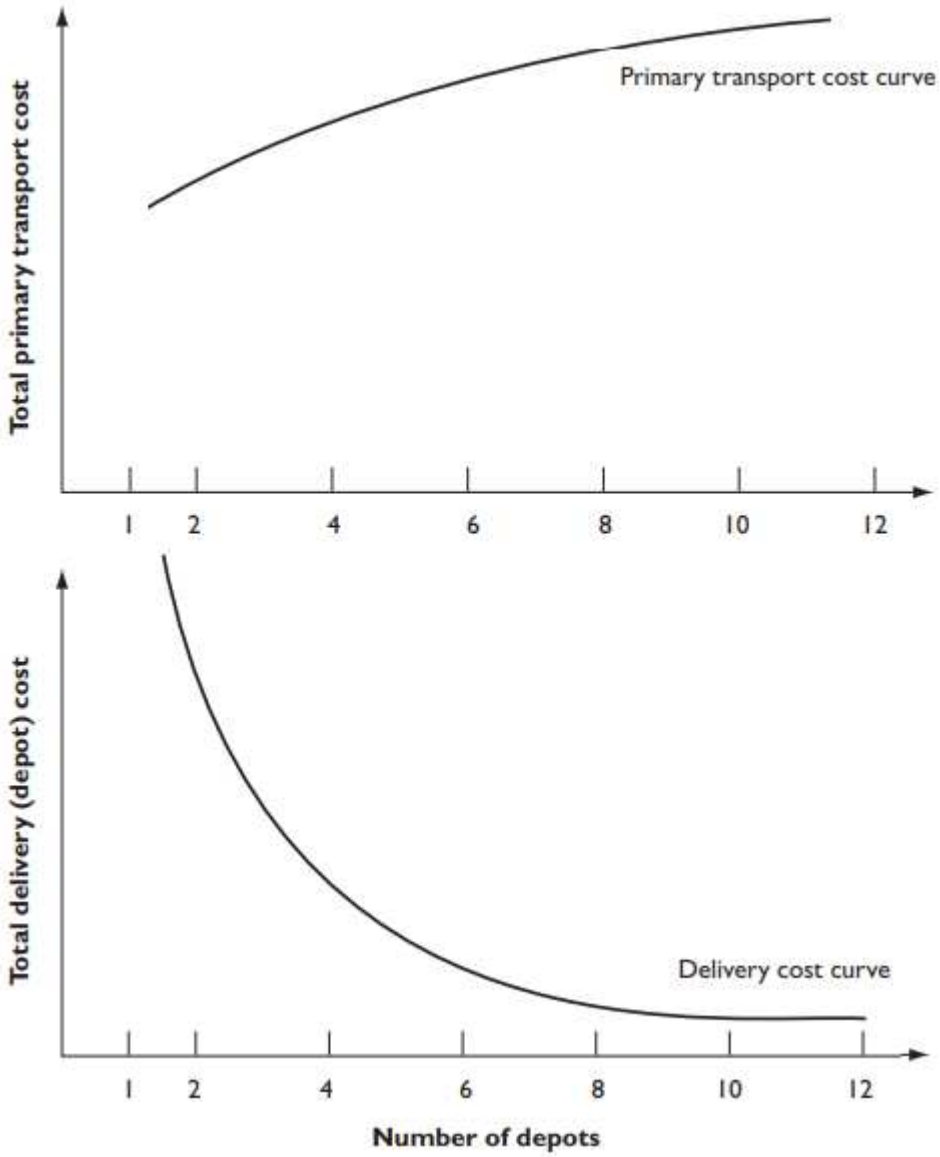


Figure 15 Primary and secondary transports costs.(Source: (Rushton Alan, 2010))

It can be seen that with a higher number of DCs in the middle range, the gradient of cost reduction from the secondary transportation costs is faster than the ascendant gradient of the primary ones, leading to a result such as the one in fig 16.

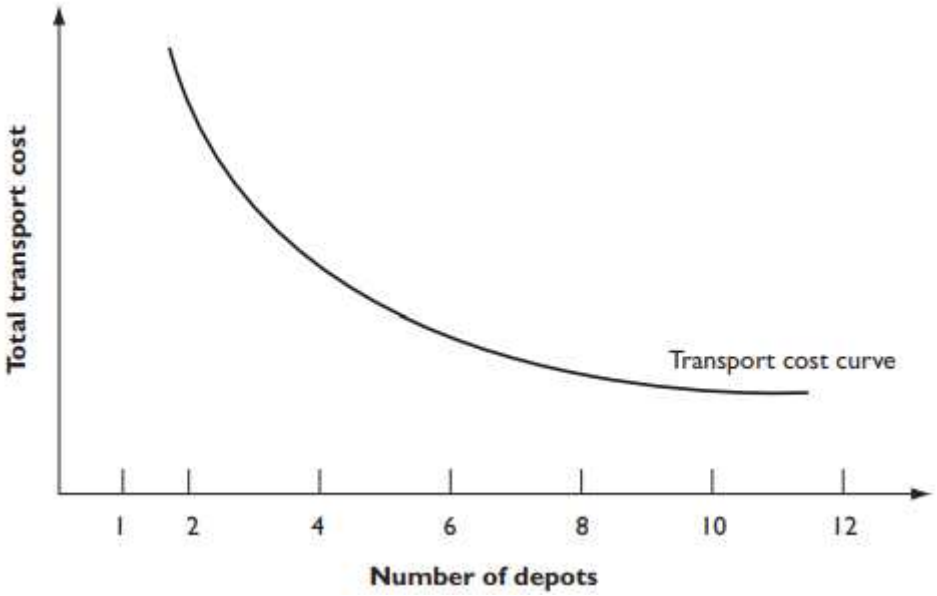


Figure 16 Total transport costs (Source: (Rushton Alan, 2010))[12].

Inside the warehouse of the Osimo plant, storage is not only dedicated for internal production. Many other finished products arrive to the plant from other production sites of the group. These different products are boilers, water heaters, electric water heaters and accessories. In total, more than one million[13] of these products are shipped every year. As explained before, Osimo's warehouse works as a National and International DC.

Case studies

Warehouse Management implementation in ATG raw materials warehouse

In the past, ATG decides to implement a WMS from the company into their raw materials warehouse. This implementation in the logistics aspect is of a low complexity, as the final user is exclusively the production plant in Osimo. This is not the case for the finished products warehouse where the merchandise has to be delivered to many different places and it is divided in three different divisions.

[12] The number of depots is just an example. The real values depend on the geographical and industry aspects.
[13] Value is just approximate

For this particular project, the implementation turned out to be very successful and improvements are obtained within the first year of implementation, with an increase in the KPIs of over a 40%[14].

Case study of a regional distribution center

The paper "*Warehouse Management System and Business Performance: Case Study of a Regional Distribution Centre"*, (Au Yong Hui , 2009) analyses how the implementation of a WMS impacts positively in the improvement of the IA (Inventory Accuracy), among other aspects.

This application is in the frame of an electronic parts regional distribution center in Malaysia.

It is remarked how the implementation of a Warehouse Management System and barcoding for tracking the materials, improves the identification of the stock in the shop floor and the system's database. Also, typical warehousing tasks such as stocking and picking are performed more efficiently, leading to client satisfaction as a result of fewer mistakes during the order's execution.

Automated Warehouse

A study entitled "Development of Automated Warehouse Management System" (Mingxing Deng, 2018) states the advantages of implementing AGVs in a three dimensional warehouse, using WMS to order the execution of activities.

According to the results and conclusions, WMS works as a bridge between the hardware (AGVs) and the software, by giving the commands as a Master-Slave relationship. It is also remarked that WMS is a vital tool in order to keep correct track of all the stock data in the warehouse safely, aiding for Inventory Accuracy activities and making it easier to find the merchandise.

[14] The speaker is not allowed to present exact numeric results

Specific aspects of ATG project implementation

These different applications state very important advantages regarding the use of WMS. Each company and warehouse is different from each other and these differences vary from countries and industries, where needs are also different. In the specific case of OFP, the products are delivered to over one hundred and thirty countries, there is more than one WH division to be programmed in the software (increasing the complexity of customizing and final user's activities) and the operators are not very keen in working with new technology equipment.

Justification of this project: Problematics, motivations and Objectives

Problematics and Motivations

In order to improve, weaknesses and problems have to be determined. This is why, the working site is evaluated to find the starting point to search for the root of the problems.

The high level problematic is determined as recursive mistakes in the orders sent to customers regarding delays and/or wrong amounts/items. This affects the company's reputation and in some cases, it can even lead to economical penalties, with strong distributors whose contracts are very strict regarding supply due dates. These problems lead to extra costs and possible loss of revenues, which are sufficient reasons for the company to invest resources both to find the lower level root of the problems and to solve them.

An extra-monetary motivation is the desire for high quality standards recognition within the WCM methodologies previously named. To accomplish this, there are many pillars in which the company can invest, but it is the responsibility of the cost analysis pillar to determine the most critical problematics to be solved and underline those that, once solved, are going to cause the highest return on investment.

To make this evaluation, workshops are performed by this pillar with the internal clients (other company's departments and pillar managers) to get first-hand information regarding their concerns, needs and future project possibilities.

As a result, the Logistics pillar is assigned with the resources for improving the OFP warehouse. Once implemented, it is expected to obtain high costs savings as well as a raise in the mark of the plant within WCL standards.

In the following subsections, the different problematics are enumerated and explained.

Material's lack of traceability (within Warehouse structure)

As stated before, for Inventory Management (IM), the MM module is used. With this one, the company is allowed to upload the merchandise that enters in the warehouse and store it in

its database. Given that the current surface is over six thousand SqM., it is difficult to find a specific product when required for the operators and practically impossible to anyone external or new in the task.

Another inconvenience, is that the company highly depends in the human factor in order to execute its activities. This is because, for the different products that are to be picked or put away, there is one person that is an expert in each area/product.

Possible lack of space due to wrong management

Another problem is the warehouse usage. The entire surface is correctly filled up, but the height is not efficiently used. This is because high locations are more complicated to use and monitor, leading to the usage of overstock positions which are easier to handle, but also the first ones to be shipped. A direct consequence is the incorrect stock rotation, as overstock positions work with a LIFO[15] logic, while all the other areas with FIFO[16]. Also, the fact that when there is a very high demand, and so an increased level of production materials to be stocked, space might not enough.

Inventory matching

Inventory activity takes place few times (at least one time per product) a year. This one is the comparison between the actual stock in the physical warehouse and the one available in the database. To do this, operators check the database and go to the physical warehouse to look for the merchandise, which is very time consuming. The duration of this activity is very critical and should last as least as possible given that while it is being performed, the warehouse can't work normally as all inbound and outbound orders are required to be "frozen". What is more, there is an additional limitation that is that the person in charge of each area in the warehouse has to be present as he is the one who knows with more detail where he is going to find the products.

[15] LIFO = Last In, First Out
[16] FIFO = First In, First Out

High Material Handling Time

Regarding the picking and put away activities, it has come as a result of the evaluations that the operators could fulfill their handling tasks in a most efficient way. Additional journeys are done than the required ones, plus the planning time. This is not an inconvenience during the low or mid demand seasons, but it is in during peak demand.

Human error during activity planning

Until now, the "governance" of the entire activities within the warehouse are commanded by the warehouse manager. The high dependence on human factor in this aspect, often leads to mistakes in the shipments or unavailability of the required products due to poor planning. Due to the fast growth being experimented by the company, this is to bring complications in the short-mid-term.

Mistakes in outbound scanning

Boilers that exit the company are manually scanned their barcoded serial numbers, which are stored in the MES and all its production data can be obtained (batch number, production date, etc.). The scans are useful for tracking the product's final destination and exit of the warehouse. Today, the accuracy in the scans is perfect. But as the tendency in production increases along time, it is a risk that operators become overflowed and fail to read the barcodes. As a consequence, the product would seem to be still stocked in the warehouse, when it has in fact already been shipped. Even worse, products can be mixed up and finish in a different truck than the one that is linked to the client's order (same kind of product, different serial number), giving place to incorrect data.

If products are correctly traced and a problem should arise, a company is able to call back the products that only belong to the same batch of production of the damaged product.

Otherwise, it is required by law to collect the totality of the products, incurring to much higher costs. An example of this, is the Toyota Unintended Acceleration case, where the company was required to take away of the market all of its production from 2002 until 2010, with a total cost in legal claims of over a billion dollars (Koopman, 2014). Today, traceability is in a 100%, but it is feared that with the constant growth of the demand, the current process might not be enough to endure its performance in time, which demands for a more robust solution.

Lack of information on certain processes

It is analyzed by the speaker; that more useful data can still be collected from the actual processes than the one that is currently obtained through KPIs measure. This means, that for some processes that are responsibility of the warehouse and of the external distributors, there is only one measured indicator, which in the opinion of the speaker, can be furtherly decomposed in other indicators. This allows to identify with more precision the performance of each of the parts.

