POLITECNICO DI TORINO

Master of Science Degree in Industrial Production and Technological Innovation Engineering

Master of Science Thesis

Designing and implementing smart and lean solutions for warehouse processes and operations.

The first phase of the Smart DC plan in the Schneider Electric DC of Venaria.

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Abstract

The thesis is intended to highlight how the projects carried out during my internship contributed to making the Schneider Electric DC of Venaria leaner, potentially smarter and more efficient. Being these projects about warehousing and included in the Smart DC plan of the centre, I will give a brief overview on how things work inside a warehouse and what are the features and technologies of Smart DCs. This will help to clarify that becoming a Smart DC is not easy and that the environment in Venaria DC is not mature enough for these technologies because there are still some gaps to deal with.

The two projects of the thesis are closing some gaps in the consumable management and the picking processes through standardization and technological adaptation. Their description will specify what has to be standardized or upgraded, how and why, while reflecting the way Schneider Electric faces innovation.

The first project is about standardization and optimisation of the consumables management process. This project was carried out following the lean principles and tools and contributed to an increase of productivity and to the definition of the Water Spider's future role.

The second one is about the commissioning of next-generation touch handhelds realizing both the migration of all Terminal Emulation apps of the WMS and the physical installation of the devices. This will enable the company to open to smarter initiatives like Augmented Reality, E-tracking or intercommunication between operators.

Foreword

I would like to thank all those who supported me during these 5 years because they have contributed to my personal and professional growth.

I would like to thank also Schneider Electric spa for the opportunity of carrying out the internship there, my tutor for having involved me in interesting and diverse projects and all the colleagues and the operators I worked with because they enriched me personally and professionally.

I would like to express gratitude also to my academic tutors for the advice they gave me throughout the execution of the thesis.

Finally, I would like to thank my friends and my family because they have always believed in me.

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Introduction

Origins and motivation

In the recent years Industry 4.0 has been changing the paradigms in both manufacturing and logistics.

After the participation to the Amazon Innovation Award, I became really interested in and curious about smart warehousing. This topic really drove my curiosity to try to deeply understand the processes and the criticalities of warehousing in order to develop solutions by myself.

Thanks to this internship, I discovered a different environment from Amazon. It was not the advanced Amazon fulfilment centre with the Kyva system but a more traditional distribution centre that was going to become smarter and leaner.

The contents of the internship were very inspiring for the thesis. I had the opportunity to explore some very interesting projects related to the implementation of smart warehousing. Furthermore, I got familiar with the warehouse processes in a traditional distribution centre and I experienced how to approach to technological change and what are the actions and methodologies to follow for turning into a Smart DC.

Objectives and Scope

This thesis aims at providing a description of what is a distribution centre (DC), what kind of processes could be identified into it and what are the technologies and actions that can turn it to a Smart DC, putting more emphasis on this last point in the second part of the thesis.

By taking as reference two projects carried out during my internship, it will be highlighted how the transition from traditional to Smart DC is not so immediate and simple, even for a big multinational company like Schneider Electric. But it occurs gradually, following a step by step scheme which considers standardization and technological adaptation as the first fundamental stages.

For every project, I will analyse what, in the Schneider Electric distribution centre of Venaria, had to be standardized or upgraded, how this was achieved and why by giving some insights on future developments.

The projects I carried out are included in the first phase of the Smart DC plan for the Distribution centre of Venaria by 2020. The final goal of this implementation plan is "making the DC leaner and smarter" but being in the first phase, it declines into "becoming first leaner and, wherever it is worthy, step up with something smarter". This is in accordance with both the Schneider Electric innovation philosophy and the need to preserve economic efficiency.

So, the projects that I am going to talk about, should be seen in this light, as intended to prepare the ground for future smart projects in the longer term, and improve the overall efficiency in the shorter term.

Structure

In order to facilitate the explanation of what above mentioned the thesis will be structured as following:

The first chapter will provide an overview of the multinational and the business unit in which I undertook my internship. Then, there will be two theoretical chapters for describing the context of the projects I carried out.

Chapters 2 will start with the definition of distribution centre, followed by the description of the typical warehousing processes in order to frame the status of innovation inside Venaria DC.

Chapter 3 focuses on the description of the features of a Smart DC and will reflect on the meaning and the implications of the Smart DC plan for Venaria DC. It will conclude with the introduction of the projects carried out during my internship.

Chapter 4 describes the first project. As it is about standardization and waste removal, some insights will be given regarding these concepts. After describing the context and the long-term implications of the project, it will be explained the methodology followed to complete it. The description of the project will go through every stage of the PDCA cycle. So, in the Plan stage after defining the problem and goal statements, the process will be analysed in order to identify the main criticalities and the main opportunities for improvement. Then, in the Do stage the different improvement initiatives will be implemented and in the Check stage their effect will be compared against the initial scenario. Finally, in the Act stage will be commented the documents which contribute to standardize the process and future improvements actions will be pointed out.

Chapter 5 describes the second project. Again, it will be offered the context for better understanding the objectives and the implications. Then, the salient steps for the success of the project will be analysed.

In the conclusions, the main concepts tackled in the thesis will be summarised.

1 The company: Schneider Electric

1.1 The group history

Schneider Electric is a French multinational corporation with almost 180 years of history. Its story began in 1836, during the first Industrial Revolution, when Adolphe and Josephe-Eugene Schneider took over an abandoned foundry and founded Schneider & Cie which became in few years one of the major players in the steel and heavy industry. In the late 20th century, the Schneider Group diversified its portfolio expanding into the electricity sector with the acquisition of one of the biggest manufacturers of electrical distribution equipment in France.

A few years later, the company divested from the steel and shipbuilding business, which expected not to be strategic anymore, and focused on the electrical, energy management and automation fields carrying out important acquisitions.

In 1999, in order to emphasize its expertise in the electrical sector, the Group changed its name to Schneider Electric.

In the 2000s the company consolidated growth with other acquisitions and reinforcing its position in software applications, while in more recent years, developing advanced integrated and connected technologies they have become the global specialists in energy management and automation[1].

Schneider Electric history has been characterized by courage for taking risky strategic decisions and strength for finalizing crucial business acquisitions which contributed to change the identity of the Group in terms of know-how and expertise.

The most relevant business acquisitions in building the Schneider Electric brand are represented in Figure 1.

[1] (Schneider Electric, 2019)

Figure 1 Schneider Electric brands

1.2 The company profile

Being ranked since 2001 as a Fortune Global 500 company[2], according to the 2017 annual report, Schneider Electric counts 24,7 billion revenues, more than 140000 employees in over 100 countries, 200 plants and 90 distribution centres around the world. The rest of the figures completing the company profile are contained in the picture below[3].

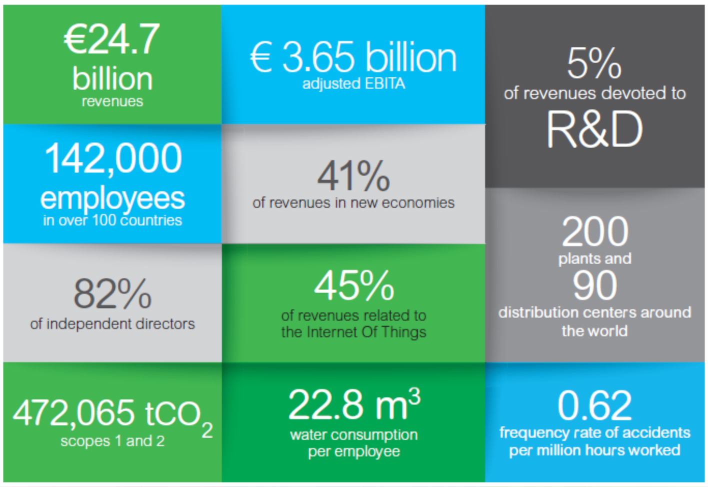

Figure 2 Schneider Electric main indicators[4]

The significant transformations and technological breakthroughs the Group has experienced are the result of a robust company mission and a strategy every year more and more ambitious. Schneider Electric's mission is to provide customers with innovative products and solutions in order to simplify their lives. Today, for Schneider

[2] (Fortune, 2019)
[3] (Schneider Electric, 2018)
[4] (Schneider Electric, 2018)

this means leading the digital transformation of energy management and automation in four markets: homes and buildings, industries, data centres and infrastructure. Their intent is to ensure that energy and the global ecosystem are safe, reliable, efficient, sustainable and connected[5].

In a world that is getting more and more digital and electric, Schneider Electric has a very central and active role. This is the result of a proactive strategy which aims at capturing the megatrends in the energy environment to create opportunities for growth. The strategic pillars of the group are based on two fundamental beliefs that are the present is digital and the future is electric. Digital Transformation in industry and digital energy transition will be the key driving forces for the next few years while in the long-term Schneider will have to be able to take advantage of the opportunities given by electrification, decentralization and decarbonization of energy generation[6].

Schneider Electric has a global presence in over 100 countries and both employees and revenues are geographically balanced and well distributed as shown in Figure 3.

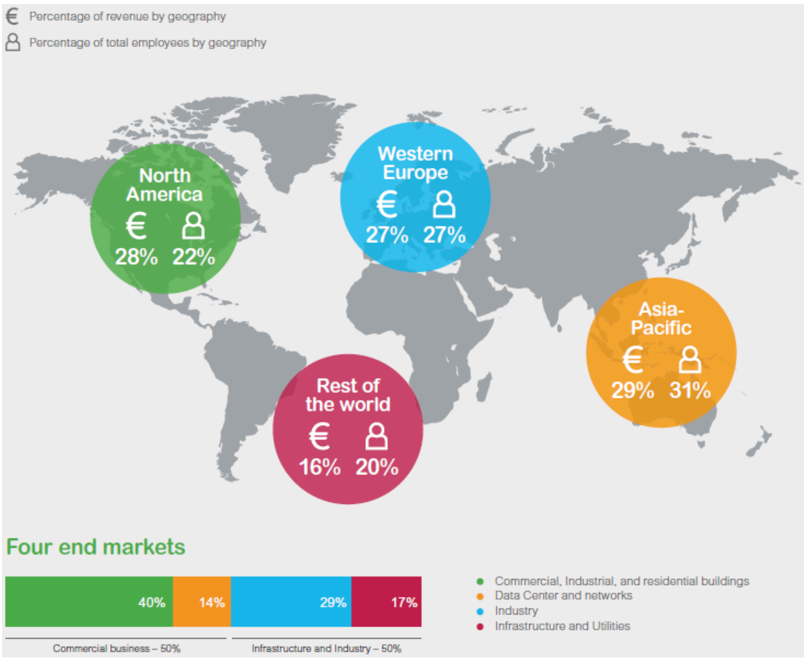

Figure 3 Schneider Electric market segmentation and revenues distribution[7]

[5] (Schneider Electric, 2018)
[6] (Schneider Electric, 2019)
[7] (Schneider Electric, 2019)

This economic and market segmentation helps to mitigate the risk of downturns in specific areas but also maximise opportunities. The most important markets for Schneider, now, are the residential and non-residential buildings and industry with almost 70% of the revenues[8].

Schneider business model is focused on two core offerings: energy management and industrial automation. The former is about electrical transformation and distribution, energy security, measurement and control of consumption, the latter is about control and supervision of machinery and processes.