Objectives

In this section, the objectives are presented. Once the project goes live and the new software is working, it is expected that most of the previously introduced problems are diminished. What is more, an important impact is expected in the KPIs that are measured by the group[17]. This implies an upgrade in the WCM standards, which are in line with the company's expectations of making Osimo plant the first Silver Medal of the group. The objectives to be obtained within the first three months of the implementation are enumerated below:

- Identify the data and set up the correct measurement procedures in order to be able to monitor the proposed KPIs named in the KPIs subsection of the Theoretical Frame section, that are considered useful by the speaker. These are:
    - REFIX.
    - SM.
    - ROF.
    - PAA.
    - PP

  Specific objectives regard the identification and source of the specific data required for the measures.
- Improve the efficiency in picking and put away processes.
    - Specific objectives regard the reduction of material handling times and eliminate unnecessary journeys performed by the operators during picking and put away. Also, the correct set up of signs and banners for a correct guidance. An increase in the following KPIs is expected:
        - PiP.
        - DTS.
        - OTP.
- Increase and monitor warehouse usage, in order to analyze the internal movement's performance. This is also contained within the proposed KPIs.

[17] The speaker is not allowed to distribute the As-Is values of these KPIs.

    - The specific objective here is to state the procedures to measure the SM and monitor it along time.
- Decrease the time and complexity for performing the Inventory Activity at the end of the year.
    - The specific objectives regard:
        - Correct mapping and supply of the warehouse with banners and indicators to easily identify both locations and storage types.
        - Respect the exact locations and storage types where it is ordered to put away or pick up a product.
        - Maintain or improve the value of the IRA KPI.
- Continue with the perfect tracing of the products.
    - Specific objectives:
        - SC: The approximated value is around 100%. It is expected to be maintained along time with this new structure and with the current growth trend in demand.
- Reduce errors and delays in deliveries in order to increase client satisfaction:
    - Specific objectives include many of the specified ones in the previous objectives and an increment in the following KPIs:
        - TA.
        - OTP.
        - FTL.
        - PA.

The specific objectives in order to improve in each of the previous sections, regards the actions that contribute to raise the KPI values. It is expected an increase of the stated KPIs of around a 30% in the first three months. This increase regards their margin to reach the 100% for those measured in percentages[18], while those that are measured in PPM, it is expected a reduction of the 30%.

[18] If current value is 95%, there is a 5% margin of increase, so the new value improved 30% should be 96.5%.

Only in the case of IRA and SC, this implementation is a defensive measure in order to be ready for the future demands, that it is believed, the market is to require. It is then expected to maintain their current values along time, as they are practically perfect.

Benchmarking: Choosing the optimal solution

In this section, a benchmarking regarding the different solutions that can be found in the market is performed by the speaker. As anticipated, the different WMS software solutions and the traceability components are analyzed. The ones that fit the most with the company's needs are chosen.

Traceability

Regarding the traceability, the following possibilities are in the reach of the business:

- Barcode tags.
- RFID tags.

Barcode tags demand a low implementation time and cost, as it is only required to buy and link the required number of printers in the LAN network in order to print whenever it is required by the software. Even more, the OPEX are only paper and ink (estimated in 2 cents of euro every 10 printings on some producer's website). The RFID option instead, requires the installation of more expensive printers for producing the tags, gateways to read the data, a new station in the production line to stick the tags and the complete installation of the antennas. Also, the OPEX are much higher, as each tag requires above 6 cents of euro per tag in the best case scenario[19].

As a starting pilot, it is chosen to start straight ahead with barcoding paper tags. In the pages to come, it is anyway analyzed by the speaker, the possible introduction of RFID technologies as a second phase of implementation in the future, as its benefits are very interesting for taking them into consideration.

WMS software

[19] According to the information found by the speaker.

Regarding the WMS, these are the possibilities in the market found by the speaker:

- SAP WMS.
- Customized Solution.
- 2 other suppliers[20]

The criteria for selection are the following ones:

- Set up time: It is required to Go Live with the implementation in no more than eight months. This is why the time period for a complete integration of the system is a criticality for the selection.

  In this aspect, the best option is the SAP WMS, given that it uses as a basis the MM module already working. This leads to no requirements regarding data migration between platforms of the existing data, with a guaranteed time period for implementation of no more than six months.

  The worst one in this aspect is the custom development, given that the company does not have the necessary human skills, so either training of the existing analysts or hiring new workforce is required, plus the data migration time. All of this is estimated in a time period of around two years, which makes it unviable.
- Costs: Year license, first time (CAPEX) costs and daily maintenance resources such as internal workforce are taken into consideration.

  Regarding CAPEX and year licensing, the best option is the custom solution, as it demands a high initial investment, but then the cost is very low[21] in contrast with the other options that demand the yearly payment for licenses. The remaining possibilities are quiet similar among them.
- Benefits obtained from the system's functionalities: Takes into consideration the potentially satisfied business needs by each system. In this characteristic, all the options offer (or can be developed to do) what the company is looking for.
- Flexibility for improvements: As a plus, it is taken into consideration, that some of the mentioned options offer the possibility of an improved version, if it happened to be required a WMS with higher benefits in the future.

[20] Names are omitted.
[21] Only internal analysts performing maintenance.

For this aspect, the custom solution is the clear winner, as the development is internal by the firm and any further requirements can be developed with no further inconvenience. This is not possible for any other prepackaged software, as they are much more inflexible. Anyway, SAP WMS counts with an extension which is SAP Extended Warehouse Management, which expands the functionalities of WMS, giving the possibility to implement new required functionalities.

Justification of the choice

The Logistics department of Osimo, in association with the ERP sector of the Information and Communications Technology department, have decided that the best way to start improving warehousing activities is to implement the SAP WMS software, redesign the warehouse layout structure and use barcodes for product's internal traceability.

This decision is based in the fact that practically all of the inconveniences today present are tackled with its implementation.

Also, it requires the shortest time for implementation and seems to guarantee a very short Post Go Live period, given that no data migration is required and operators are already used to the virtual environment.

Furthermore, the Extended Warehouse Management module can be adopted in the future if required. This one grants the company the possibility to easily improve the functionalities of the WMS if needed. Also, the fact that the company has already performed another implementation of this system with successful results, is as well encouraging.

Regarding the traceability, as anticipated, barcode tags are chosen as the best solution. This is mainly due to the low OPEX and the shorter time for implementing them in contrast with RFID (Radio frequency identification) tags. Anyway, it is further analyzed the possibility of its future implementation as they can be a following development to be inserted in order to increase the benefits that are obtained today from barcodes. A further business scenario regarding this subject is done in the pages to follow.

The key improvements that are to be expected (which are sufficiently in line with what is meant to be achieved) with the introduction of all these developments are:

- Traceability increase.
- Implementation of highly efficient picking and put away strategies.
- Increase the warehouse usage.
- Reduce mistaken in orders.
- Higher accuracy in stock locations.

A consultancy company is contacted in order to form part of the team and aid in the development and implementation of the project. It is initially agreed with them that if they do a first visit in the warehouse to evaluate feasibility and prepare a Business Blueprint within certain restrictions, they are to be directly allocated the project. Also, they have already performed other similar projects in other companies with very good results.

Final Solution: SAP Warehouse Management System

Implementing a WMS in a warehouse correctly, implies much more than just installing a software module. “Integrating a successful WMS program into a warehouse is like tying a knot” (Mulcahy David. E, 2008), meaning that one strand is the warehouse and its current processes, while the other one is the WMS and its functionalities. If the knot if not correctly done, at some point it breaks.

In this section, it is explained in detail the development of the solution. The implementations to be done are: the new warehouse structure, the WMS implementation and barcodes (and RFID in the future) for traceability.

Warehouse’s New Structure and Handling flow

For a successful new warehouse layout design, it has to be clearly analyzed which are the highest rotation products, where to stock them, choose strategic staging areas for packaging and palletizing according to the docking areas, size of new unit cells, among others. With these defined, a proper design can be performed in order to guarantee the smoothest flow of the merchandise and of the operators in order to speed up processes and guarantee the highest possible efficiency during the activities. Also, the warehouse space is to be better profited, being able to store a higher amount of products.

Limitations of remodeling a warehouse

For this implementation, remodeling of the warehouse is required. The main limitations to do so, are the rigidity to change the already established structures and processes within this one, due to the fact that operators have to change their working procedures and tend to show resilience to do so. Even more, their activities are to be strictly monitored with the objective of establishing specific procedures for inbound and outbound processes and also for stocking the merchandise in specific areas. Furthermore, the rack structures are old and not totally

compatible with the current product's measures, requiring the installation of new ones where required (one in the external tendon and another one in the internal warehouse accessories area). These modifications affect the following internal activities:

- Order Picking.
- Packaging and palletizing.
- Cross docking.
- Customer or vendor returns.
- Quality checks.
- Customer order processes.
- Storage and put away.

Which is practically the totality of the processes.

Handling Analysis

As stated before, the OFP warehouse receives finished products from other companies of the group and semi-finished products (accessories) from both external and internal plants. This division of the products is going to be the key for the design of the merchandise flow and the final location of their destination. It is now proposed their process flow to be implemented taking into consideration the conclusions taken from the analysis performed:

- Inbound:
    - All the accessories are to be placed within a staging area in which the quality check is done. If the merchandise is already palletized, it follows to its corresponding storage type (which is always Rack storage). Otherwise, it is moved to another staging area where it is palletized, and then stored.
    - External production boilers: They are placed in the staging area and the quality check is performed. They are never palletized, so they go straight to their dedicated storage section in racks.
    - Internal production boilers entering the warehouse: As soon as they pass through the physical division from production, they are automatically ordered and picked up by operators to be then stored. They are not palletized.

- Outbound:
    - Accessories are picked up from their current locations and moved to a staging area where they are prepared for shipping within the other products that involve the same client's order.
    - All boilers: Same process as accessories.

Accessories

The accessories are small or mid-sized products (compared to boilers) of medium rotation. These are "complicated" materials for the company as their demand is very irregular and unpredictable. This forces to dedicate a great part of surface to their stock, which can turn out to jeopardize the stocking of other products.

In its majority, they arrive already palletized, in the 90% of the cases. For those that do, the only operation to be performed after quality inspection, is their stock in the final location. On the other hand, the others require to be palletized before being stocked. So an extra step is verified for these cases.

Their stocking area is determined as a rack storage (inside the internal warehouse and in one of the tendons with a rack), just as they are currently, with the difference that each of them is to be within specified unit cells for their fast and easy picking, which is today a critical problematic as explained before. Below, the schematic flow is shown:

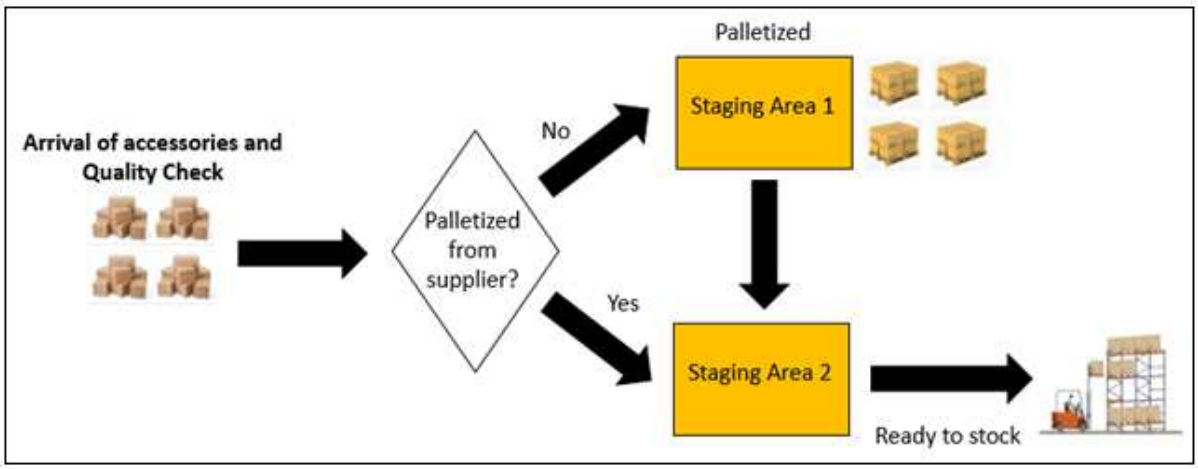


Figure 17 Accessories storage flow.

Boilers

Boilers can be produced inside or outside the plant. For the first ones, which are of a very high rotation, are to be bulk storage on the ground. This section is divided between other two internal brands. Plus, among this group, the company receives damaged products which require a further analysis in order to determine what to do with them, so they are to be located in a staging area called the Transit Point. For those coming from external companies, they are to be stored within racks in specific fixed positions, meaning that they are always in the same unit cell. The logic behind this choice, is the possibility to easily distinguish them from the internal production ones in the bulk. The remaining ones coming from other Italian companies, are stored within one of the tendons as bulk ground storage or in the transit point.

Boilers are only palletized for outbound processes. For inbound, they are stored by unit. Below, the decided schematic flow:

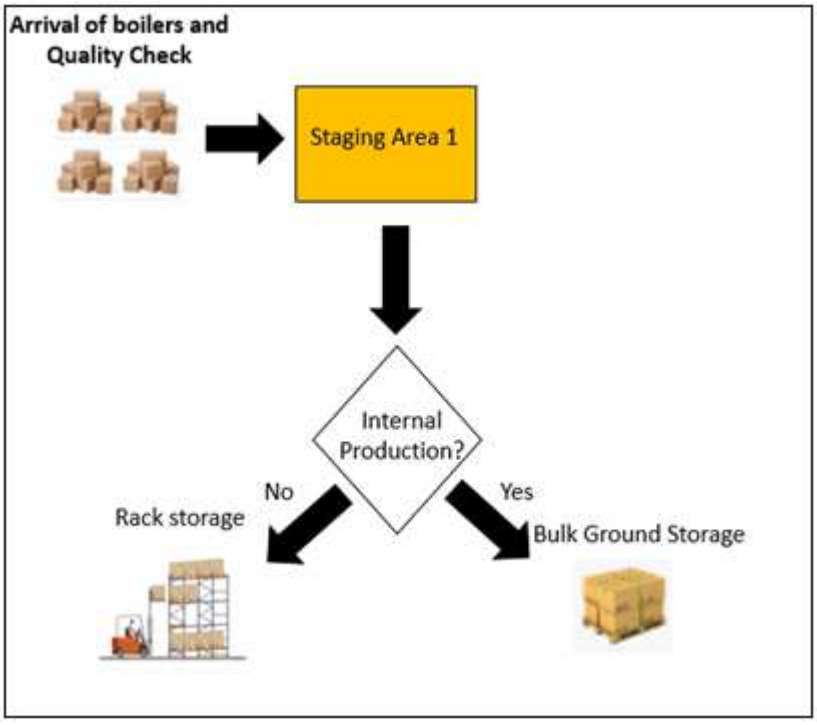


Figure 18 Boiler's Inbound Flow

For outbound, both accessories and boilers are to have the same flow. The only thing that varies is their picking position. Below the diagram flow:

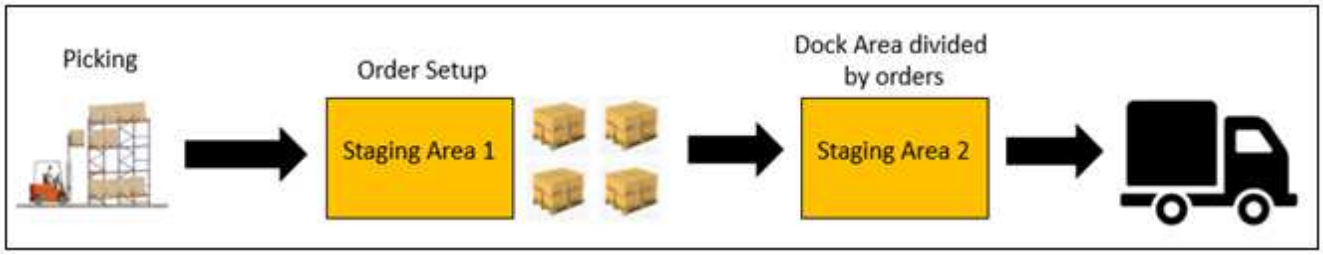


Figure 19 Outbound Flow.(Truck Icon made by Freepik from www.flaticon.com)

It is remarked that merchandise is to be normally picked up and stored in their respective pre-defined storage/picking sections. In case that these areas are completely full (which can happen in any peaks on the demand) a special area is going to be defined in order to stock this overstock. Only once this area is emptied, the picking should be performed in the others sections.

User Manuals

A special area is designed for user manuals. It is clarified that there is a user manual for each country with its official language. They are inserted into the final packaging of boilers before being shipped. They are to be managed with a cross docking strategy.

Those for the Italian market are having a specific storage type, diverse from all the international ones. For simplicity reasons, two storage types are located very close to the docking area, one for Italian Market and another for Transit Center. These are refilled from a third storage type, containing all the user manuals, which works as a buffer. The merchandise flow for input and output is the same as internal production boilers.

Final Warehouse Layout

Taking into account the previous analysis, a new design of the warehouse is developed. It is divided into more specific storage areas and unit cells (with its recipients) where in each of them, a certain material has the priority to be stored into. Also, a new rack structure is to be

installed, satisfying the new measures. All the different storage types and their unit cell locations (if any) are indicated with barcode tags for visual assistance and to make it easier for the operators performing the transactions with the barcode scan pistols that require this data.

The internal warehouse building and tendons continue in use, but different storage types are defined now, with a three-digit code where the first letter is either a G or an R (depends if it is ground or rack storage). Within each area, the storage locations can be unique[22] leading to a reduced precision for locating the product, or they can be multi bin[23], leading to a more accurate product storage.

Below, it is defined each storage type and their respective storage areas[24]:

- Internal Warehouse areas:
    - 916: Shipping section. It is the final staging area before loading the merchandise in their corresponding trucks.
    - OSS: Overstock location. If a product has to be stored in a certain area that is full, it is then stocked in this area. When a transport order is created, the system picks first the stock in this section if there is any.
    - LE0: Italian user manuals are stored in this section.
    - 910: Reception area. The products arriving to the warehouse are received in this section before they are prepared for palletizing. The quality check is performed here.
    - EM0: Internal warehouse reception section. The products are strategically organized and prepared for palletization. This is the first staging area.
    - IP0: Internal warehouse pallet identification area. This is the second staging area, before products are finally stocked.
    - 201: The merchandise here is being set to be shipped.
    - L00 (user manual's buffer): Foreign user manual stock. They are not stored in this position straight ahead. First they are stocked in L90 when they arrive in the warehouse. If they are not immediately used, then they are stored here.

[22] The location is the entire storage area, no unit cells defined.
[23] The entire storage section is subdivided into unit cells
[24] The structure is just approximated and only aims to providing a general idea. It varies regarding the real one, as the student is not allowed to provide the exact one.

The user manuals are picked from this storage are only if there is none left in L90.

- R00: Internal rack where accessories are stored. It is a multi bin section, which at the same time, divides the different locations in sub groups or areas taking into account the high and slow rotation of the stock.
- R21: Used only for external boilers. This is a multi bin storage section. Each product stored in this precise area is always stored in the same location. It is then called “fixed bin” storage section.
- R30: As the previous one, but for other external production units.
- G00: Ground storage internal area. Stock in this area is not going to be more than forty-eight to seventy-two hours until it is shipped.
- NAV: Merchandise returned by clients is stored here after it is determined as such. They are blocked for sales. As it is determined that it is not damaged, it requires confirmation to be set as a salable item.
- NDL: Damaged merchandise.
- NDS: Damaged goods provided by a supplier is stored in this section awaiting to be picked up and sent back.
- NDP: Damaged goods from the production are stored in this section.
- NHT: Hard tool products are stored here. It is internally called hard tool to the first finished good of a series of a new production. For security reasons, it is not salable.
- L90: Storage section used for cross docking of user manuals. As soon as they are received from the suppliers, they are stored in this area. They are shipped back away in no more than forty-eight hours. Otherwise, they are stored in L00.

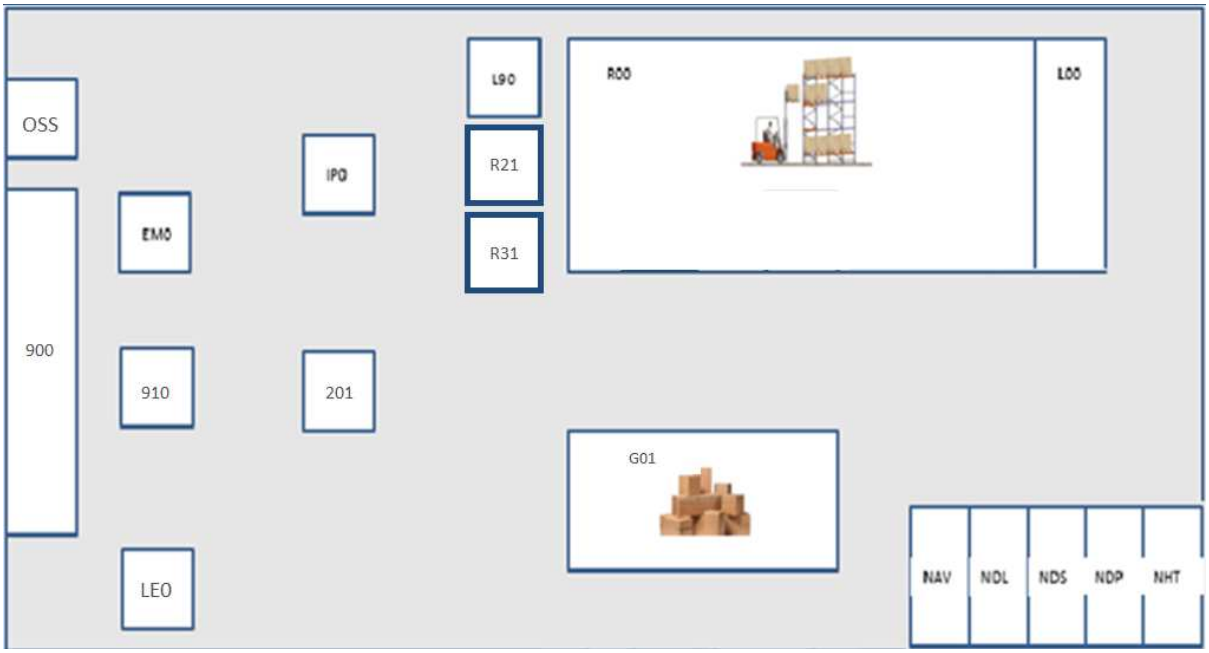


Figure 20 Overview Mapping of Internal Warehouse Storage Types

- External Warehouse Areas[25]:
  - R03: External warehouse rack storage. Both finished products and some accessories are stored here.
  - G05: External warehouse ground storage. It is managed with a single location but ordered in rows. Both finished and semi-finished products are stored here.
  - EMT: External warehouse reception section. It is the first staging area for products with final storage destination in tendons. The products are strategically organized and prepared for palletization.
  - IPT: External warehouse pallet identification area. It is the second staging area (like IP0) but from the external tendon.

[25] The structure is just approximated and only aims to providing a general idea. It varies regarding the real one, as the student is not allowed to provide the exact one.

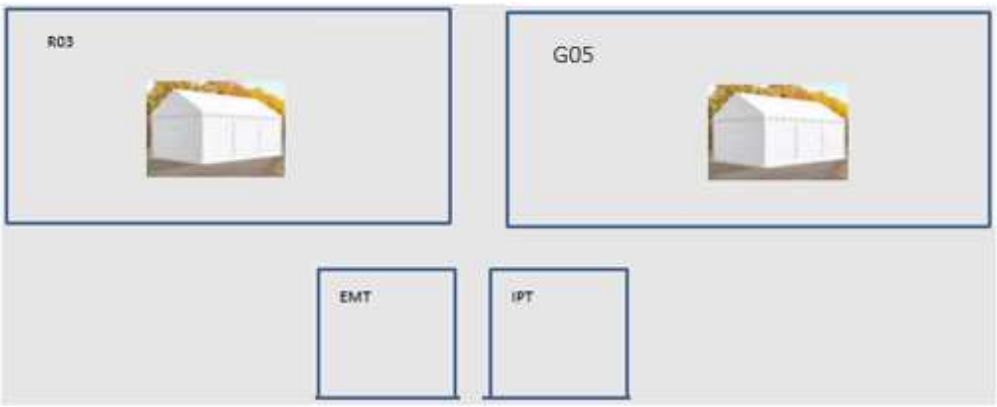


Figure 21. External Storage Types (tendons)

The WMS implementation

It is remarked that the previous warehouse layout is designed taking into consideration the functionalities of the software and what this one allows. The next step is to make them both match with the flow of the processes and materials of the warehouse. It is now explained the different physical flows of merchandise and its representation in the software.