The Group is the absolute leader in the energy management sector being the number one worldwide in the low and medium voltage and secure power businesses. The low voltage business is the most important one representing 45% of the revenues, it addresses to the four markets and the portfolio is very extensive ranging from cables, busways, emergency lighting, electrical car charging to power monitoring and control systems (EcoStruXure) for buildings, homes, industrial machine to improve connectivity. Medium voltage business addresses mainly to buildings, infrastructure and industries and it encompasses medium voltage switchgear, transformers, protection relays but also SCADA software and asset performance management software. The secure power business involves data centres and critical buildings (hospitals, power plants, etc) where it is necessary to guarantee the continuity of the electrical supply, therefore, the portfolio includes power distribution units, security and cooling systems and uninterruptable power supplies. Regarding industrial automation, Schneider Electric is the fourth actor worldwide and its offering includes instrumentations, software for simulation, modelling, industrial operations management along with control and safety systems for process automation.[9]

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[8] (Schneider Electric, 2019)
[9] (Schneider Electric, 2018)

1.3 Venaria DC general overview

In Italy, Schneider Electric counts more than 3000 employees spread over 1 customer centre in Turin, 1 logistic centre in Venaria, 8 commercial areas and 6 industrial sites across the country.

Figure 4 Schneider Electric in Italy[10]

The distribution centre in Venaria (see Figure 5) was opened in 2001 to serve the entire Italian market. It employees almost 150 workers and it extends on a surface of 13 thousand square metres. Venaria DC is not only a logistic centre but also includes a local adaptation centre for the assembly and customization of specific high current circuit breakers and electrical distribution switches[11].

Figure 5 Schneider Electric distribution centre in Venaria[12]

[10] (Ciotti, 2018)
[11] (Stefanoni, 2001)
[12] (Maps, 2019)

Schneider Electric product offering numbers more than 100 thousand products, however, Venaria DC has a limited stock capacity due to the fact it is conceived to serve only one country market. The warehouse can stock up to 10 thousand references, of which 90% is ordinarily managed with a make-to-stock logic while 10% is managed following a make to order logic and it can be any product from the catalogue.

Every day on average around 10 thousand lines are shipped with less than 5 errors detected. This attention to the customer makes Venaria DC is one of the most effective centres in Europe with a service level almost equal to 99%.

Looking at the upstream supply chain, products are received mainly from Schneider Electric plants (50%) and other European distribution centres of the Group (49%) and only 1% is provided by external suppliers. Instead, the downstream flow, which is about shipping products to the customers all over the country, is managed by 2 different transportation companies depending on the delivery time and the freight weight (see Figure 6).

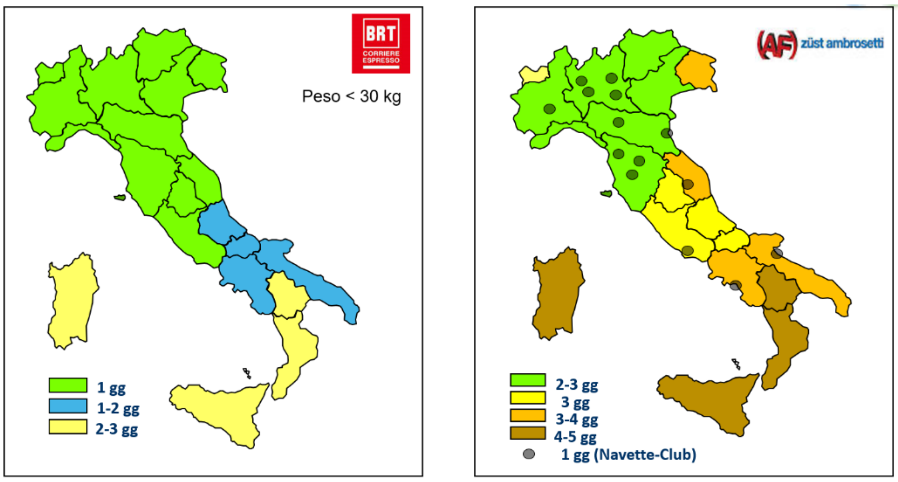

Figure 6 Delivery time throughout Italy

Schneider Electric customers in the Italian market consist of wholesalers and distributors (63%), original equipment manufacturers and systems integrators (27%), and panel builders (10%).

The portfolio of products managed in Venaria DC is considerably wide, there are different types of products with different size, volumes and suppliers; all this variability makes warehouse processes complex and unique. But before explaining how things work inside Venaria DC it could be useful to clarify what are the typical key processes into any warehouse.

2 The Distribution Centre: Venaria DC

2.1 Warehouse and distribution centre definition

Before going forward with the thesis it is better to give some definitions starting from the word DC.

DC is the acronym of distribution centre and it is often used as a synonym of warehouse. These two terms cannot be used interchangeably because they have a different meaning.

The concept of warehouse is linked to the traditional supply chain whose rule was to store the maximum quantity of every product, everywhere and every time. This was due to the fact there was no information flow between customers and factories or planning mechanisms. So, warehouses were used to stockpiling a huge quantity of products even though they have very low rotation, or they would be shipped some months later.

With the development of more advanced information systems 2-3 decades ago it was possible to predict the demand and plan the logistic operations accordingly. The new rule for the modern supply chain became supplying the right product, in the right quantity, in the right place and at the right time. In this context, we find the distribution centre.

Being more specific about the difference between these two terms we can say that:

- a warehouse is conceived to store products while a DC apart from this function offers value-added services like order fulfilment, product mixing, packaging, product customization, cross-docking.
- The average stock time of products stored in a DC is lower than the average stock time in a warehouse because the rotation of products in a DC is much higher

- A distribution centre is focused on the customer and its purpose is efficiently meet customer requirements measured with the service level. A DC is built to serve customers and retailers. A warehouse is more focused on production and storing products efficiently.
- The operations in DC are usually more complex than those in a warehouse.

However, warehouses still exist, for example, they are used to build months in advance inventory to meet the high seasonal demand. The goods are stored in typical warehouses before being sent to a distribution centre to serve the customers. However, the importance of warehouses is decreasing because they are evolving in DC.

2.2 The typical warehouse processes

As stated by the Logistics Bureau manager, Mal Walker, in his article of 2018, each DC is different from the other except for the 7 key processes they share, and this applies to Venaria DC as well.

In fact, if we take two competitors with the same products, they probably will share the same technologies such as barcoding and radio frequency controls, but they will have different ways of doing things because of several factors like magnitude of the warehouse operation, storage capacity, order profiles, legislative requirements, company culture, volume of goods, etc. However, there are some key processes that are recurring: 3 related to inwards flow, 3 related to outwards flow plus 1 related to value-adding[13].

These processes, as shown in Figure 7, form a sort of cycle which starts from the distribution centre and ends either to the customer if the purchasing process finished successfully or to the warehouse in case of returns.

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[13] (Walker, 2018)

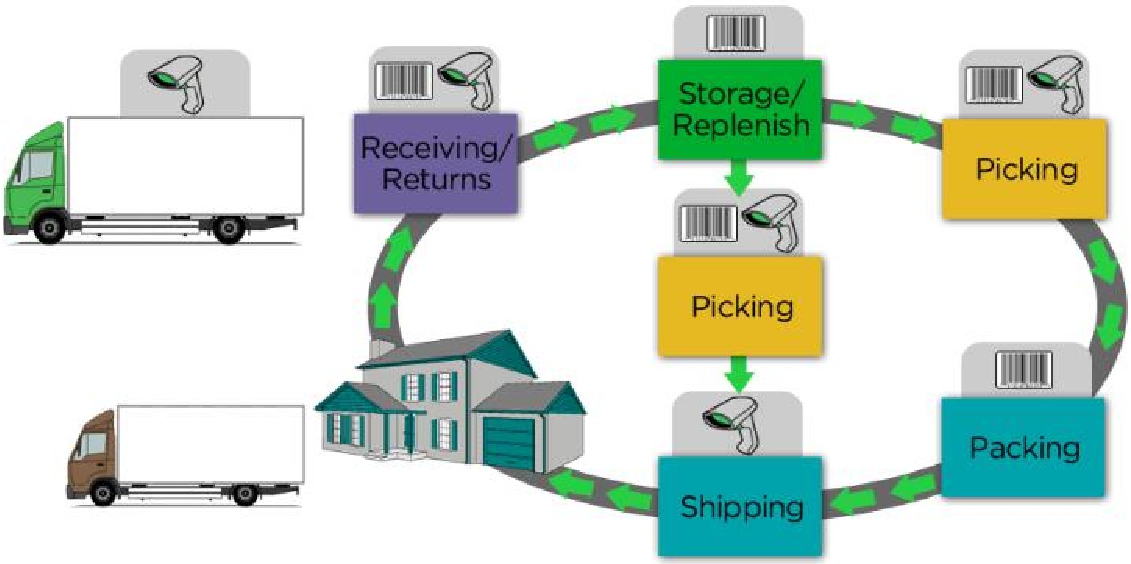

Figure 7 Warehousing cycle[14]

2.2.1 Receiving

The receiving process is about handling and managing the incoming products into the warehouse and onto the information system. This phase is crucial because for running an efficient warehouse it is imperative receiving the right product, in the right quantities, in the right condition, weight, and dimensions all at the right time. Therefore, if it is done wrong many criticalities could occur in inventory management and in the subsequent phases jeopardising the overall productivity. For the same reason, it is also important to avoid bottlenecks in this stage and keep the process smooth. The receiving process consists of four different operations[15]:

1. Pre-receiving

   This activity is very important, and it relates to establish and enforce receiving requirements for suppliers, shippers, and/or carriers. The objective is driving them to present the cargo in a quick and easy way to process. Some of these

[14] (Wheeler, 2014)
(Sunol, 2018)[15]

requirements could be standard packaging requirements such as label position and label information but also proper documentation in hand upon arrival, specific time window for goods reception. It is all about providing the suppliers or the carriers with all the necessary information about the process and the procedures in order to speed up operations.

2. Unloading

   In general, the objective of this activity is to unload the cargo in a safe and efficient way. When the carrier arrives, after the registration process, it is assigned to a loading bay and then goods are put in a temporary stock area. Depending on the features of the unit load (boxes, pallets, etc) and product characteristics unloading can occur with different types of forklift. In this activity, forklift operators should be skilful and well trained to face any issue.

3. Quality control

   Once the cargo is received, it should start the verification process that includes checking the quantity received, product code, and conditions of the cargo like seeing if it is damaged or not. There are also some cases where it is necessary to conduct more advanced inspections such as verifying weight, dimensions, temperature, etc for example through an integrated pallet/parcel dimensioning system. This activity is very time-consuming, especially if it is performed manually and it is not automated. This activity can be executed following three different approaches: individual item count, usually conducted with random checks, count of pallets and good faith receiving which remains the most common[16].

4. Labelling and sorting

   If the goods pass the quality control, then they are identified, sorted towards the correct flow and labelled, based on their physical characteristics and their scope. For example, there could be non-palletised products which would need at first to be registered and grouped together, palletised products which will follow the

(Mecalux, 2019)[16]

normal process, or returns that would need to be processed in a different way to understand the instance of non-compliance. Finally, labelling is essential for ensuring traceability both in traditional warehouses and in advanced warehouses with a Warehouse Management System (WMS). In the latter case, we can say that labelling is imperative otherwise it would be impossible to perform the subsequent phase because there wouldn't be any match in the WMS for that product regarding its place and the stock.

2.2.2 Put-away

Once the receiving process is completed the stock is waiting to be transported to a storage location and here, the put-away process begins. Put-away can be related to sales returns, transfers, or production output according to the warehouse configuration. Receiving, put-away and returns are considered inbound processes while the others are considered outbound processes.

Basically, it starts when the operator accepts the put-away request from the Enterprise Resource Program (ERP) or the WMS, scanning the barcode of the unit load. At this point, the system will direct the operator to the storage location assigned in advance to that product and when the operator will be on-site, he/she will scan the stock location barcode to confirm the bin location has been found. Finally, the operator will place the goods in the correct slot and will confirm the process has been carrying out. There are various storage policies: dedicated storage, random storage or class-based storage where products are allocated in specific zones based on their turnover rate. Products may be inbounded into high-density storage such as drive-in racking or in upper levels of traditional shelving. It can be included in the put-away process also internal replenishment which is about moving Stock-Keeping Units (SKUs) from upper levels locations to pick slots in ground levels[17].

[17] (Habazin J., 2017)

2.2.3 Picking

Picking has been identified as the most labour-intensive and costly activity representing almost 70% of warehouse operating time and more than half of the warehouse operating expense. In Figure 8 it is shown the percentage of time and cost related to the main warehouse processes.

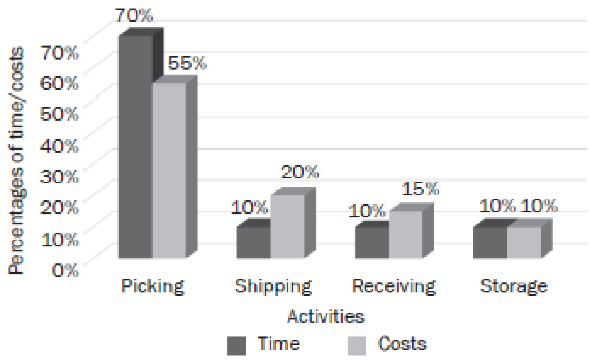

Figure 8 Percentage of time and cost of main warehouse processes[18]

Picking is related both to the purchasing and manufacturing process, with the difference that in the former case we refer properly to picking while in the latter case we refer to kitting. In general, the picking process consists in retrieving products from specific units load in specified locations in the warehouse to fulfil customer or production orders.

As picking is an outbound process where every unit load in storage is broken down in multiple units load to be dispatched, it is necessary to re-establish their initial stock level. The reverse process of picking is called refilling or replenishment.

Basically, picking is very straightforward, it concerns few actions like lifting, moving, picking, putting and packing, however, there are several picking methods and systems that can be adopted in a warehouse. Each solution though will impact differently on the warehouse efficiency because it will contemplate different storage and handling systems.

[18] (Habazin J., 2017)

When designing the picking process, there are two possible technical schemes which can be implemented[19]:

- The picker to part strategy: it is the most commonly used in warehouses. In this configuration, the picker goes and get the items to fulfil each customer order from the same area where products are put away.
  The classic storage solutions with this kind of system are pallet racking, live-storage racking or static shelving, while the handling systems used to refill the picking locations can be forklift-based or specific order picker models. Even though it is a labour-intensive solution, there are many technological advances to speed up operations such as pick-to-light and voice picking systems. The former one informs pickers of which product to pick by shining a light on it, the latter one, instead, tells operators which items to pick via headsets.
- The part to picker strategy: conversely to the previous approach where the operator was moving towards the products, in this concept products are moved from the storage area to picking bays. When items of various orders converge in these bays, picking operators sort or collect the products to fulfil the customer orders. Some of the typical storage solutions are vertical and horizontal carousels, mini-load and automated warehouses, the handling systems, instead, can be both forklift-based vehicles or conveyors.
  This concept leaves space for a more automated environment, however, one drawback might be represented by the waiting of items to be delivered in the picking locations and the cost of technology. An example is represented by pick to box systems where there is a series of picking zones connected by a conveyor system. The box is transported by the conveyor to various picking zones where operators put in it the items required until the order is completed. With this solution, the operator doesn't loose time in collecting every single item in different locations, however, the investment cost is high and could neutralize the benefits in efficiency that it offers. The most innovative part to picker solution is

[19] (Murray, 2019)

the one implemented by Amazon with Kiva technology in which they are using robots to move shelvings to the picking stations where the picker will get the items. Amazon robotic fulfilment centres are becoming even more automated because Amazon is developing picker robots that will be able to collect items and place them into bins.

The picking process is also influenced by the methods of operation. The top 4 picking methods that are important to mention are the following:

1. Discrete order picking

   It is the simplest and the most common type of order picking because it is very straightforward. The picker travels to different locations to collect all the items of one specific customer order and only when it is fulfilled the operator can execute another order. Basically, every picker executes one order at a time processing one line at a time. Most of the times there is only one scheduling window during the shift, therefore, orders can be processed at any time without any priority. This method is ideal for environments with a low digital and technological level where information is kept on paper. It allows to easily track orders and control pickers accuracy, but it is the least efficient model because moving is definitely not optimised[20].
2. Cluster picking

   This method consists of picking multiple orders at a time but conversely to batch picking, which will be described further, there are separate totes and cartons for each order. Cluster Picking is more efficient than discrete picking because the system generates a picking list which allows the operator to pick multiple items at the same time with the most efficient route. Through cluster picking, the WMS can set priority to a set of orders over others. This method is used in pick to cart operations[21].
3. Batch picking:

[20] (Wheeler, 2014)
[21] (Wheeler, 2014)

This order picking protocol consists in creating a unique picking order from a batch of orders where most of them contain the same SKUs. The picking is done one SKU at a time but pickers, instead of picking multiple orders directly into shipping cartons, put all the similar items together in the same container or unit load to minimise the travelling time to reach the same bin location for that SKU[22]. Later, these batches of products will be split and distributed into shipment cartons or pallets in a specific sorting area to fulfil individual customer orders. Sorting operations can be manual or automated, furthermore, they can be either concurrent to the picking activity as in the case of cluster picking or deferred to the picking activity as in the case of batch picking. This method is efficient when orders are little (less than 4 SKUs) and SKUs volume is relatively small. Usually, there is only one order scheduling window per shift.[23]

4. Zone picking

   In this picking method, the picking area is divided into individual pick zones, each operator is assigned to one and is responsible for picking all the items within that zone for each order. In case of orders with SKUs located in multiple zones, when picking is completed in that particular zone, the order tote or shipment carton is moved to the next zone via a conveyor. This pick and pass system helps to reduce the travel time and the traffic in the picking aisles during pick hours. Moreover, this method improves the specialization of pickers and consequently their productivity, because they will be quicker in identifying the product location and less inclined to do errors. Zone picking has usually one scheduling window per shift[24].

The picking process has been very sensitive to technological innovation. The most important tech upgrade which contributed to making the process more automatic was the implementation of Barcode and RFID scanners which allowed to increase the picking

[22] (Kerr, Wave picking vs batch picking: which is the best?, 2018)
[23] (Wheeler, 2014)
[24] (Sunol, 2018)

accuracy ensuring the right products were selected. For guiding the picker to the next pick location in a faster way it was implemented the pick-to-light system. This solution is effective only in case of zone picking otherwise it risks to be too confusing. The latest innovations are going to create a handsfree environment and they are voice picking headsets and vision picking. The former uses a voice to instruct the picker about where to go and what to grab and it also uses voice recognition. The latter uses augmented reality glasses to instruct operators and automatically scan product tags.[25]

2.2.4 Packing

Once all the items associated with a customer order are picked, it is necessary to prepare them properly for the shipment. Packing consists of providing the items that are going to be shipped with appropriate equipment and packaging for the containment, protection, handling and delivery of the goods.
The packaging is imperative and vital for facilitating goods transportation, warehousing but also sales, marketing and end-use[26].

The packing process needs to be fast and accurate. In the packing station a series of activities are performed:

- Controlling that products and quantities match with the order requirements and the right items in the right quantities were picked usually also labelling and quality control are performed.
- Packing items into suitable loads for transport with the proper packaging materials according to the product characteristics.
- Labelling the package to ensure that once goods are shipped they are traceable.
- Consolidating orders in pallets

[25] (Boehm, 2019)
[26] (Conai, n.d.)

In most of the cases the cartonisation activity, which consists of choosing the best box or envelop to suit each order, is already done during picking operations. This will allow saving time in packing by avoiding to pick items twice[27].

2.2.5 Dispatching

Dispatching is the final process to occur inside the warehouse. It is where packed and labelled goods are going to be loaded into trucks. A dispatching process is efficient when the goods are available for shipping just in time for the carriers' arrival. It is necessary to schedule and organize goods preparation and all the previous processes taking into account of the different time windows of carriers, otherwise, there would be problems in the loading operations which might cause delays for deliveries. As dispatching performances are influenced by inefficiencies of all other processes, many firms have implemented an information system to manage efficiently these tasks[28].

2.2.6 Returns

Returns generally occur because of one or more failures in some processes throughout the supply chain. This kind of occurrences became much more frequent with e-commerce success. Returns represent a cost for companies in terms of transportation, labour, product, brand image and definitely they would do without all of this. This process is expensive especially because each task has no value-added. Once faulty products are received in the warehouse or DC, they are sorted based on the reason of return and then sent to the processing stations. Here the return practice will be analysed to understand the causes of the failure and the consequent actions to adopt such as repair, refurbishing, remanufacturing, replacing or refunding. So employees should have strong knowledge about the product, and they should be highly trained to take the right decision. At the end of the process, the employee should also provide traceability about the practice recording causes of failures and actions taken and reporting to support operations[29].

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[27] (Kerr, Improving your picking and packing process, 2019)
[28] (Walker, 2018)
[29] (Stock, 2003)

2.2.7 Value-Adding

This expression refers to all other activities into the warehouse which can add value to the customer. For example, value-adding processes, that are not included in the previous ones, are the assembly process and product customization activities which are performed in Venaria DC. In addition, implementing information systems like WMS or reviewing the existing valued adding processes are considered value-adding as well[30].

These are the 7 key processes that can be identified in every warehouse or DC, however, each process will be strongly adapted and personalised by humans to support every individual case and situation. Even though IT technological innovation is making warehouse management more automatic and centralized with less paperwork and spreadsheets, labour is still predominant and it is still crucial for running an efficient warehouse, so far.

[30] (Walker, 2018)

2.3 Operations in Venaria DC

In this section, it will be provided a summary description of the logistic operations in Venaria DC in order to further evaluate the status of innovation of the centre with respect to the concept of Smart DC.