Inbound

The WMS allows the creation of official acquisition orders, with which it gets to understand that an inbound activity is to be required for a specific amount and type of materials. Acquisition orders allow the buyer to know their confirmation or refusal, the time required for arrival and the incoming materials. Also, the shipping service provider is able to reserve his docking space in the time schedule provided by the system. Like this, it is possible in some cases for the WH operators to manually organize the available space and block the locations to be used for storage. In the usual circumstances, the put away strategies are activated and the locations to be assigned are automatically blocked. As soon as the merchandise arrives, the Material Document (Figure 23) is created and printed in the case that materials are not palletized. If the next stage is stocking, the put away list is also printed. This last one, orders the incoming stock with its location destination so that the operators follow them in the

specified order, guaranteeing that the least amount of journeys are performed, with the highest efficiency. It is remarked that every time that the operators are performing a radiofrequency transaction, they are using a pistol like the one in Figure 23 and scanning barcodes which are located in the black rectangles of the same figure. The pistols contain a user menu that they have been trained for using by the speaker along the KUT.

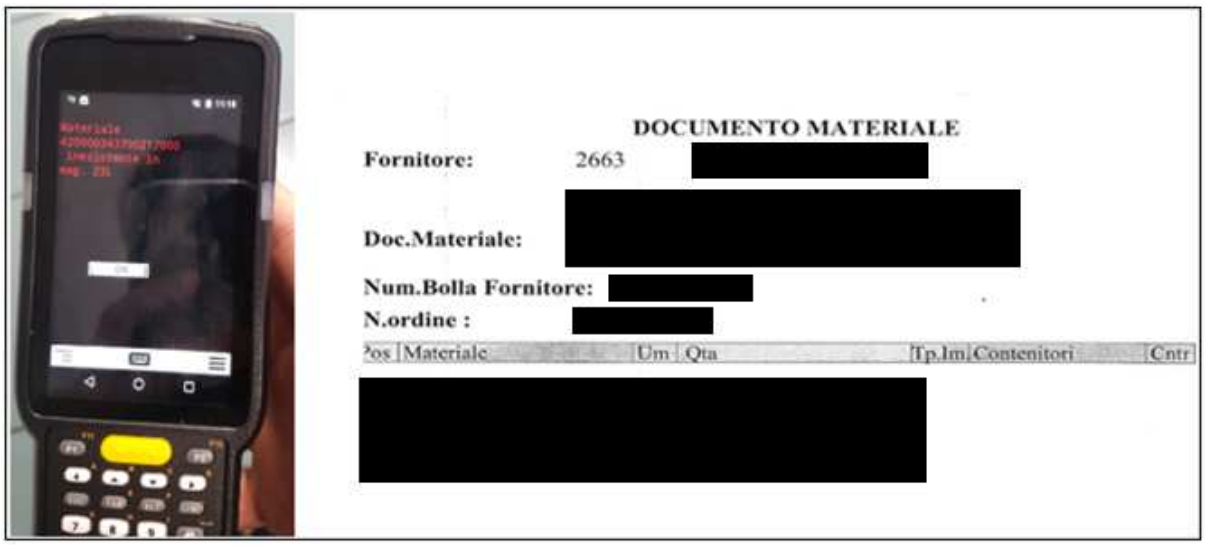


Figure 22. RF pistol used by operators (Left) and Material Document (Right)

It is also possible to perform the same activities allowed by the pistols using the WMS account of each operator in a computer, by executing the transaction LM01. In figure 24, the flow of this menu is shown and explained, in order to better understand the different merchandise flows that take place.

- Entrata Merci (Merchandise inbound): When the materials arrive in the warehouse, they are either positioned in EMT or EM0, depending if they are or not palletized, which is indicated with their special movement code[26]. To make the passage from this storage type to IP0/IPT, the option 1 (Smistamento) is chosen by the operator and chooses the corresponding option. This one generates a TO from one storage type to the other one. To complete the TO, the operator scans Material document number.

[26] Its influence in the process is to be better explained in the pages to come

Once this is done and the material is in the IPX[27] location, the handling unit (Figure 24) data is printed and stuck in the pallet.

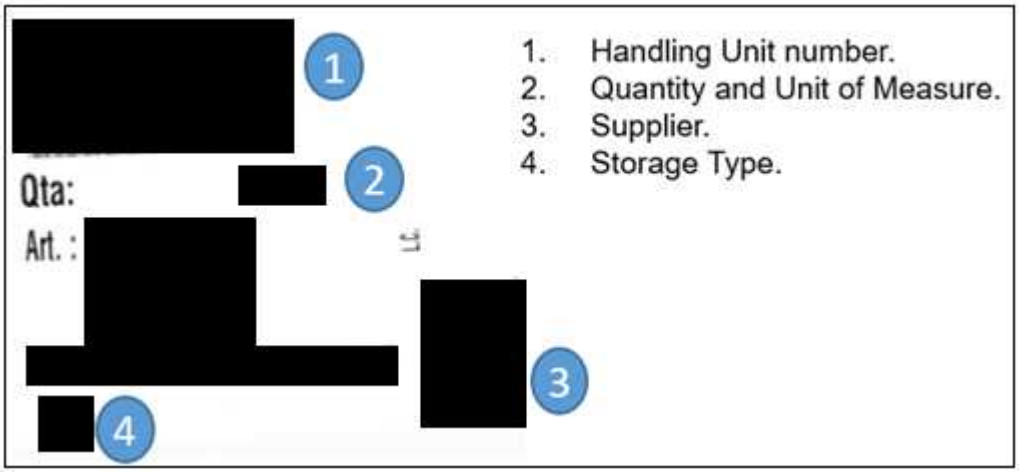


Figure 23. Handling Unit Data

To do the final storage of the palletized material, instead of choosing the smistamento option, the operator chooses Stoccaggio UDC and scans the Handling unit's barcode number. This generates a TO from the actual storage type, to the final destination location picked up by the system by means of the predefined put away strategy for that material.

- If the operator is required to perform an internal handling activity, such as the material transfer between two storage types normally used for final storage, he should press the option 2(Trasf. interni). Among these different values, he is able to choose between the different materials such as accessories, boilers, user manuals and complete handling units. Once he chooses the desired option, he must insert the material/handling unit number and scan the future location.

  The reason for which the operator requires to differentiate which kind of material he is moving, is because the 7-digit material number is not randomly found in the printed barcode of the boilers, user manuals and accessories. Instead, the barcodes are presented as in Figure 25.

[27] IPX= IP0/IPT

Figure 24 Accessories and Boiler's barcoded material numbers.

It is observed by the speaker, that in some of the cases such as in those in the figure 25, from the entire barcode, only the first 7 digits (starting with a 3) represent the number with which the material is uploaded in the database for accessories. In the case of the user manuals, their barcodes come from suppliers with twenty-eight digits, where the first fourteen correspond to their identification number and the rest are all zeros. For the boilers, the last seven out of 21. It is then proposed by the speaker to perform a subroutine after the barcode is obtained in order to filter the correct data that is required for searching the specific kind of material in the database. On the negative side, such a design is not defined in the initial Business Blue Print, so proof of its simplicity and understanding by the business side is required to be shown to avoid extra expenses.

Even if it seems as the most efficient solution, another one is proposed. Specific transactions for each product are performed that read the entire barcodes and keep only the useful sections to find the materials. This slows down the process, as the operator is required to perform one extra step regarding the previous process, but it is as well safer in the sense that the operator's possibilities to make a mistake are as well reduced.

- Uscita Merci (Merchandise Outbound): In this case, the operator is performing the outbound of the materials. He is required to insert the number of the "Consegna" that he is in process of completing. This one, is linked with the picking order, so the operator is required to scan the materials that he is picking from its locations and are to be packed and prepared for shipping. Then, the scan of each material's SN is required for confirmation the outbound.
- Uscita TP: For materials that are in the Transit Point storage type, there is a mixture between those from the Italian Market (MI) and those that are to be delivered abroad (CT). In this particular case, the operator is required to scan the barcoded material

number of the product and then its serial number to complete the outbound operation.

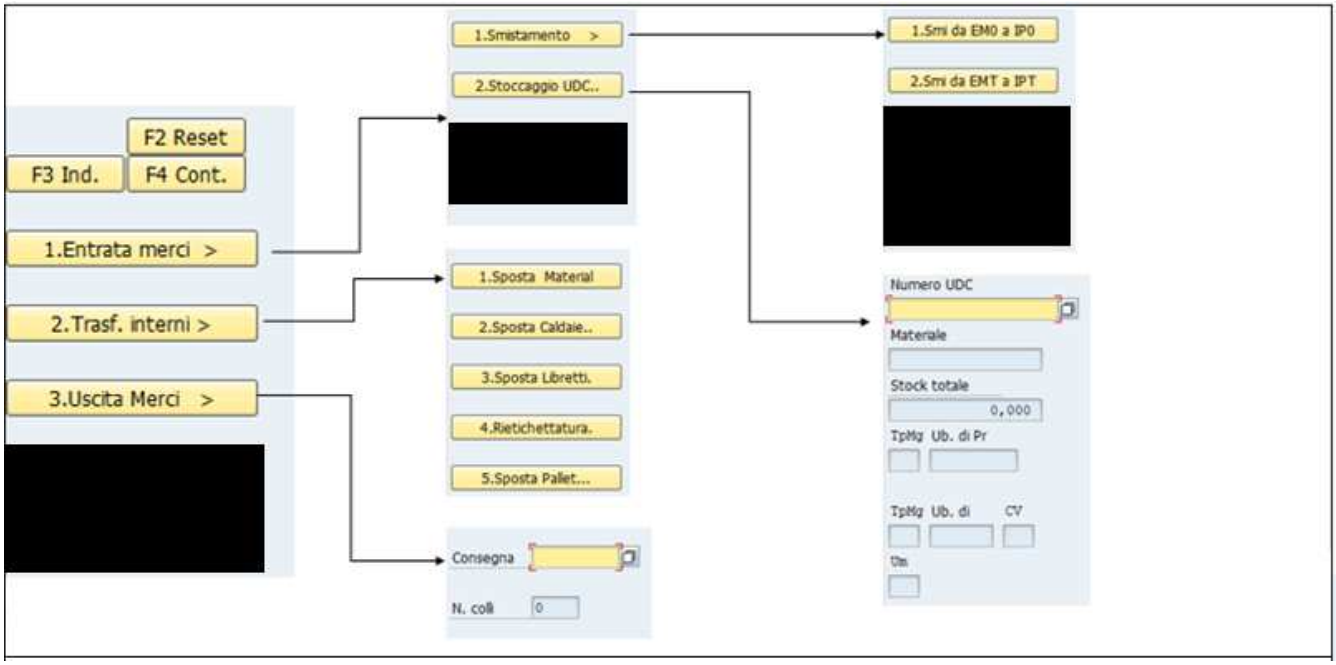


Figure 25. RadioFrequency User menu.

External Accessories

This is the most complex storage flow. When accessories arrive to the warehouse by means of an acquisition order from an external vendor, they are sent to their corresponding staging areas, which can either be EMT/IPT (if their final storage type is in a tendon), or EM0/IP0, depending if they are or not palletized. If they are not palletized, they remain in EMX until an operator moves them via Radiofrequency transaction to the pallet area IP0. If they are already palletized, they go straight ahead to IPX. Here, the merchandise is manually palletized by the operator and the handling unit is formed. The system automatically prints the barcode tag with the handling unit's number to be further identified and it is stuck in the pallet. Finally, it is stored in its location.

In terms of software flow, the materials are positioned in their staging areas with their dynamic location equal to the storage type as soon as the WH manager receives the order. If the special movement code is such that it indicates the system that the material has

predefined pallet data, this one checks the MMD and collects this data, positioning the arrival order in the IP0/IPT storage types divided in pallets of the specified amount which are to be handled by the system as single handling units. The handling unit data is automatically printed.

On the other hand, if the special movement code indicates that the materials have no pallet data, they arrive to EM0/EMT and so the Material Document is printed. Then, the materials are moved to the palletization storage type by means of a TO from EMX to IPX. It is now manually inserted with the pistol by the WH manager or operator the palletization number and the data is printed. After this, the system generates another TO to store the Handling unit, so the system makes use of the predefined put away strategies and stores the material in its final cell location into one of the racks of the R03 tendon, R20 or R00. The flow is shown in Figure 26.