For this purpose, providing some graphic documentation like a simplified layout and a material flow representation might be of help to give a clearer understanding of logistics operations in Venaria DC. Having a look at the layout in Figure 9 it is possible to identify 6 different working areas:

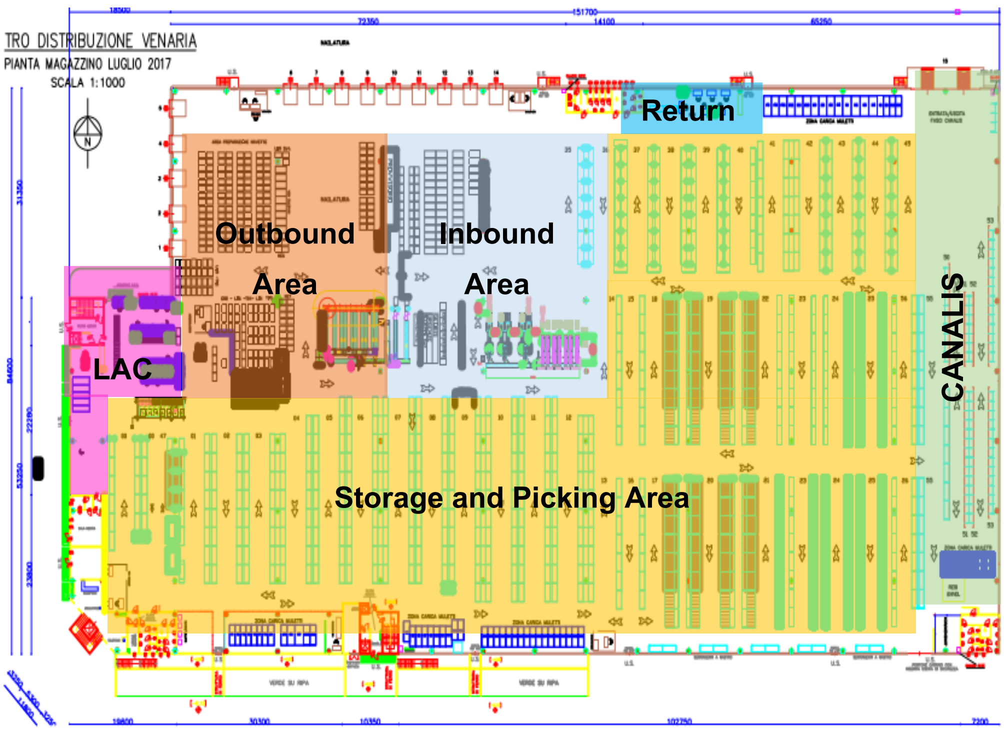

Figure 9 Venaria DC simplified layout

1. Inbound area: in this area, there are flush docks for unloading trucks, reception desks for carriers attendance and different unloading bays for goods reception depending on the product characteristics (high/medium/low rotation products, high/standard volume products, suppliers' profile, consumables or finished goods etc). The receiving area also includes 8 sorting stations connected by a

conveyor system for processing multi-reference pallets, and 2 single-sided pallet racks facing each other for the storage of consumables (boxes, covers, air pillow rolls etc).

2. Canalis area: it is a reception and storage area dedicated to bulky items with large sized profiles that are not transported onto pallets and that can be handled only with the forklift. In this area, there is a larger dock which allows unloading trucks from the side. The storage solution used for this kind of products is cantilever racking.
3. Returns area: it is a small area next to the inbound area and it is made of 4 workstations.
4. Storage and picking area: it is the widest area of the warehouse and it consists of different storage solutions based on ABC inventory analysis and products' weight and volume criteria.

To better understand this point, it is important to highlight some facts[31]:

- Around 20% of SKUs generate 80% of sales
- 80% of all items are small in size
- Most of the orders have small lines and it is very rare they are supplied in full pallets. This makes picking the most important operations in terms of effort and time in the warehouse
- There is a great variety of products in size, from small components of a few grams to heavy and bulky materials like electrical cabinet panels.

Putting together all these elements it is clear the reason why diversification of storage solutions is fundamental both for a logistic point of view and for efficiency purposes.

[31] (Mecalux, n.d.)

In Venaria DC like other logistics centres, conventional storage systems for pallets and boxes are used but they are controlled by a Warehouse management system.

The main storage in Venaria DC is represented by a static pallet racking system which extends for 13 corridors. In here, SKUs with high rotation are stored in 2 different types of pallets 1200x800mm and 800x600mm. This solution reveals the Venaria DC biggest limit, which is the limited surface area. In fact, in bigger logistic centres like Sant Boi the same class of products is stored in double-deep live pallet racking with different aisles for replenishment and picking tasks. Instead, in Venaria put-away and picking operations occur in the same aisles, as a result, there are higher waiting times and traffic. Further, there is a static shelving along 2 corridors where make-to-order SKUs are stored into boxes. These are products of Schneider Electric catalogue with very low demand which are ordered occasionally in the form of the lowest storage unit (box) when the customer makes the order. Medium rotation goods that can be contained into standard boxes are stored in live storage shelvings on lower levels while upper levels are used for the deposit of reserve pallets of those SKUs. This kind of solution contemplates 2 separated aisles: one used by high-level order pickers for replenishment and one used by low-level order pickers. Low rotation SKUs are stored in the form of standard boxes into static shelvings at lower levels, while upper levels are used for the deposit of palletised SKUs. Finally, bulky items that travel onto pallets whose dimensions are superior to 1200x800 up to 2000x1000 are stored in conventional pallet racks. This kind of warehouse is called MGA and it extends from corridor 35 to 43.

5. Local adaptation centre (LAC) area: this area is divided into 2 sections: the kitting zone and the assembly zone. In this department, different components are picked from the storage and they are assembled to electrical distribution switches or high corrent circuit breakers by specialized operators to create customized solutions. Then, the finished goods are packed, labelled and sent to the shipping area. The level of automation in this area is very low both in the

assembly and the packaging process because all the operations are still performed by operators.

6. Outbound area: this area is composed of the packing zone and the shipping zone. In the packing zone, there is a conveyor belt for sorting shipping boxes and palletise them correctly. Then there is an area for preparation of shipping pallets and preload areas close to the loading flush docks.

With these considerations in mind, it will be easier to understand the material flow inside the warehouse. Just like in any warehouse, in Venaria DC there are two opposite workflows: inbound and outbound.

First of all, it is important to remember that Venaria DC is a quite advanced logistics centre because inbound and outbound flows are coordinated by SAP and many activities are performed with technological equipment controlled by the warehouse management system.

The inbound material flow, as shown in Figure 10, includes the receiving and put-away processes and it involves the inbound area, canalis and the storage area. LAC, as said before, is quite autonomous in operations, but it is also affected by inbound operations.

The inbound flow starts when trucks arrive. Depending on the type of material transported, trucks are addressed to the assigned unloading doors for goods reception. Here, two different flows can be identified: one in the inbound area and one in canalis. In both cases, operators of the receiving area will proceed to unload the truck using counterbalance trucks leaving the goods in different bays based on the inventory criteria. So, for example, palletised SKUs, that are ready for storage, will be separated from multi-reference pallets that first need to be processed in the sorting stations, close to the conveyor system. Before the put-away process, it is necessary to execute goods reception to update the system and put labels to each SKU. This activity is performed manually by operators who enter the system the reference code and the quantity and print the labels with this information. In the sorting stations, in addition to scanning each box to update the system and labelling, operators have also to sort different items into boxes and create a box for every product reference, in case of multi-reference pallets coming from plants. In fact, a considerable part of goods coming from plants is mixed, meaning that in the same box you could have different type of product. Mono-reference boxes are put on a conveyor belt and finally palletised by an operator. Being make-to-order products or medium/low rotation products they will be stored in a different area than palletised SKUs.

Now the put-away process can start. Depending on the type of storage of interest there are different means used by operators to do put-away and replenishment tasks. For example, palletised SKUs, which are high rotation products, are handled with reach trucks because they need to be placed in pallet racks. Instead, multi-order locations pallets with medium rotation products are handled with high-level order pickers into carton live shelvings. Pallets with boxes of low rotation and make-to-stock products are handled with low order pickers and placed into carton static shelvings located in the right side of the warehouse. MGA products are handled with reach trucks and put into conventional pallet racks, while bulky items in canalis are located in cantilever racking with a forklift.

The replenishment task is performed when the inventory level for that SKU is critical. Rather than putting pallets or boxes to the higher levels like in put-away, for replenishment goods are lowered to the floor to be made available for picking.

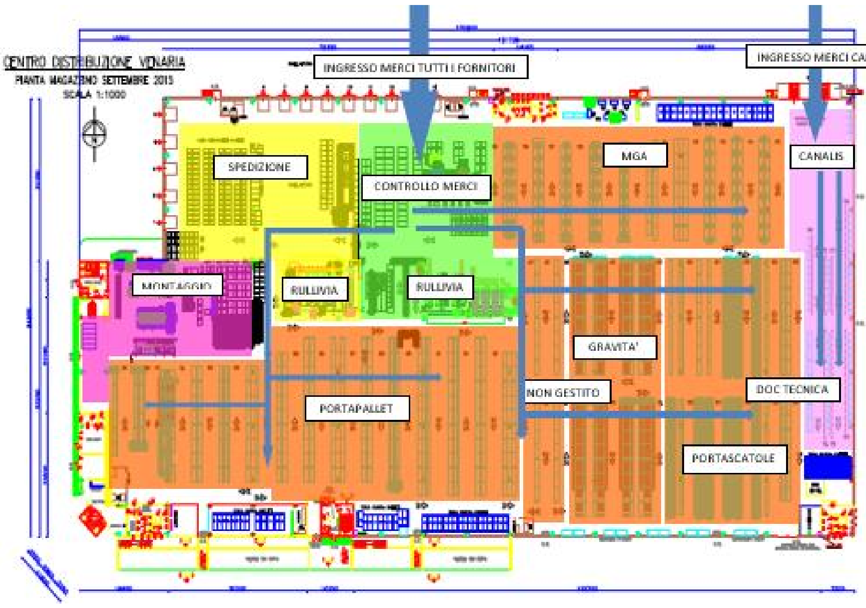

Figure 10 Venaria DC inbound workflows

On the other hand, the outbound flow as shown in Figure 11, gathers the picking, packing and shipping processes and involves the picking area, canalis and outbound area. Once orders are received, they are clustered by WMS into different picking pools based on certain picking logic and criteria. Basically, in Venaria DC 2 picking methods are being used: discrete order picking and cluster order picking with concurrent sorting. Picking pools are also differentiated based on the order volume and weight while picking and replenishment routes are organized following ascending order of bin locations. Picking activities are performed mainly by low-level order pickers because the picking area involves only the lower levels of storage racking and shelving systems. However, because of space restrictions there are also some picking pools that are specific for high levels picking and they are performed with reach trucks.

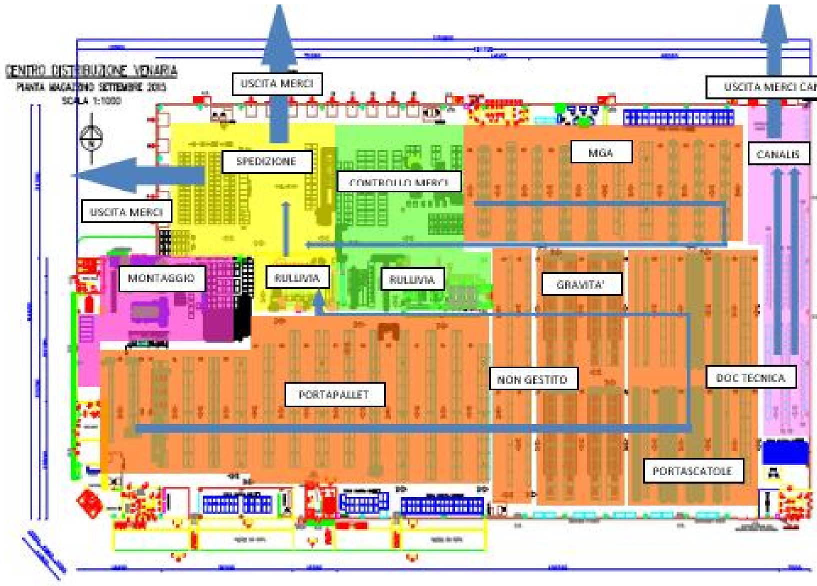

Figure 11 Venaria DC outbound workflows

Pickers go to the storage location, pick to quantity told by their handhelds, put the items into a box. Boxes are not placed in picking carts but they are put on a pallet carried on order pickers or reach trucks. Once the orders have been fulfilled the pickers leave their pallet with the shipping boxes in the packing area. Here, every single box is picked up from the pallet, opened and filled with air pillow packaging by an operator. Then boxes move through a conveyor where they are weighted, controlled, wrapped with plastic bands and then sorted by geographic area and finally palletised manually. In the shipping area, instead, shipping pallets are prepared for shipping by wrapping them with a film and then they are moved to preload areas so that when the carrier arrives they are ready to be loaded.

The most important tool in performing put-away, replenishment, picking and shipping activities is the computer handheld connected to the WMS which tells the operator what to do, where to go, what to grab and how many items.

In canalis, goods are packed and shipped directly in that area.

3 Smart DC concept

3.1 Smart DC definition

In recent years, there has been a significant growth in the use of connected technologies in manufacturing, which led to the birth of the so-called Smart factories. However, Industry 4.0 had an impact also in warehousing and distribution making operations faster, more scalable and more efficient. A Smart DC is the result of the application in warehousing of Industry 4.0 technologies.

Technological innovation in warehouses historically focused on 2 areas: automation in material handling and warehouse management system software. Nevertheless, the solutions applied in both areas were presenting lack of adaptability or "smartness” because were static, and they worked only under prescribed conditions. For example, automated systems had to be kept separate from workers for safety and high standardization of processes and products was required. In addition, there was no automatic exchange of information between the warehouse control system and the working environment. But Industry 4.0 technologies, thanks to low-cost sensors and data acquisition systems, will make possible this kind of integration paving the way for Smart DCs. It will facilitate the creation of a unique ecosystem where machines and humans will be more connected and reactive to changes

The most popular and mature Industry 4.0 technologies implemented in Smart DCs are:

- Internet of Things (IoT) and wearables: basically, consist of smart devices with embedded sensors, internet connectivity and processors to elaborate and transmit data. This technology makes possible the creation of a complex network infrastructure that allows communication between physical devices at different levels, real-time data acquisition and remote control. Moreover, it also involves the development of applications connected to the World Wide Web. IoT technology can be applied to wearables like smartwatches, smart glasses, smart gloves, but also to mobile devices, scanners, cameras, actuators of conveyors till autonomous mobile robots. Internet of Things is the most mature Industry 4.0 technology because it is getting more and more affordable and it is really speeding up material handling, storage and shipping[32]. For example, IoT allows accurate tracking of vehicles and goods during transport through GPS sensors and continuous inventory monitoring[33]. Another noteworthy application of IoT is the Smart facility and building management which enable through the use of sensors the optimization of energy consumption.

- Big data and analytics: IoT permit to generate a big amount of real-time data but they should be securely stored, analyzed and interpreted in order to make decisions and take effective actions. Big data and analytics are about developing hardware structures and software applications to manage these data, monitor performances and get more detailed insights. Cloud computing is the latest frontier in terms of sharing and processing data between different platforms. It is essential for information systems to coordinate operations inside the warehouse real-time, but also to improve communications among the supply chain players[34].
- Automatic Identification Technology (AID): this technology is used to enter quickly information into the computer systems like the WMS rather than input data through the keyboard. It may be Bar Coding, Radio Frequency Identification (RFID) and Voice Recognition Technology (VRT). Bar Coding is the simplest and cheapest one because identification occurs with printed horizontal strips of vertical bars and it used to control warehouse operations and update inventory. RFID is a technology that uses a chip to store large amount of information which can be read at a certain distance by readers without any scanning. This is a faster solution than the former because it allows instant transmission of data. Actually, this technology has been being used for decades but it shows its full potential

[32] (Datex, n.d.)
[33] (Yao, 2018)
[34] (Kamali, 2019)

only with IoT. Finally, VRT avoids entering data manually by interacting directly with the WMS and letting operators' hands-free[35].

- Augmented Reality (AR): it is a technology supported by smart devices, for example, smart glasses, which should help the staff and warehouse managers in their operations. In picking AR enables Pick-by-Vision that lets operators' hands-free during the picking activities. AR also could be implemented in inventory management to give immediate insights of the location of the product and to see real-time data about products, performances and machines[36]. In addition, AR could optimize transportation by giving information about the dynamic traffic in the aisles showing the best route, it could also help to improve the verification process to verify orders completeness in a single glance and it could improve cargo loading and unloading operations for providing instructions to the operators about products destination[37].
- Robots and cobots: a Smart DC also involves implementing advanced automation. The first and most successful robots to be implemented are Automated Guided Vehicles (AGVs). At first, AGVs were very rigid in fact wired navigation technology and guide-tape technology were keeping AGVs separate from human workers and absolutely static. But with the progress of technology now AGVs use laser-based technology and camera-based technology and they can follow an open path passing through an area where humans are going to work[38]. AGVs are used both in factories and warehouse to accomplish standardized transportation of unit loads which in the latter case are pallets. AGVs in performing this task may have to make many decisions, for example, considering the best route or stopping because there is a human or going to the battery station. Hence, AGVs must be supported by a robust control system

  The most innovative example of the application of AGVs in logistics is Amazon Kiva system. Through Kiva, Amazon was able to change the paradigm of

[35] (Kamali, 2019)
[36] (Scandit, 2018)
[37] (Yao, 2018)
[38] (Addverb Technologies, 2018)

warehousing introducing a good to person logic in their most advanced fulfilment centres. Traditional warehouses used a person to good system to manage storage and picking operation which means that it was the operator with a forklift to bring goods to their storage locations and it was the picker to move to the bin location to fulfil the order. In Amazon, shelving is moving to bring goods to the picking station where they will be picked by the operator. The power of this solution stays in the sophisticated software which guides the robots and controls the material flow using Wi-Fi signals. As shown in Figure 12, the layout is like a grid and the cartesian coordinates of every point are identified with a QR code printed on the floor; also pods (the specific Amazon movable shelves) are identified in the same way. Using cameras and infrared sensors and these mobile robots recognise the position to go and get inventory pods and bring them to the picking stations.

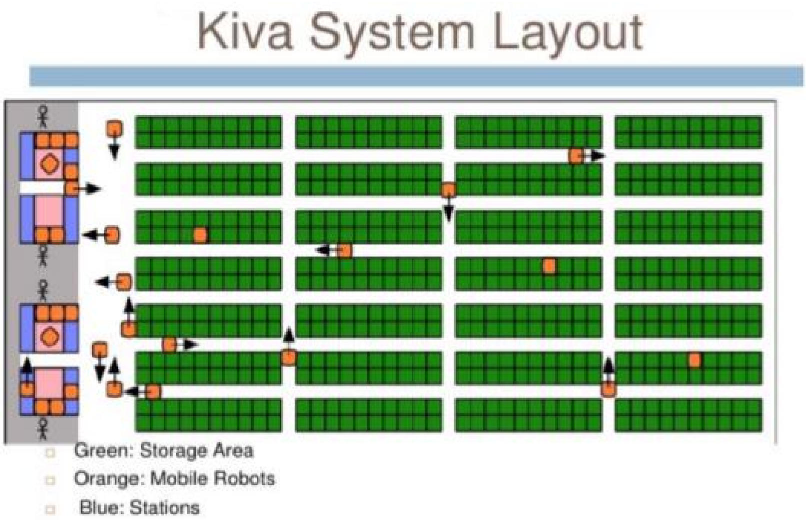

Figure 12 Kiva system layout[39]

Instead, collaborative robots or cobots could be employed in material handling operations like machine feeding, loading and unloading, packing, palletizing. Collaborative robots are specific robots designed to work and interact with

[39] (Yao, 2018)

humans in the same environment. Cobots are defined according to 5 characteristics: safety because they have to work with humans, lightweight so that they are portable, simplicity in the to interact with, low expenditure for purchase and maintenance and flexibility in movement and technology. Amazon is also developing collaborative robotics system to pick individual items from shelves and work with picking operators to gather the objects for packing[40].

3.2 Schneider Electric Smart DC

One point of the Schneider Electric development strategy is to lead the digital transformation of energy management and automation not only in industry but also in the Group own plants, DCs and other facilities. So, the Schneider Electric Smart DC also concerns with implementing the smart solutions which represent its offerings to customers like EcoStruxure technology.

In July 2019 Schneider announced to have completed the digital transformation of its 2 flagship DCs in Ingleburn, Australia, and Shanghai, China. After these investments, the company has been ranked 11th in the Gartner Supply Chain Top 25 for 2019

Schneider Electric concept of Smart DC is based on some principles that are:

- Agile management and process efficiency
- Asset performance management
- Energy efficiency and reliability
- Empowered operators and automation

These principles are strictly related to its core business which is about energy management and process automation control. The first 3 principles are implemented through the EcoStruxure platform which is an integrated architecture with 6 different domains that allows connecting field level technologies to enterprise level (see Figure

[40] (Yao, 2018)

13). EcoStruxure is a combination of IoT, big data and analytics that helps to translate data into intelligence for being able to act and optimize performances[41].

Figure 13 EcoStruxure architecture[42]

Some of the main technologies used in the Schneider flagship Smart DCs include[43]:

- EcoStruxure Power to control and monitor energy consumption inside the building in order to reduce energy usage.
- EcoStruxure Machine and EcoStruxure Plant for real-time performance monitoring and analysis of workers and machines.
- EcoStruxure Machine SCADA Expert for the management and monitoring of machine production lines.
- EcoStruxure Machine Advisor, a platform in the cloud that tracks machines in operation, monitors their performance and allows predictive maintenance.
- EcoStruxure Augmented Operator Advisor a custom application that uses Augmented Reality for instant diagnosis or monitoring real-time operational data.
- AGVs and RFID traceability to speed up material handling

[41] (Schneider Electric, 2019)
[42] (Arnó, 2018)
[43] (Energyreview, 2019)

3.3 Smart DC plan in Venaria DC

Having defined how warehousing declines in Venaria DC and what are the features of a Smart DC in general and for Schneider Electric, it is clear that Venaria DC is still a traditional logistic centre. In fact, processes are highly labour intensive, and the level of automation is low in every area. For example, activities like input data in the system to finalize good reception, labelling or palletizing boxes are performed manually despite there are solutions which could automate the process. All warehousing operations are carried out by operators driving order pickers or reach trucks, so there is no AGV. There is no use of IoT, wearable solutions or Artificial Intelligence algorithm applied to WMS to optimise storage location, picking routes, inventory level.

Venaria DC, however, can count on a solid and reliable WMS which is the basis for starting to get smarter.

When passing from flagship DC to common DC, as the case of Venaria DC, it has to be taken into account that things are a little bit different. Resources in terms of money, time, employees, know-how, are limited and the environment could be not yet completely mature and suitable to be ready for the implementation of all the technologies of a flagship DC because there are some gaps to overwhelm yet. Some of these gaps such as the lack of standardization of logistic processes, and their low technological level, or the lack of information will be identified over the description and the analysis of the projects undertaken.

As shown in the manifest (see Figure 14), in accordance with the Schneider Electric principles, the solutions planned in the program belong to 5 different business areas. There is the familiar area of energy efficiency with the EcoStruxure implementation, then there are the areas of demand and forecast management, digital employee, customer experience and finally logistic efficiency which is the field my projects are dealing with.