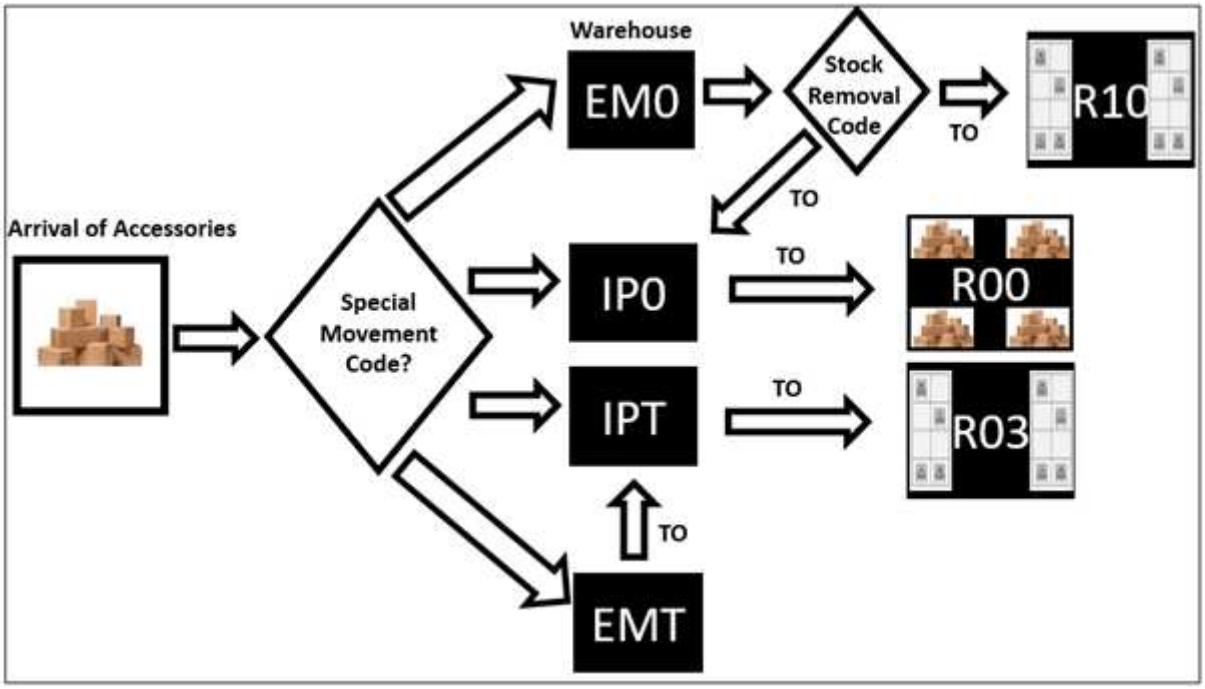


Figure 26 Accessories Flow

Internal Production Boilers

As explained in previous sections, the flow of this material is from production to the warehouse through the barcode reading at the MES stage, where they are automatically ordered and picked up with the forklifts to be left in the bulk ground storage area G00.

In terms of software flow, the products enter the warehouse thanks to the Order Management. After this, they are automatically “moved” in G00 storage type. The flow is as in figure 27.

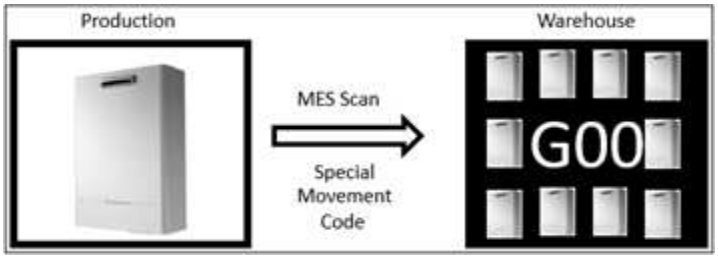


Figure 27 Internal Production boiler's flow

External Production Boilers

In this case, when the products arrive in the warehouse, they are left in the staging area 916 for quality check and are then sent to EM0/EMT, where the Material Document is printed. Then, when the operators put away the material, depending on the boiler’s origin brand, its final destination is the R13 or R20 storage type. They are not palletized.

In the software’s “view”, when the material arrives, the warehouse manager makes the reception of the acquisition order and so the system positions these materials in the EMT/EM0 storage types, with dynamic locations equal to the acquisition order number. Through a Radiofrequency transaction performed by the operator, a new TO is created to transfer the materials from their corresponding staging area, to the final storage location. The confirmation of the TO is done by scanning the physical barcode tag in the locations. The flow is shown in Figure 28.

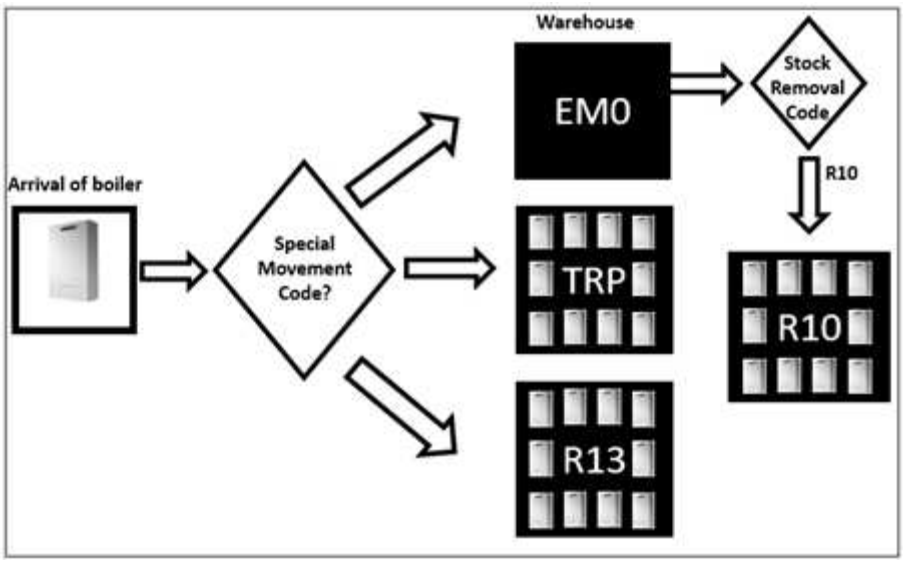


Figure 28 External Boiler's Flow

Damaged Boilers

All damaged boilers arrive in Osimo after being received by other plants of the Marche region such as Cerreto and Genga. As soon as they arrive, they are left in their staging areas and then moved to their corresponding NXX[28] storage types.

In terms of software flow, the plant passage, diverse from an intercompany acquisition order, is only done through a TO, created by the warehouse manager of the sending Italian plant. As soon as this one is confirmed, which should be done by the receiving warehouse manager when the merchandise has arrived, the boilers are virtually transferred within the software to the Osimo warehouse into the EM0 staging area and a Material Document is printed, with a dynamic location equal to EM0. After this, via radiofrequency transaction, a TO is opened by the corresponding operator taking the order to transfer the material from EM0 to its final NXX. The confirmation takes place when the operator scans the barcode of the final location. The flow is represented in Figure 29.

[28] NDL, NDS, NDP. One of the storage types receiving damaged merchandise

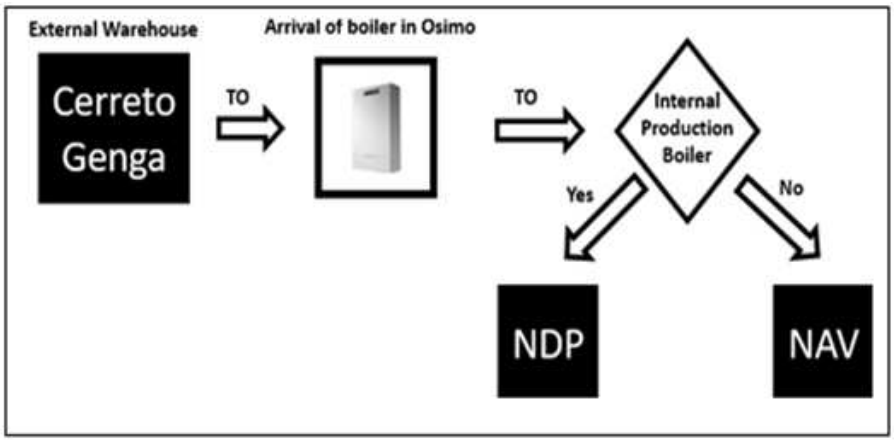


Figure 29 Damaged Boiler's Flow

Hard Tools

As previously explained, Hard Tools are the first units of a new production batch. To differentiate them from the rest of the production, they are marked up with a red line in their carton boxes and when they pass by from production to the WH, they are left in the NHT storage type area.

The software flow is the same as for any production boiler, that is left in G00. Then, a transfer order is automatically done by the system that moves a boiler from G00 to NHT. It is remarked that this kind of movements are of a very low frequency (2-3 times a year). The flow is shown in figure 30.

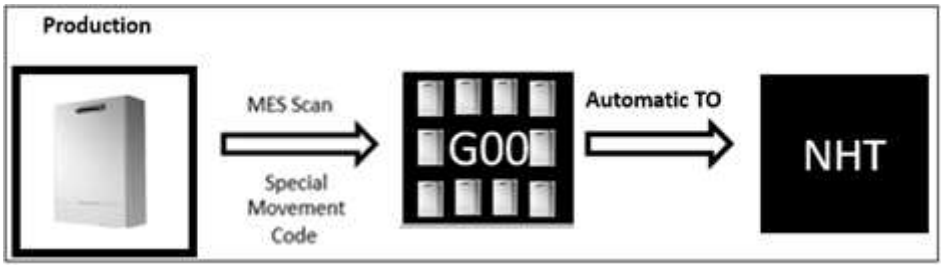


Figure 30 Hard Tools flow

Outbound

Outbound processes in the warehouse are to be born due to acquisition orders performed by clients or other plants of the group (internal clients) that arrive through the WMS. When the warehouse manager decides to take control of a delivery or acquisition order through his user interface, the software automatically builds and prints the picking orders with the detailed amount of each product and its location. It is remarked that, while building the TOs, the system takes into consideration the picking strategies (according to each material) and orders the items to be picked in such a way that the operator is required to do the least amount of journeys as possible. In the outbound case, there are only two variables of flow whose only difference is either the external tendon or internal warehouse.

Outbound from Materials in the External and Internal Warehouses

The products are picked by the operator from their corresponding order and location and are moved to the area 201, where they are packed and set up for shipping. Then, they are moved to the area 910 and are organized with all the items of the same order ready to be shipped. Operators insert the user manuals in each package, scan the merchandise's SN and load the materials on their corresponding trucks. The only difference between external and internal products, is that those stored externally, need to be picked up and brought inside to the area 201.

In the software flow, as soon as the acquisition order is taken care of, the picking list and the TOs for each product that needs to be moved from its current location to the storage type 200 is automatically generated. The confirmation of the TOs is automatic as soon as the operator scans the material number and location of each product being picked up. After this, via the pistol's menu, the operators create a TO that moves the merchandise from the area 200 to the 910. The outbound of the materials is completed for the system as soon as the operators scan the SN of the products located in the 910 storage type. It is not relevant for the system if the products are stored in the external or internal warehouses, it only picks up

the merchandise from its current storage location and moves it to the area 200. The flow scheme is shown below:

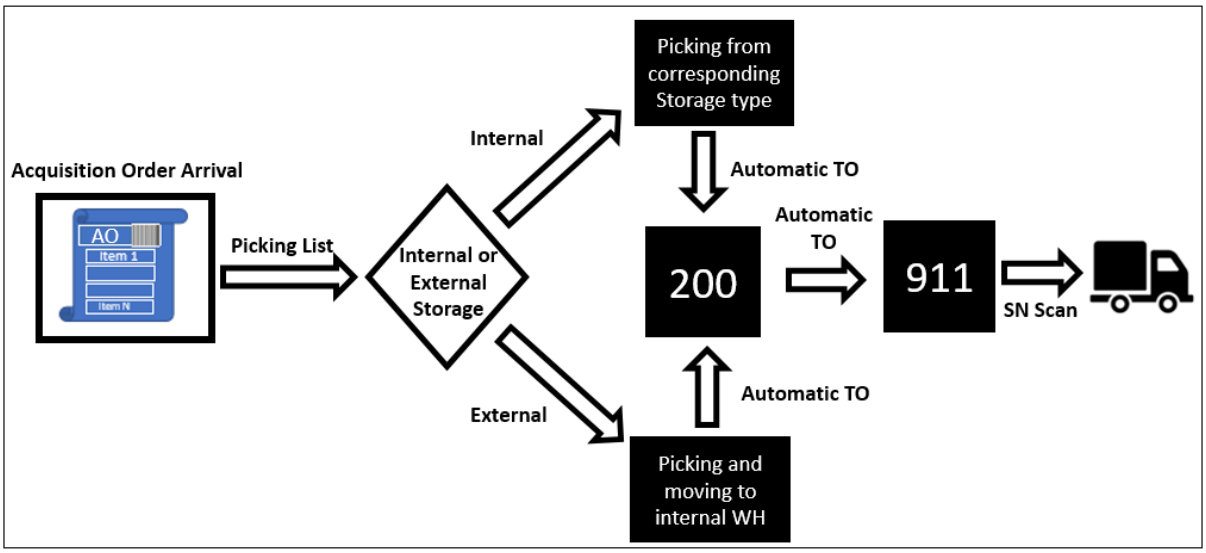


Figure 31 Outbound Flow of Materials.