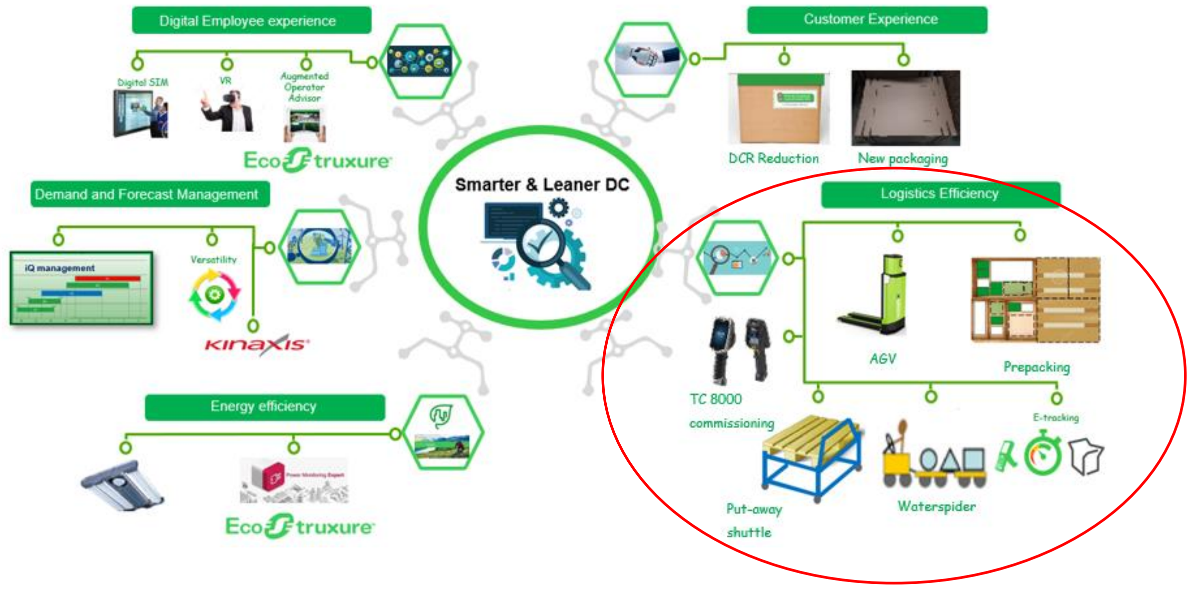

Figure 14 Smart DC program for Venaria DC

In the logistic sphere, there are some ambitious projects linked to the Smart DC concept. One of them is the installation of AGVs in the transportation of the pallets to put-away from the receiving area to the corridors for speeding up the put-away process. Another interesting project is Pre-packing which is an algorithm that should calculate how many boxes and which types are necessary to fulfil the order, maximising the space saturation of boxes.

The value proposition of the Smart DC program is “making the DC smarter and leaner “. Here, the Smart DC concept is combined to the idea that instead of making the logistic centre soon smarter, you need to make it at first leaner in order to gain immediately savings and prepare the ground for smart innovations.

This is a win-win situation because getting leaner is both functional to budgetary reasons and to smart initiatives.

3.4 Project introduction

With respect to the double-faced goal of the Smart DC plan for Venaria DC, looking at the two projects carried out during my internship, the first one is more related to make the DC operations leaner while the second one contributes to make the DC smarter.

Both projects are included in phase 1 of the Smart DC plan because they are about standardization and technological adaptation rather than innovation. More advanced projects like AGV or Pre-packing are included in fact in phase 2.

Project 1 or consumable management optimisation is about process standardization. It is a continuous improvement project that, with lean tools, aims at redesigning the flow and organizing the consumables supply operations in order to increase productivity. The outcomes of this project will be very important for the realization of the Water Spider project that consists of an internal logistics solution like a milk-run, for integrating into a unique flow the consumables management and waste management processes, maybe with the help of smart technology.

Project 2 or TC 8000 commissioning is about technological adaptation. It is an IT project concerning the installation of smart handhelds and the transition of the WMS app (SIM+) from an analogical view mode into touch interactive interfaces. TC 8000 commissioning is absolutely a milestone because it establishes a technological upgrade in the warehouse enabling opportunities for smart picking, IoT, and augmented reality

In the following sections, every project will be analysed by describing what they intend to standardize or upgrade, how and why. Some insights on future developments and opportunities will be also provided to complete the overview.

4 Project 1: Consumables management optimization

4.1 Standardization & waste

In Schneider Electric when dealing with projects regarding process improvement or innovation inside factories or DCs, there are some pillars and guideline to keep in mind. They suggest always facing problems and structuring projects in different steps.

From a theoretical point of view, the principle that you should consider for defining the purpose and the scope of the project when facing an operational problem is

“Think big. Act small. Scale fast.”

While from an operative and practical point of view, the guideline to follow when structuring a project of innovation is “

Standardize” applying lean principles, “Step up” with innovation and “Advance” the whole process.

This project shows how, when dealing with projects of improvement and innovation, the first basic requirement to be met, before going for any technological solution, is the standardization of processes.

But what does it mean standardization?

According to Kaoru Ishikawa, "An individual may choose to do things his own idiosyncratic way, and it may prove to be the best method for him. But an organization cannot rely on a method thus derived. Even if it were a superior technique, it would still remain the specialty of one individual and could not be adopted as the technology of the company or workplace[44]."

Standardising a process refers to the establishment of a set of rules for governing how people in an organization are supposed to carry out a given task or sequence of tasks[45].

[44] (Ishikawa, n.d.)
[45] (Brandall, 2018)

Standardized work represents the baseline for kaizen or continuous improvement. In fact, once the standard is defined it helps to create new standards supporting improvement activities, therefore improving standardized work is a never-ending process[46].

According to lean manufacturing, standardized work consists of three elements[47]:

- Takt time, which is the rate at which products must be produced in a process to meet customer demand.
- The precise work sequence in which an operator performs tasks within takt time.
- The standard inventory consisting of quantity of materials required to keep the process operating smoothly.

Being the project related to warehousing and not to manufacturing these principles has been slightly adapted, however their concept will be maintained. Therefore, the takt time became the frequency per shift for the different tasks, the work sequence became the working plan the operator had to follow in performing the tasks and the standard inventory became the quantity to supply during every task.

The benefits of standardized work include[48]:

- Provide documentation of the process along with a data collection system to control it and study further improvement actions.
- Facilitate the training of new operators.
- Improve clarity in responsibilities and in the way to do the task because a standardized process will eliminate guesswork and ambiguity, this will also boost the employee morale.

[46] (Kaizen Institute India, 2013)
[47] (Lean Enterprise Institute, n.d.)
[48] (Brandall, 2018)

- Increase quality and safety because the activities have been designed to minimise defects and injuries.
- Increase productivity and efficiency by removing waste and reducing inefficiencies and sources of variability.

Being the basis for Kaizen, standardisation is linked to the reduction of waste and inefficiencies. According to Lean manufacturing, there are 8 types of waste

Figure 15 The 8 Wastes of Lean [49]

Some of these types of waste will come out also in the project that is going to be described. Knowing this kind of waste will be helpful in the phase of analysis of the inefficiencies and design of improvements.

[49] (Skhmot, 2017)

4.2 The business case

Consumables management optimisation is part of a more complex and extensive scheme of improvement, the Water Spider Master Project.

Water Spider or Mizusumashi is a Lean Manufacturing term used to indicate a person, in a warehouse or factory, whose job is to supply the consumption points with what they need in the right quantity, at the right moment[50]. According to Lean principles, each worker or station should avoid Mudas and be committed, as much as possible, with value-added tasks. Water spider is conceived as the owner of all the non-value-added and auxiliary tasks of the shop floor so that the rest of operators can focus full time on value-adding activities being more productive and efficient.

In Venaria DC, there were two no value-added processes concerning consumables management and waste management, but they were not both in the hands of the Water Spider. At that moment, every shift the Water Spider was focusing only on the consumables management process, while another operator per shift was involved in waste management. This situation was causing a huge loss of productivity at the end of the year because one more operator per shift besides the Water Spider was delivering 0 productivity. The idea of the Water Spider Master Project is to increase the overall productivity by integrating the consumables and the waste management flows into one unique process, make the Water Spider responsible for that and have more productive resources during the shift.

But because of the complexity of the problem and the lack of standardization of both of the two processes, it was decided to split the project in two:

- Consumables management optimisation
- Waste management optimisation

[50] (MakeITLean, 2017)

Then, see if standardizing and optimising at first each individual flow, there would have been a concrete opportunity for the integration of the 2 flows in the Water Spider role.

The impact of consumable management optimisation on achieving the yearly productivity target was quite significative and estimated around 25%.

4.2.1 The Schneider Electric approach

This way to structure and interpret projects of continuous improvement and innovation reflects the Schneider Electric thinking highlighted some chapters before.

Think big. Act small. Scale fast, when facing an operative problem.

Standardize, step up and advance, when facing a project.

In fact, the idea of the Water Spider Master project should be seen as the result of the Think big phase. In this regard, it was also thought to some technical and technological solutions. For example the use of a tow tractor equipped with special couplings and trolleys to collect trash bins and to supply raw materials to the stock points (see Figure 16). Or the use of IoT would have created a smart system to assign tasks automatically telling the Water Spider what to do next.

Figure 16 Water Spider example[51]

[51] (Fallsway.com, n.d.)

But since the problem was these two processes were quite complex to study and they have always been considered independent, it was quite hard to imagine them together. Therefore, it was decided to “Act small” and improve each process separately before, without thinking too much about the solutions of the big idea but keeping in mind the value proposition. This strategy appears to be more result-oriented than studying both processes together. In fact, in the latter case, the project duration would be longer and there would be the risk of finding a solution that didn’t optimise any of the processes but simply brought them together. So, less efficiency.

The third phase “Scale fast” is represented by the fact that the concept of joining together two non-value-added processes is easily applicable in all DCs of the Group despite the different levels of technology and technical solutions.

From the operative side, when starting up a project, instead, the first goal to accomplish is the standardization of the process. During my internship, I worked on the standardization phase of Consumables management optimisation. However, over the course of the chapter, I will point out some possible opportunities regarding the “Step up with innovation” phase related to the introduction of smart initiatives.

The advance phase, hopefully, will consist of the final integration of the two processes but what the result will look like depends on the previous stage.

The same logic will be followed by the Waste management optimisation project.

To conclude, following the Schneider Electric project management approach, consumables management optimisation is an “Act small” project regarding the Standardization phase.

4.3 Context

Before going any further to the context and avoid misunderstandings, it should be clear that the consumables management process was the current workload of the Water Spider in Venaria DC. Therefore, optimizing the consumables management process means optimizing the current work of the water spider.

Generally, in any production environment, when looking at the Water Spider's job, it could appear a little bit chaotic also because it aims at mitigating the variability and the unexpected that are affecting the system. In fact, besides bringing and taking materials, Water Spider can also be involved in other auxiliary tasks such as transporting finished goods away from the work area, removing waste, packing materials and supporting less experienced personnel[52].

But in Lean everything should adhere to standards. Thus, even though it could consist of a plethora of activities, Water Spider's work should be mastered by a standardized process with a clear set of tasks to be done following a standard physical route. So, as shown in Figure 17, Water Spider should follow a specific working-schedule which dictates the points to visit, the materials to supply, while the quantity, the frequency and the timing depend on the needs of the process[53].