Software Set Up

In order to be able to exploit all of its benefits, the correct software set up has to be performed taking into consideration the previous warehouse layout data and the flow that each material has to perform for inbound and outbound. It is then required to upload all the storage types and the different materials with their anagrafic data:

- Unit cells (Locations): Their customization regards the different characteristics of the products that can be stored inside them. When the location is created by means of the LS01N transaction, the view shown in figure 32 appears and the following data has to be defined:
  1) Warehouse Number: It makes reference to the warehouse in which this location is going to be. For Osimo's warehouse, the number 23L has been chosen.
  2) Storage Type: In this particular case of the rack accessories (whose locations require the most data in comparison to any other storage type) it

is chosen the R00, where R stand for Rack and 00 as it is the first rack in the internal warehouse.

3) Storage Bin: It is the name of the location, unique for each location in each storage type
4) Storage Section: It is decided for accessories stored in the R00 storage type, that storage section should be defined. The criteria for the division is the size and rotation of the accessory. The table of values can be observed in the Figure 24.
    a. HA0: Stands for high rotation and high altitude material. These consist in the higher half of the rack close to the 916 section (Figure 22). Bigger accessories with high rotation are stored here,
    b. HB0: Stands for high rotation and low altitude material. Small accessories are stored in this section. They are the lower half of the R00 rack, closer to the 916 section.
    c. LA0: Low rotation and high altitude materials. Biggest accessories with lo rotation are stored here.
    d. LB0: Low handling and low altitude material. Smallest accessories with low rotation are stored here.

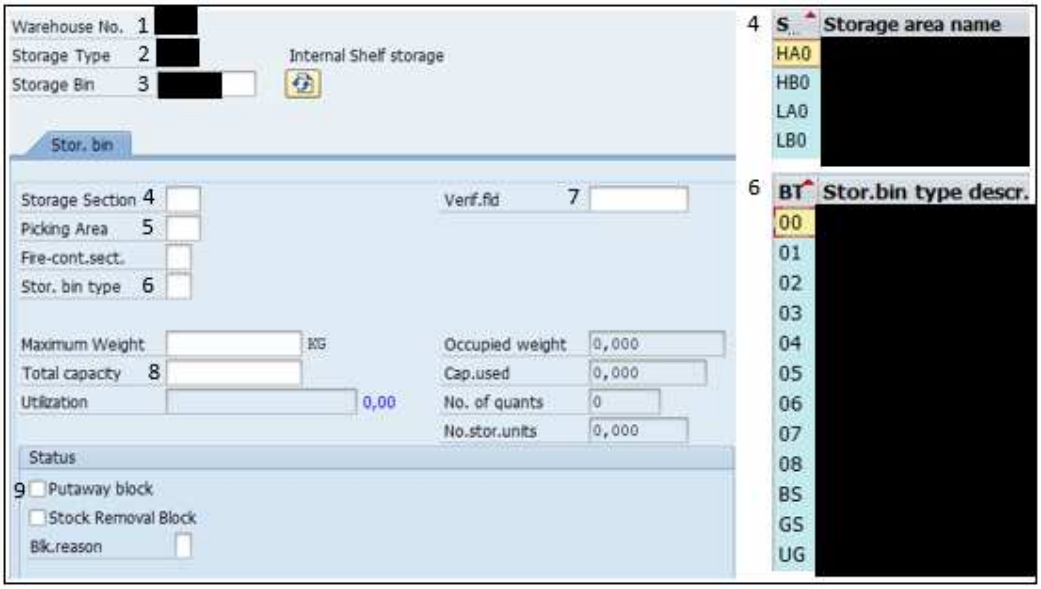


Figure 32 Creating a new Location

5) Picking Area: It is defined as the storage type.
6) Storage bin Type: This value is used to specify the allowed type of pallets that can be stored. It depends in the physical characteristics of the locations.
7) Verification Id: When a picking or put away activity is performed, the system requires the confirmation (for security) that the material is effectively picked up from the location that is ordered by the system, otherwise, mismatches take place. The operator is required to insert the location verification code that consists in the storage type and the name of the location. For the example of figure 32, it is “R00 A1-090”.
8) Total capacity: This field defines the maximum capacity of materials that can be stored in this location.
9) Put away/Stock Removal Block: If the first field is ticked, the system forbids the storage of a material in the location. If Stock Removal is ticked, picking in this location is not allowed.

- In Osimo, different put away strategies are to be applied according to the physical characteristics of products such as weight, dimensions and rotation. Also, the physical distance between the staging areas and the list of possible location destinations is taken into consideration. The put away strategies implemented in this project are the following ones:
    - Manual: The system determines the WH type and the operators choose the bin. This strategy requires the location scan through a transaction with the pistol.
    - Fixed Location: The system automatically determines the Storage Type and the location. It is also required the scan of the location in order to confirm that the transaction is complete. In the anagrafic data of each material that is stocked using this strategy, it is necessary to indicate this location and the maximum quantity of this material that can be supported inside it.
    - Generic location: The system determines the Storage Type and proposes the first bin (which is the only bin, as in this case, the entire

storage type corresponds to a bin). Materials that are stored in Ground storage sections use this strategy.

- Empty bin: The system chooses the storage type and chooses a list of empty bins that are compatible with the received pallet. To do this, the locations must have their measures properly defined and an internal list in which they specify the type of pallets that are compatible.
- Stock adding: The system proposes a location in the storage type that already contains the material to be stocked. Capacity control is a must in these cases.
- Bulk storage: Used for ground storage. The system determines the storage type and the location. In this case, the location is a specific line in which the product is to be stored.

- Material definition and update: Each material that is uploaded and working in MM has a lot of data that is still useful for WMS. The difference is that now, a lot more of information is required about a product in order to be able to manage it in the most efficient way for the warehouse activities. A material view is shown and explained below:
    1) Material: Unique code identification of the material.
    2) Stock Removal: Indicates where the material is to be picked up from.
    3) Special Movement code: It is used to determine the first staging areas that the material has to be addressed to.
    4) Palletization data: This field is to be set by default as 9999. It is only to be changed for materials whose palletization data is known. The quantity is the amount of quantity per pallet. Like this, the total amount of materials arriving is divided in pallets of the specified amount. UM field allows to specify the unit of measure (always pieces) and UMT is the type of pallet that is arriving. This value is to be compared with the location's storage bin type to ensure that the pallet fits correctly in the destination location.
    5) Storage bin Stock. These fields are only to be completed for materials that are stored with Fixed Bin strategies. For Osimo, only

materials stocked in R10 are stored with this strategy. All other materials stored in other storage types, have these fields empty.

With all these parameters correctly set up, the software is completely functional.

Barcodes and RFID future implementation and business case

Current use of Barcodes

Four different printers are introduced within the warehouse connected to the network through wireless connection. They receive the order of printing whenever a transaction is customized to do so.

One of them is located in the tendon, another one within the EM0 location, the third one close to the R00 storage type and the last one inside the office of the warehouse manager for manual printing, in case that an error takes place in the automatic printing.

Limitations solved by RFID

During outbound processes, it is analysed by the speaker that the scanning of boilers before being loaded on the trucks, consumes a lot of time. It is around four minutes for every one hundred items. During the peak production periods, it is over three hours. A possible solution proposed by the speaker, is the use of RFID in order to make the process smoother.

Proposed application

After contacting consultant companies for information regarding implementation costs and the best practices, the speaker arrives to the conclusion that the following key aspects are to take into account in order to develop a viable solution to be presented to internal managers:

- Key tracking points of the merchandise: It has to be determined where it is required to position the RFID gateway readers that are registering the passage of the merchandise through them. Each tracking point of interest requires a gateway, which for this case as a pilot point, is to be the outbound stage. This has a direct impact in the CAPEX and in the Payback period(PBP).
- Tag unit cost: This depends in the quality of the required tag, which is linked to the application itself. The Osimo warehouse is an area with high Electromagnetic interferences, given that is located very close to the production site and forklifts are continually in use. Also, boilers contain over 70% of metal, which block the magnetic signal passage. Regarding the quantity discounts, in this industry, high volume is considered when the production consists in a demand of over 3 million products. According to the consultants, the tag costs can vary among 0.06-0.11 €. This aspect is highly impacting in the OPEX. A solution needs to be furtherly analysed.
- Gateway unit cost: Like tags, their cost depends on the application. It is remarked by the consultant that the amount of antennas, their frequency and power is going to impact in the quality of the readings. The price of a suitably shielded gateway can vary between 12k-20k € depending on the quantity and required power, which has to be determined with an experimental field analysis.
- Tag application: The tag has to be inserted within the packages at some point before arriving to the first tracking point. This has to be done either during production and packaging[29] or by the warehouse operators[30].
- Time and cost reduction with the application: As previously analysed, this solution brings a time reduction of over 3 hours in high demand days. This produces savings of at least one warehouse operator per shift and so an important direct cost reduction. Plus, it makes the process flows smoother and so cheaper for the external service provider, raising as well the client satisfaction as delays and mistakes in the merchandise should be reduced. Also, the 3PL is paid by single scan, which with RFID are not necessary for outbound procedures.

[29] Incurring to extra CAPEX expenses.
[30] Impacts in time savings.

Complete RFID governed warehouse

A scheme of a complete RFID governed warehouse recommended by consultants works as in figure 32:

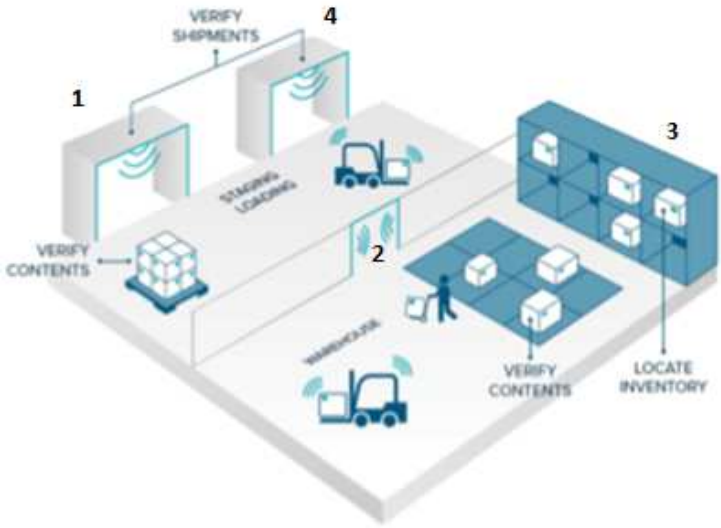


Figure 33 Complete RFID Warehouse layout

1. Inbound gateway: In an ideal WH structure, all elements enter the warehouse from the supplier with their corresponding RFID tag containing the required information. The data is read when products pass through the gateway and they are uploaded in the corresponding WMS software.
2. After the first staging area, products are directed to the storage area. This physical translation is registered when the products pass through the second gateway.
3. Another possible feature, very useful in case the company is able to invest on it, is the insertion of RFID readers in each unit cell. Like this, the storage of the product is automatically tracked. This guarantees the highest possible traceability both for picking and put away.
4. Outbound Gateway: Registers the outbound of products. It allows to link each shipping order with the exact products that are being sent. This

information is very useful for traceability and for the Customer Relationship Management.

As anticipated, the speaker is able to discern that the scanned products in the outbound, are only boilers. During inbound of external suppliers, as a consequence of quality checks and palletting, the scanning activity is not so crucial. Neither it is regarding the inbound of internal production, that is done automatically by the software when the machine in the MES is reading the SNs.

Taking this into consideration, it is well-thought-out that a pilot can be designed to be used only for the outbound of products. This is due to the fact that it implies lower initial costs, and is solving the most critical activity. Plus, it has to be considered that in such a structure, where all the stock is barcoded and the working processes are deeply established to work in this way, the passage to RFID must start slowly and gradually taking over the different stages of the warehouse.

In this way, only internal production boilers and those coming from external companies are inserted an RFID tag with their SNs and when they are being shipped, this data is read by the gateway. The RFID tags in the production boiler are to be inserted during the passage from production to the warehouse as a first pilot, in order not to affect any other part of production. In this way, the data is read and an RFID tag is printed, being stuck to the external carton package of the boiler by a machine.

Required deliverables and Business Case

It is demanded a market research regarding the technical characteristics that the tags and gateways should count with for a possible implementation. The main objective of this is to instruct the management with a better understanding on the subject.

In order to do this, the speaker performs research in bibliography, papers and based on his previous knowledge, suggests that the choice has to be among an UHF or an HF RFID tags. It is cleared up that the readers and tags must be tested simultaneously and in the environment

where they are going to work at. This is because, RFID tag's air interface[31] (Se Won Oh, 2010) varies according to the surroundings and the working surface where the tag is to be stuck on.

It is also proposed by the management of the plant to develop an Excel model that can allow the testing and modification of different parameters in order to evaluate the economic feasibility of the project for the outbound stage of Osimo and another one considering that every warehouse of the group counts with them. This excel files can be found in the Appendix 2. The second case is then considering that for all the secondary DCs, Gateways are installed to read the incoming production from Osimo, the case becomes feasible as this impacts in a cost reduction of the workforce in the other warehouses and their scan costs are much higher than those in Osimo. Their PBP is very acceptable (below 3 years). A problem that emerges for this, is warehouse moving (as explained before) along time. In this sense, it is mandatory that installed gateways can be easily dismantled and re-installed in future warehouses.

Finally, it is proposed a third case scenario, after the speaker analyses the cost of the services of the 3PL in the different Italian warehouses, being one of them, the Borgo Tufico's finished products warehouse. In this last one, the actual cost of the manual scans performed by the operators and handling activities are very high, so their reduction is very promising for a fast PBP in an implementation of this type.

The PBP results (in years) of the different cases is calculated below taking into account a fixed Handling saving in the outbound activities of 3% and a total production of 200k units in Borgo Tufico and 700k in Osimo[32]. The tag and gateway cost variation is analysed:

Borgo Tufico

Handling 3%

	Tag cost					
Gateway	€ 0,11	€ 0,10	€ 0,09	€ 0,08	€ 0,07	€ 0,06
€ 20.000,00	1,88	1,80	1,72	1,65	1,58	1,52
€ 18.000,00	1,78	1,70	1,63	1,56	1,50	1,44
€ 16.000,00	1,69	1,60	1,53	1,47	1,41	1,36

[31] The environment that separates the tag with the reader.

[32] Data for simulation purposes in all the calculations. It is not actual real values, as the student is not able to provide them.

€ 14.000,00	1,59	1,51	1,44	1,38	1,33	1,28
€ 12.000,00	1,49	1,41	1,35	1,29	1,24	1,20

Table 1 Borgo Tufico's PBP.

RFID in Osimo and other DCs

Handling 3%						
	Tag cost					
Gateway	0,11 €	0,10 €	0,09 €	0,08 €	0,07 €	0,06 €
20.000,00 €	5,55	3,91	2,99	2,40	1,99	1,68
18.000,00 €	5,08	3,57	2,72	2,18	1,80	1,52
16.000,00 €	4,62	3,24	2,46	1,97	1,62	1,37
14.000,00 €	4,15	2,90	2,20	1,75	1,44	1,21
12.000,00 €	3,68	2,56	1,94	1,53	1,25	1,05

Table 2 Osimo and other DCS Gateways PBP.

Osimo's specific implementation

For such an implementation, it is considered the system structure that was specified in the previous RFID section, where a front, back end and a middleware are present.

Regarding the back end, it is required to continue with the WMS software, as it is not viable to consider any sort of modifications in this sense. Like this, this one it is to be the master of the whole process. Its main activity in this sense, is to process the outbound of the correct products. Today, an outbound order is handled by the WMS inserting the order's number. In this way, the system knows the SNs of the boilers and handling units that are leaving the warehouse, so it is to be used for checking the correctness of the products leaving and emitting an alert in case one of them is mistaken or misread.

The middleware is to be the linked between the WMS and the hardware reading the RFID tags through the LAN network and format the data with the correct protocol communication. The upgrade module from EWM, already contains this middleware and would simplify this phase significantly, but is not an option for the moment.

Plus, this middleware is going to be used as a filter when reading the tags by considering the power with which the signals arrive in the reader. If they are below an expected power value,

they are discarded, as they are considered to be in a close area from the reader, but not in the pallet. This is a defensive measure in case any neighbour tags are read, which would be less necessary if the gateway was highly shielded. Also, using the known SNs that are going to pass through the gateways, the middleware should contain a routine that matches the arriving values with those expected and emits an alarm if any read tag above the power soil is read or if there is a missing item that is not in the pallet or misread. This should be warned with an alarm lighting up a red light in the gateway and a user interface explaining the problem.

For the front end, gateways' and tags' working frequency need to be properly selected. For this, it is required to consider many things of the working environment and, as already said before, must be certified with field testing. The different aspects to consider are:

- Electromagnetic Interferences: An industrial area is usually very polluted in this sense. The production plants some meters away, but inside the warehouse there are many forklifts constantly working and that will pass through the gateways, making communication between reader and tag very difficult. In this sense, HF tags are more robust.
- Local requirements: In Italy, UHF cannot exceed a magnetic field of 150 nTesla, while 400nT for HF for a working site such as the warehouse. The effected radiated power can't exceed 2 W ERP. This limits the use of UHF significantly, reducing one of its main features, which is its ability for longer distance reading against HF's.
- Required reading distances: The margin between the forklift passing through the gateways has to be at least of thirty cm. In this sense, UHF can provide higher reading margins. For HF on the other hand, it is tougher to find them in the market, but it is possible to find tags with reading distances of fifty cm or even one meter[33].
- Material on surface reading: The tags are stuck on a carton box, which contains inside high quantities of metal. This is a complication due to the reflection that is produced and reduced the possibility of reading a tag that is misplaced and not facing the antenna. In this sense, HF tags are more robust, as in the first point, they are less affected by their surroundings.

[33] Always depending in the environment where the tags are working.

- Required quantity of simultaneously read tags: The pallets usually contain eight units. So, simultaneously this is the amount required to be read. In this sense, UHF and HF both deal with this aspect satisfactorily. In the case of UHF, it is remarked that the readings can be taken up to over a hundred readings.
- Memory bytes: It is necessary to store the SNs of each product. These ones contain 21 numbers, that if stored as ASCII, will require one byte per character. In the market, both tags can be found with a user memory of around 64 bytes and higher.
- Reading and writing in memory: Preferably for safety reasons, it is recommended to use a Write Once/Read Many tag. Its main advantage is the fact that the it guarantees that the initially written serial number is not to be changed.
- Antennas: They can be either directional or omnidirectional, but these are to be better tested in the field study.
- Communication requirements: Independently of the frequency, it has to be considered as well if a passive or active tag is required. Given that it is not necessary that the tag communicates in any other moment but when it exits the outbound, a passive tag is all that is required. Plus, the costs of an active tag would make the implementation unfeasible.

As a summary of this, the speaker suggests to perform the tests with UHF antennas and regulate their power in order to confirm the feasibility of the readings. If this power is within the regulations and desired accuracy of above 95%, it is then the best option. This is because, thinking in future projects, UHF can allow the Inventory activity to be done practically in much faster, considering the high amount of simultaneous tags that can be read in each section and its reach. With HF, this is not possible as in the best conditions it can be expected a reading distance of no more than 1.5 meters. Anyway, given to the high influence of external factors that affect UHF, it is likely that this option does not end up being feasible or that it requires very expensive and extra shielding for the readers that raise its cost significantly and not feasible in this sense for the business as a pilot project.

If this is the case, HF is the option. This is thanks to its robustness towards external conditions and the fact that the Italian restrictions are much less severe with this technology. So, as a pilot project, it still works considerably well. The results of the proposal performed by the speaker are presented in the results section.

Proposed KPIs

The required data and the recommended timeframe for the measurement of the KPIs proposed by the speaker is presented below. The formulas have already been presented in the KPI section.

Put away Productivity KPI

To be measured every three months. To obtain the volume of goods, it is to be obtained the good's type **i** amount stored in the time period from the WMS operation history and multiply them by their corresponding volumes.

$$\sum (Amount\ of\ goods\ type\ \mathbf{i}) * (Volume\ of\ \mathbf{i})\ (M3)$$

This is done for each product and all added up to be divided by the amount of working hours in the time frame and by the total amount of operators that worked each day. This results in the total volume that can be handled by each operator per day.

Put Away Accuracy KPI

To be measured in quarterly basis. Like with the previous KPI, it is possible to check the amount of products that are stored in the time frame. Every error is to be reported to the manager. According to the speaker's research, this value should be around 99% with the implementation of the WMS.

Space Management KPI

It is a good practice to do the measure during high peak demand periods. This is an internal KPI and depends on the structure of the warehouse. If this one is changed, its new values need to be adjusted so as to be compared with the previous ones.

It is obtained the total volume of goods stored in the warehouse, divided by the constant surface of the facility.

Replenishment Efficiency KPI

It is recommended to do these measures after the time elapsed of forecasted demand is over. The value shipped matches the total price in which the goods are sold, while the value requested consists in all the value in orders in the timeframe. This KPI is affected by many different aspects of the supply chain, such as the accuracy in demand forecast, the production line and in the case of the warehouse, allows to be certain that products are being replenished in time in their handy locations. Otherwise, products are not available and orders have to be postponed or even cancelled by the client.

Rate of Return KPI

It is recommended to control this values at least three times a year, as it is a client oriented KPI and an indicator of the service provided. The units returned are those under dispute, with respect to the total amount of units sold. It is suggested by the speaker to calculate this one both for damaged goods and for mistaken/wrong quantities, in order to discern where the problem is in a faster way. To get this information, it is to be uploaded in the “Reso” order of the product in the system the motive of the return which allows then to filter these values in order to obtain their amount.

Results and Discussion

KPI improvements

After three months of the implementation of the project, the first measures are performed. Regarding the KPI objectives, they have been satisfied in most of the cases, with improvements varying around 25 to 30%. The highest improvements are found in the PiP and PA. In the cases of SC and IRA, values are maintained with no variation, which is within the expected values. The speaker is not allowed to provide the exact results in each area, but the expected improvement estimates are presented in the table below.

KPI	Calculation	Measure Analysis	Suggested Frequency	Estimated Improvement
Picking Productivity	$PiP = \frac{Time\ Required\ (minutes)}{Amount\ of\ handled\ rows}$	Row pick up time	3 months	30%
Dock to Stock	$DTS = \frac{Number\ of\ unloaded\ positions\ items\ in\ time}{Number\ of\ total\ position\ items\ to\ be\ unloaded} * 100$	Time from dock arrival to storage	3 months	30%
On Time Picking	$OTP = \frac{Number\ of\ shipments\ picked\ within\ the\ time\ frame}{Total\ number\ of\ required\ to\ pick\ shipments} * 100$	Orders ready in time for delivery	3 months	20%
Inventory Record Accuracy	$IRA = \frac{Absolute\ value\ discrepancies}{Total\ stock\ value\ in\ pieces} * 100$	Match between database and real stock	Once a year	In the order of previous measures
Scanning Coverage	$SC = \frac{Scanned\ Serial\ Numbers}{Shipped\ Products(scannable)} * 100$	Potential product traceability	4 months	In the order of previous measures
Transportation Accuracy	$TA = \frac{Number\ of\ disputed\ deliverted\ pieces}{Total\ number\ of\ delivered\ pieces} * 1000000$	Unsuccessful order completion	6 months	20%
Picking Accuracy	$PA = \frac{Number\ of\ disputed\ delivered\ pieces}{Total\ number\ of\ picked\ pieces} * 1000000$	Correct order picking	3 months	30%
Load/Unload Time	$FTL = \frac{Number\ of\ working\ hours}{Total\ operations\ performed}$	Hours required to load/unload operation.	4 months	20%

Figure 34 KPI results overview

New KPIs

Considering the proposed KPIs by the speaker, it is successfully identified the data to be used for their calculation, allowing the logistics department to measure them if required. This provides the management with a wider range of indicators that allows a more accurate analysis of the different processes taking place inside the warehouse and gives extra indications on where the future improvements should be pointed to. In the figure 37, a table representing them is presented.

KPI	Calculation	Measure Analysis	Suggested Frequency
Rate of Return	$ROF = \frac{Units\ Returned}{Units\ Sold} * 1000000$	Split in damages and mistakes. Indicates quality of service.	3 months
Replenishment Efficiency	$REFIX = \frac{Value\ Shipped}{Value\ Requested} * 100$	Stock availability for demand's supply	3 months
Space Management	$SM = \frac{Volume\ Stocked(M3)}{Warehouse\ Surface\ (M2)}$	Efficiency in surface usage	3 months
Put Away Accuracy	$PAA = \frac{Items\ stored\ correctly}{Total\ Items\ to\ be\ stored} * 100$	Locations indications by the software are or not respected.	3 months at the beginning
Put Away Productivity	$PP = \frac{Volume\ of\ Stored\ Goods(hour)}{Operators\ Required}$	Volume of goods put away per operator in an hour	3 months

Figure 35 Proposed KPIs overview.

RFID Future Traceability

Thanks to the initiated study by the speaker, it is in the company's intentions to continue with this application in the longer term thanks to its potential benefits. For this, it is started the feasibility study within the company to analyse the kind of tags required[34], amount of gateways[35], the frequency of communication, the type of environments to be faced not only

[34] Depending on reading distance, obstacles blocking the magnetic signal, among others.
[35] As previously remarked, depends on the amount of tracking points

inside the warehouses but also during shipping, among others. This leads to the following approximate results in the table below.