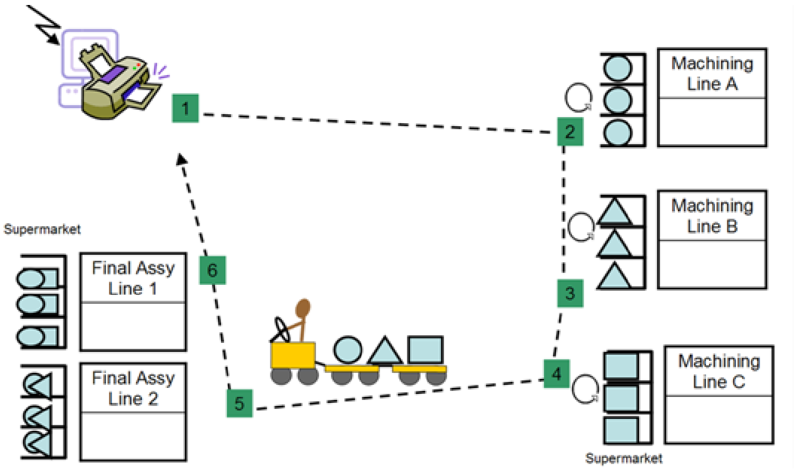

Figure 17 Water Spider flow[54]

[52] (Shmula.com, 2017)
[53] (Shmula.com, 2017)
[54] (Miller, 2010)

Only by defining these standards it will be possible to keep the production and Water Spider's process under control. Otherwise, Water Spider would be just a free floater improvising a variety of tasks like a gofer while supplying materials in the production area[55].

This is the most common mistake that companies could be making, and unfortunately, this misleading concept of Water Spider had taken root also in Venaria DC. Here, the work of the Water Spider, corresponding to the consumables management process, was chaotic and totally unstructured. In fact, there was no working schedule, no written procedure, no standard at all in the process guiding the operator acting as a Water Spider. Consequently, rather than a real Water Spider working efficiently following a fixed plan, the operator was more similar to a guy that, despite doing his best in his own way, was basically running around the warehouse without a clear purpose, to see where to intervene first. Moreover, there was also a cultural issue because the role of Water Spider was undervalued and enjoyed a very low status inside the production environment.

All this is due to the fact the process followed by the water spider is not standardized.

In order to fix this problem, I was asked to start up the continuous improvement project regarding the consumables management optimisation. This project was carried out following the lean philosophy of waste removal and continuous improvement while using the PDCA cycle while.

PDCA is one of the most common frameworks used to manage continuous improvement projects developed by Dr. W. Edwards Deming in 1950. It is often used when making little changes to a process or implementing a solution to a problem that is known or starting a Kaizen program or when identifying the root causes of an unknown problem[56].

[55] (Shmula.com, 2017)
[56] (Reverscore.com, n.d.)

PDCA, as shown in Figure 18, is an iterative method that consists of a sequence of 4 steps that should help the team preventing stupid mistakes that could compromise the success of the project:

Figure 18 PDCA cycle[57]

- Plan: this is the longest phase because it defines what is the project going to change and how. Therefore, this phase is about identifying problems or opportunities, establishing goals, gathering and analysing data concerning the current situation, and coming up with a potential solution and a plan to test it.
- Do: this phase is about implementing, preferably on a small scale, the solution developed and keep track of results and effects.
- Check: this phase is about examining the results of the experiment and verify if the process was improved comparing the current data with the original ones. In case of negative outcomes go back to the previous stage and try again
- Act: this phase is about implementing the validated solution massively and updating the standard operating procedures. It is also about the definition of new problems that might be investigated in the plan phase again.

With this in mind, we can move to the Plan stage.

[57] (Zwart, 2017)

4.4 Plan

4.4.1 Project scope

The project scope was defined under the supervision of the logistic Lean leader. This person is responsible for improving the performances of 3 Schneider Electric DCs in Europe, so he has a broader vision of possible improvement actions to apply inside a DC. He is usually the one that suggests and approve the most important improvement projects for every DC.

In this regard, during a regular lean diagnosis for boosting the productivity of the centre, he decided to start up the first phase of the Water Spider Master project which was about the consumables management process optimisation.

Every project carried out following the PDCA cycle should start with the definition of the problem or the opportunity within an existing process coupled with a set of clear goals.

In this case, the project was not referring to a problem with unknown causes to solve but rather to an opportunity of improvements corresponding to the standardization of the consumables management process. This opportunity comes from the following "problem" statement:

"In Venaria DC there is one operator per shift working as a Water Spider performing all tasks linked to consumables management without a clear procedure."

We can notice how this statement is already revealing the solution: standardize the process. However, the goal statement, taking into account the considerations of the business case, had to be more ambitious. It was formulated as follows:

"Define a clear process of who has to do each action, when and how to do it. Reduce the consumable time spent by the Water Spider at least by 30%, from 15 to 10 hours a day, by the end of July2019."

The scope of the project was related to two points. The first one implies focusing only on the consumables management process without considering the waste management process. The second one was related to the cost of the solution which should be close to 0 Euro. In fact, faced with a process that is not standardized with 0 information it is better to define a standard and a procedure first, so that there could be a baseline for assessing more consistent investments later on. The third one was the possibility of changing also other value-added processes for optimising the consumable management process by introducing some no value-added tasks related to consumables. So, optimising the consumable management process could admit the act of increasing the workload of resources if their capacity was not saturated but could not jeopardize the overall productivity.

The challenges in facing the problem were several. The main one was related to the total lack of data about the consumption of consumables at every point, the time spent or the frequency of every task. The consumables management process seemed a sequence of random activities without any data-driven control system in place. There wasn't any working schedule or instructions for doing activities, any list of the activities regarding the consumable, any written information about the route of the Water Spider, any standard at all. The inputs of the process were deriving from verbal communication by various operators or physical inspection by the Water Spider. Under these circumstances, it was clear the difficulty in gathering data for doing any sort of analysis. Another challenge was represented by the variability of the demand, and the high variety of products in the warehouse which were influencing the consumption of consumables and so the work of the Water Spider. As said before, the Water Spider enjoyed a very low status inside the DC so, another challenge, maybe the biggest one, was introducing a "change management" in the mentality of the staff. Then, of course, also the resistance to change by operators had to be taken into account especially in this situation where they have always worked in that way.

The risks associated with the project were basically two. The first one was regarding the possibility of not being able to define a fixed route of the Water Spider at the end of the project because of the too high variability in the consumption of the different types of consumables (pallet, boxes, air packaging called "Bubbles", packaging straps, labels etc).

The second one was the risk of affecting the productivity of some value-added processes for reducing the lead time of the consumables management process and not being able to perceive this because of the lack of data or their low level of accuracy. Another risk could also be represented by the fact of forgetting the Water Spider original function which is supplying materials to the production or consumption points when needed.

The structure of the project team and the high-level timelines are shown below. I was designated as the project leader but during the majority of the project I collaborated with the other methodist.

Project Team:

- Andrea Emanuel (Leader – Methodist)
- Mohamed Samir (Methodist)
- Water Spider
- Team Leader Receiving
- Picker
- Supervisor
-

Gate	Key Deliverables	Date	Status
D	1.Project Charter	14/05	done
M	3. Prepare Templates to collect data	08/05	
	4. Collect Data + R&G analysis	30/05	
A	5. Analyse the frequencies & time of each task (AS IS TODAY)	15/06	
	6. Define FUTURE STATE (different scenario)	30/06	
I	7. Implement Solution (Kaizen – 2,5d)	w27	
	8. Work Instruction + Trainnings	w27	
C	9. Ensure process is respected	w31	
	10. Get the results expected	w31	

Figure 19 Project structure

4.4.2 Gemba walk

This expression is referred to high-level employees and literally means "Go to real place (where value is created)" meaning the shop floor. So, in lean a Gemba Walk is what methodists, managers, leaders, supervisors, do to see and understand, in first person, the state of the process or possible problems that they are going to study[58].

As there was no written documentation or information about the consumable process, I heavily applied the Gemba approach to start understanding what the process was about and how it works. So, I started following the Water Spider during his work, observing, asking questions and starting to point out inefficiencies.

58 (Btoes insights, n.d.)

After this "Go see, ask why, show respect" phase I started to get some insights about the process. The first thing I did was identifying all the activities concerning the consumable process. Hereunder, there is the list of all the tasks divided per working area and category of consumable.

Area	Task N.	Task	Category
Montaggio(LAC)	5	Supply boxes Kit	Boxes
Montaggio(LAC)	10	Supply bubbles Kit	Bubbles
Montaggio(LAC)	15	Supply boxes Assembly	Boxes
Montaggio(LAC)	20	Supply bubbles Assembly	Bubbles
Mga	25	Supply pallet 215x100	Pallet Mga
Mga	30	Supply pallet 215x90	Pallet Mga
Mga	35	Supply pallet 150x80	Pallet Mga
Mga	40	Removing pallet 120x80	Pallet
Mga	45	Supply pallet80x60	Pallet
Mga	50	Supply coperchi MGA 215x90	Pallet Mga
Mga	55	Supply temporary stock pallet Mga	Pallet Mga
Mga	60	Supply boxes & covers FTA	Boxes Mga
Mga	65	Supply S7 & covers	Boxes
Mga	70	Supply shipping pallets	Pallet
Inbound	75	Supply boxes GP	Boxes
Inbound	80	Supply Recycled Boxes GP	R.Boxes
Inbound	85	Supply boxes GV-GT-GS	Boxes
Inbound	90	Removing Cartons	Waste
Inbound	95	Supply boxes resi	Boxes
Outbound	100	Supply framework 80x60 - 80x120	Pallet
Picking	105	Cleaning	Pallet
Picking	110	Pallet Management	Pallet
Picking	115	Remove pallet 80x60	Pallet
Picking	120	Supply Boxes corr3	Boxes

Picking	125	Supply Boxes corr55	Boxes
Picking	130	Supply Recycled Boxes	R.Boxes
Picking	135	Supply bubbles corr3	Bubbles
Picking	140	Unload to the floor	Pallet
Dc	145	Monitoring	Other
Dc	150	Unload Trucks	Pallet
Dc	155	Load Trucks	Pallet
Dc	160	Cleaning offices	Waste
Dc	161	Supply puriball & straps	Other material
Dc	162	Supply labels & ink & tape	Other material
Dc	163	Supply bubbles roll	Other material
Dc	165	Inventory	Other

Table 1 Consumables process activities

By grouping these tasks by area and category, as shown below, some first conclusions could be drawn. For example, that MGA and the picking area were the most involved departments while pallets and boxes were the most handled consumables.

Category/Area	Montaggio	Mga	Inbound	Outbound	Picking	Dc	Total tasks per category
Boxes	2	1	3	0	2	0	8
Bubbles	2	0	0	0	1	0	3
Pallet Mga	0	5	0	0	0	0	5
Pallet	0	3	0	1	4	2	10
Boxes Mga	0	1	0	0	0	0	1
R.Boxes	0	0	1	0	1	0	2
Waste	0	0	1	0	0	1	2
Other	0	0	0	0	0	2	2
Other material	0	0	0	0	0	3	3
Total tasks per area	4	10	5	1	8	8	**36**

Table 2 Tasks based on category and area

During this stage, I also carried out the process mapping, which is a way of visually representing a process. There are various tools that can be used like flowcharts process mapping, Value Stream Mapping (VSM), Spaghetti charts, etc. Nevertheless, I couldn't use any of them because this process wasn't a real process but just a series of activities that were independent one from each other. In addition, during the Gemba Walk I got the confirmation that there wasn't any fixed route or specific path so Spaghetti chart couldn't be applied, as well as the VSM because almost all these activities were not creating value. So, what I draw was a visual representation of the material flow highlighting the starting and the ending points just to have a visual overview of the complexity of the process.