Frequency	Local regulations	Multiple Tag Reading	Kind of Tag	Read/Write	Minimum User Memory	Affected by EMI	Works on metal	Gateway Readers	Theoretical Reading Distance
13.56 MHz HF	4 meters maximum	Around 20	Passive	WO/RM	64 Bytes	Less affected	Less affected	2	1 meter
860-960 MHz UHF	4 meters maximum	Around 200	Passive	WO/RM	24 Bytes	Highly affected	Highly affected	2	Several meters

Figure 36 RFID proposal by the speaker

What has also been certified by the speaker is that when pallets are organized for the outbound, it is not always possible for the gateway to read correctly the tags of a boiler located between two other boilers. This is why, it is required that the pallets are a cube of 4x4 boilers, which reaches the total distance of 2.4 meters for a full truck load and have the tags always facing the outside in order to avoid the boiler's metal to block the signal, ensuring that the tags are positioned externally, to guarantee the highest possible tracking without compromising the efficiency of the readings.

Conclusion

The implementation of the WMS software in the Osimo plant's warehouse has been a huge step forward for the company. It has forced the logistics pillar to set up solid and rigorous processes within its warehousing facilities, as well as the redesign of the warehouse structure to improve the process' flows and the performed activities. Thanks to this, it is achieved the expected decrease of the mistakes and the total time duration of the different processes, increasing as well the KPI values in the expected amounts.

Furthermore, improvements regarding the WCL standards are obtained, which are expected to raise the overall mark of the plant in the WCM punctuations, in line with the. It has been a great challenge for all the different departments involved, as a lot of teams and plant managers have formed part of this implementation in the light of what is an innovative solution for the warehousing in the company. This opens a new repertory of solutions for Osimo's plant and the other ones as well.

Particularly for the speaker, it is his first project from beginning to end in a company that has helped him to start being aware of the big difference between the two worlds of university and a firm. It has also allowed him to develop different hard skills regarding those incorporated during the years of his studies, such as supply chain management, warehouse organization and World Class Manufacturing general approaches.

It is worth mentioning that limitations have been found along the dissertation. It has been very difficult for the speaker to find internal data that is considered "sensitive" for the company, such as the currently measured KPIs and their values. This happens because this data cannot be made public and it is very difficult for a new person in a company to locate the correct people that can supply it. What is more, the advances with the RFID propositions are very slow in the view of the speaker, for many reasons. One of them, is the logical absence of a specific budget for its expenses, as the 2019 budget has already been established for this year long before the speaker proposed this. Also, the fact that the speaker is based in Fabriano and the implementation is proposed to be performed either in Osimo or Borgo Tufico, where these establishments are managed by other departments, being this an extra complication

that implies time losses. Anyway, it has been a great opportunity to identify flaws and provide solutions within the project and the current organization.

Some examples of these ones, are the proposal of new KPIs and the ways to obtain the data that is necessary for their calculation. This is done with the objective of obtaining more accurate results regarding the different processes taking place. Like this, it is possible to discern in a more precise way the flaws in the processes and be more precise with the efforts to correct them. This is especially important for the Rate of Return KPI that is already in use, but it is suggested by the speaker to split it between damaged and mistaken goods, as the approaches to correct them are very different.

Another proposal from the speaker is the implementation of a subroutine in the transaction's code in order to obtain the data read from the material's barcode during some of the transactions. This takes place as a solution to the error in one of the basic requirements for the project's feasibility which is the absence of the correct barcodes in each material. This is discovered by mistake in a late phase of the project, which put in risk the time schedule and could impact in new expenses. The speaker's proposition consists in reading the entire barcode data and filtering the necessary information to continue with the transactions. Thanks to this, it was possible to continue with the implementation phase avoiding extra development costs. The final implementation differs from the one proposed by the speaker, but the principle is similar.

The most relevant proposal from the speaker, is the RFID implementation in the outbound processes of the warehouse. The speaker has worked before with this technology. After the correct understanding of the activities taking place in the warehouse, it is possible for him to identify a great loss of time and so of productivity during the product's outbound scanning before shipping. This is why the speaker comes up with a possible RFID implementation in this stage. As a result, he considers Osimo's warehouse as a pilot project with the possibility to extended it into other facilities of the group and even into further activities within the warehouse if it results feasible. A business case is performed with the obtained data and with different parameters. Also, a suggestion of the process flow to be implemented with a comparison between the different technologies that can be finally applied is delivered. This is welcomed by the logistic managers and it is in their intentions to continue with the field tests in order to guarantee its feasibility and obtain a budget to perform the implementation.

Regarding the future, this company allows the possibility as well for other students to continue with different studies and developments[36] in this area. Thanks to the National 4.0 industry plan in Italy, which aids companies to implement this technology, a lot of innovative projects are going to be introduced. Specifically, the WMS project is going to be rolled out as well in all the warehouses of the region, allowing any student interested in supply chain and logistics to form part of it and give his contribution to solve the new challenges presented in the new facility. What is more, if the RFID study advances, a lot of new possibilities are opened. First, to start this implementation in this precise warehouse for the outbound stage as described. Then, to extend it to the tracking of the entire warehouse activities, such as the inbound of materials, merchandise movements between different storage types, and even their single locations identification, with antennas being able to read when a material is picked up or put away.

[36] The company is launching many Career Programs such as the one in which the speaker formed part of

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Appendix

1. RFID Cost Models[37]

Borgo Tufico

4% Handling Discount

Scenario A					
Gateway unit cost	20.000,00 €				
Printing cost	2.500,00 €				
Labelling cost	12.500,00 €				
Tag cost	0,11 €				
Scan cost	15.000,00 €				
Products delivering	200000				
Warehouse number	1				
% Warehouse 1	0,00%				
% Warehouse 2	0,00%				
% Warehouse 3	0,00%				
Total Flow Cost	550.000,00 €				
Scan cost bar code W 1	0,02 €				
Scan cost bar code W 2	0,10 €				
Scan cost bar code W 3	0,10 €				
Handling Save percentage	4,00%				
Analisi dei costi			Anno	0	1
Gateway cost	20.000,00 €		Uscite	35.000,00 €	22.000,00 €
RFID Ariston Capex	35.000,00 €		Entrate	0	37.000,00 €
RFID Ariston Opex	22.000,00 €		Entrate -Uscite	-35.000,00 €	15.000,00 €
RFID Ariston Handling Saves	22.000,00 €		Entrate - Uscite cumulate	-35.000,00 €	-20.000,00 €
RFID Ariston Total Saves	37.000,00 €				
			PBP	2,33	

[37] Data for simulation purposes in all the calculations in the appendixes. It is not actual real values, as the student is not able to provide them.

3% Handling Discount

Scenario A					
Gateway unit cost	20.000,00 €				
Printing cost	2.500,00 €				
Labelling cost	12.500,00 €				
Tag cost	0,11 €				
Scan cost	15.000,00 €				
Products delivering	200000				
Warehouse number	1				
% Warehouse 1	0,00%				
% Warehouse 2	0,00%				
% Warehouse 3	0,00%				
Total Flow Cost	550.000,00 €				
Scan cost bar code W 1	0,02 €				
Scan cost bar code W 2	0,10 €				
Scan cost bar code W 3	0,10 €				
Handling Save percentage	3,00%				
Analisi dei costi			Anno	0	1
Gateway cost	20.000,00 €		Uscite	35.000,00 €	22.000,00 €
RFID Ariston Capex	35.000,00 €		Entrate	0	31.500,00 €
RFID Ariston Opex	22.000,00 €		Entrate -Uscite	-35.000,00 €	9.500,00 €
RFID Ariston Handling Saves	16.500,00 €		Entrate - Uscite cumulate	-35.000,00 €	-25.500,00 €
RFID Ariston Total Saves	31.500,00 €				
			PBP	3,68	

Osimo

Inviable cases in which only Osimo uses RFID even in best conditions

4% Handling discounts

Ipotesi	Solo Osimo con RFID				
Scenario A					
Gateway unit cost	20.000,00 €				
Printing cost	2.500,00 €				
Labelling cost	12.500,00 €				
Tag cost	0,11 €				
Scan cost	20.000,00 €				
Products delivering	700000				
Warehouse number	1				
% Warehouse 1	0,00%				
% Warehouse 2	0,00%				
% Warehouse 3	0,00%				
Total Flow Cost	220.000,00 €				
Scan cost bar code W 1	0,02 €				
Scan cost bar code W 2	0,10 €				
Scan cost bar code W 3	0,10 €				
Handling Save percentage	4,00%				
Analisi dei costi			Anno	0	1
Gateway cost	20.000,00 €		Uscite	35.000,00 €	77.000,00 €
RFID Ariston Capex	35.000,00 €		Entrate	0	28.800,00 €
RFID Ariston Opex	77.000,00 €		Entrate -Uscite	-35.000,00 €	-48.200,00 €
RFID Ariston Handling Saves	8.800,00 €		Entrate - Uscite cumulate	-35.000,00 €	-83.200,00 €
RFID Ariston Total Saves	28.800,00 €				
			PBP	-0,73	

2% Handling Discounts

Ipotesi	Solo Osimo con RFID
Scenario A	
Gateway unit cost	20.000,00 €
Printing cost	2.500,00 €
Labelling cost	12.500,00 €
Tag cost	0,11 €
Scan cost	20.000,00 €
Products delivering	700000
Warehouse number	1
% Warehouse 1	0,00%
% Warehouse 2	0,00%
% Warehouse 3	0,00%
Total Flow Cost	220.000,00 €
Scan cost bar code W 1	0,02 €
Scan cost bar code W 2	0,10 €
Scan cost bar code W 3	0,10 €
Handling Save percentage	2,00%

Analisi dei costi	
Gateway cost	20.000,00 €
RFID Ariston Capex	35.000,00 €
RFID Ariston Opex	77.000,00 €
RFID Ariston Handling Saves	4.400,00 €
RFID Ariston Total Saves	24.400,00 €

Anno	0	1
Uscite	35.000,00 €	77.000,00 €
Entrate	0	24.400,00 €
Entrate -Uscite	-35.000,00 €	-52.600,00 €
Entrate - Uscite cumulate	-35.000,00 €	-87.600,00 €
PBP	-0,67	

Osimo Case in which all warehouses implement RFID

4% Handling Discount

Ipotesi	Tutti RFID
Scenario A	
Gateway unit cost	20.000,00 €
Printing cost	2.500,00 €
Labelling cost	12.500,00 €
Tag cost	0,11 €
Scan cost	20.000,00 €
Products delivering	700000
Warehouse number	3
% Warehouse 1	0,00%
% Warehouse 2	80,00%
% Warehouse 3	10,00%
Total Flow Cost	220.000,00 €
Scan cost bar code W 1	0,02 €
Scan cost bar code W 2	0,10 €
Scan cost bar code W 3	0,10 €
Handling Save percentage	4,00%

Analisi dei costi	
Gateway cost	60.000,00 €
RFID Ariston Capex	75.000,00 €
RFID Ariston Opex	77.000,00 €
RFID Ariston Handling Saves	8.800,00 €
RFID Ariston Total Saves	91.800,00 €

Anno	0	1
Uscite	75.000,00 €	77.000,00 €
Entrate	0	91.800,00 €
Entrate -Uscite	-75.000,00 €	14.800,00 €
Entrate - Uscite cumulate	-75.000,00 €	-60.200,00 €
PBP	5,07	

2% Handling Discount

Ipotesi	Tutti RFID				
Scenario A					
Gateway unit cost	20.000,00 €				
Printing cost	2.500,00 €				
Labelling cost	12.500,00 €				
Tag cost	0,11 €				
Scan cost	20.000,00 €				
Products delivering	700000				
Warehouse number	3				
% Warehouse 1	0,00%				
% Warehouse 2	80,00%				
% Warehouse 3	10,00%				
Total Flow Cost	220.000,00 €				
Scan cost bar code W 1	0,02 €				
Scan cost bar code W 2	0,10 €				
Scan cost bar code W 3	0,10 €				
Handling Save percentage	2,00%				
Analisi dei costi			Anno	0	1
Gateway cost	60.000,00 €		Uscite	75.000,00 €	77.000,00 €
RFID Ariston Capex	75.000,00 €		Entrate	0	87.400,00 €
RFID Ariston Opex	77.000,00 €		Entrate -Uscite	-75.000,00 €	10.400,00 €
RFID Ariston Handling Saves	4.400,00 €		Entrate - Uscite cumulate	-75.000,00 €	-64.600,00 €
RFID Ariston Total Saves	87.400,00 €				
			PBP	7,21	