In Figure 20 all flows are reported in the same representation but it appears very difficult to read due to the numerous categories of consumables (pallet, boxes, recycled boxes, bubbles, etc) and the variety of types for every category (see Table 3).

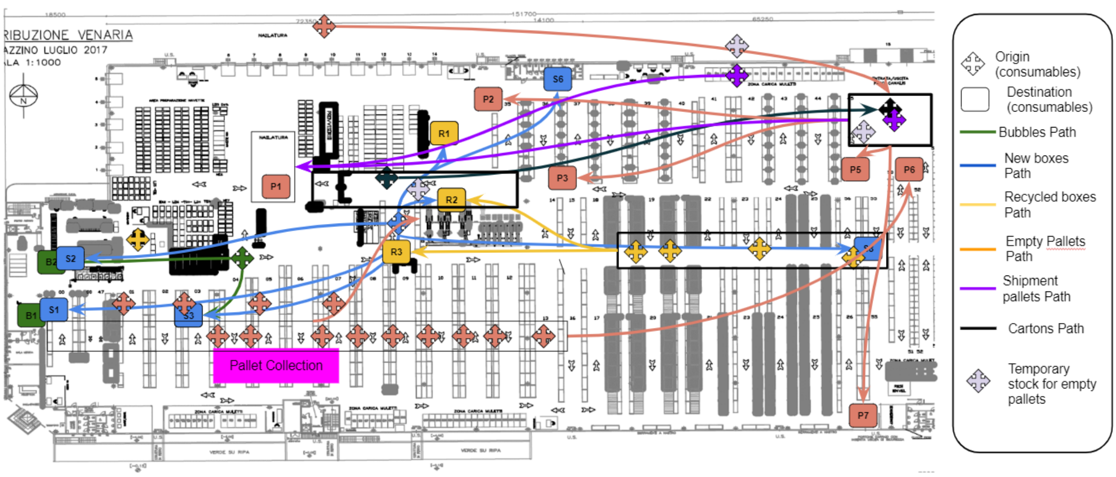

Figure 20 All consumables flow

Boxes & Covers	Pallets	Other materials
S1	215X100 MGA	Bubbles Trolley
S2	215X90 MGA	Pluriballs
S3	150x80 MGA	White labels
S4	120x80	Yellow labels
S7	80x60	Straps LAC
S9	Covers pallet MGA 215x90	Straps packaging
Covers S1		Framework 80x60
Covers S2-S3		Framework 80x120
Covers S4-S7		
Larger boxes MGA		
Larger covers MGA		
Smaller boxes MGA		
Smaller covers MGA		

Table 3 Types of consumables

Therefore, I decided to keep every flow separated and treat it individually. Figure 21, 22, 23 report the flows related the main consumable categories: pallets, boxes, bubbles and recycled boxes.

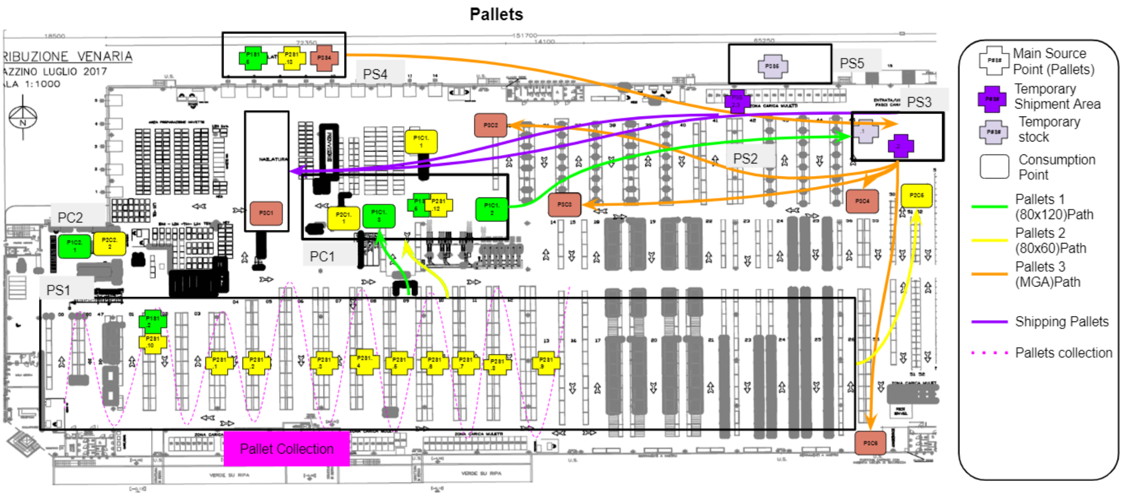

Figure 21 Pallets flow

Pallets handling, as shown in the picture above, is certainly the most dispersed flow in the consumable management process. In Venaria DC the pallet management process includes three different activities: pallet collection, pallet supply and pallet removal.

- Pallet supply is about replenishing the stock points with stacks of pallet of different size that pickers will use for fulfilling the picking orders. It involves mainly MGA pallets that are out of standard pallets. The supply of 80x60 and 80x120 pallets, instead, get confused with the pallet collection and pallet removal meaning that, when collecting or removing pallets, before put them away from the warehouse, the Water Spider checks if some points need to be replenished.
- Pallet collection is basically the activity of collecting the empty pallets left by the pickers along the different corridors of the picking area. Since only items and boxes can be picked, when pickers in the pallet racking storage pick the last item they generate an empty pallet which has to be put vertically in one side of the aisle. At this point, if the Water Spider is on the way, he will come and collect it. This activity involved only 80x120 sized-pallets in the pallet racking storage. Once

collected the pallets, the Water Spider could supply other stock points with them or remove them from the warehouse.

- Pallet removal is an activity related to the curious fact that in Venaria DC the amount of pallets IN is higher than the amount of pallets OUT. This holds for 80x120 and 80x60 pallets which at a certain point have to be removed from the warehouse by the Water Spider because otherwise, the system will explode in an infinite queueing.

The new boxes flow involves only supply activities. In Venaria DC, the pickers don't know yet how many boxes and of which type they have to open to fulfil an order. So, in order to avoid that pickers found themselves without boxes and covers in the middle of the picking process, there are several stock points with trolleys where pickers can take new boxes and covers of any type if they need. The activity of the Water Spider consists of taking boxes and covers of any type from the main stock, in the middle of the warehouse, and refill these trolleys in all different points. Generally, every trolley contains all type of boxes and covers.

Figure 22 New boxes flow

The recycled boxes and covers flow, instead, involves the only value-added activities of the consumable process which are about moving trolleys full of recycled boxes from the place where they are generated to the place where they can be reused again, which is the main area. (see Figure 23)

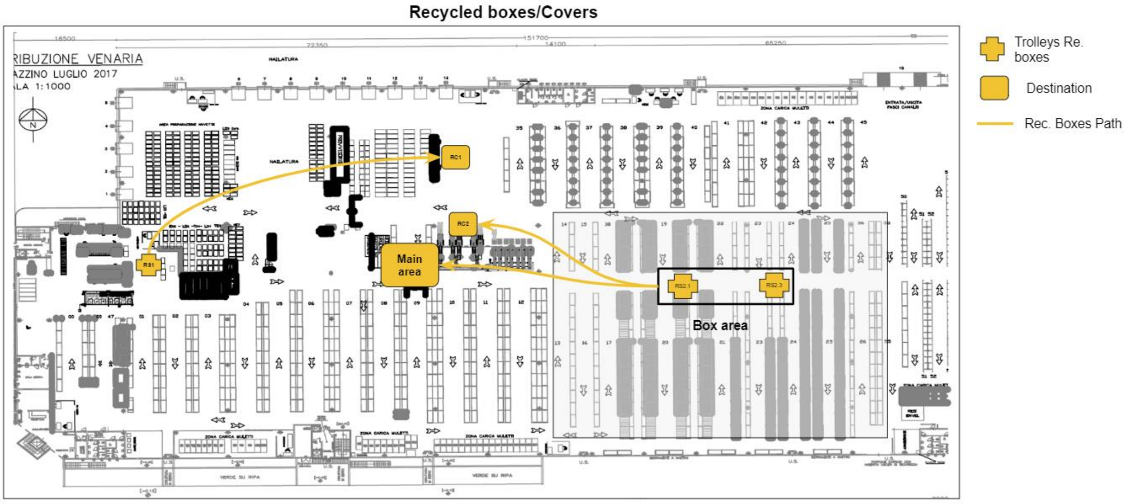

Figure 23 Recycled boxes flow

Finally, there is the bubbles flow which is very simple. It includes all the activities related to the bubbles supply which consists in taking the empty cages from different points, bring them to the air cushions machine to replenish them and bring them back to the original point. This operation was necessary because there was only one bubble machine for the three consumption points and it was far away from 2 out of 3 consumption points.

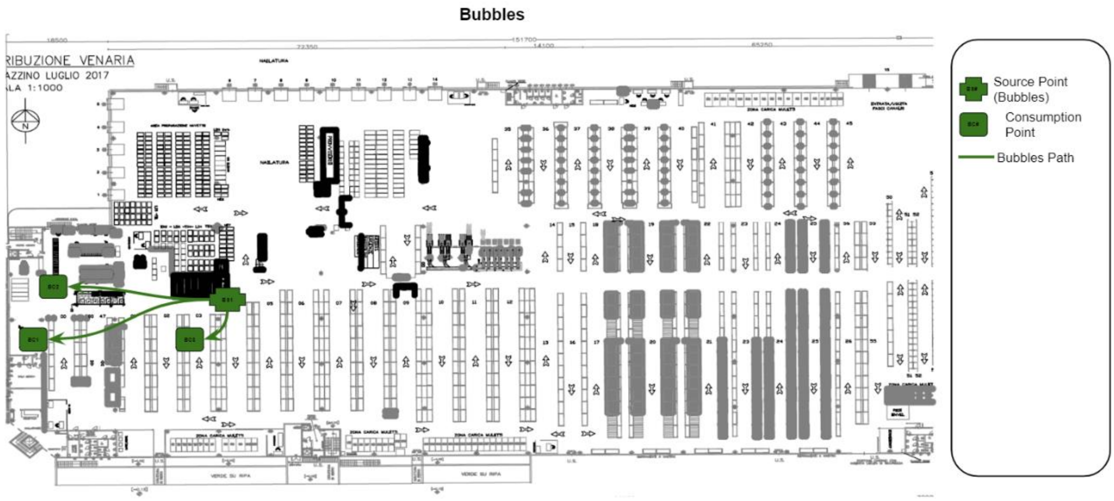

Figure 24 Bubbles flow

It is also important to state that all these tasks were carried out by the Water Spider using a low-level order picker.

After defining the characteristics of the flow, I started to point out, for every task, the main criticalities and wastes that could be detected from the way of working and the answers of the Water Spider. With this information, I tried to think about some solutions evaluating their degree of feasibility considering the timelines, the costs and other constraints such as the lack of space in the DC for doing modifications in the layout. Based on these considerations, I started to prioritize the activities defining with R (Red) the tasks which had room for an easy to do and feasible improvement and with G (Green) the tasks where the improvement was either unnecessary or difficult to put in place or expensive. The results of R&G analysis are shown below.

Area	#	Task	Priority	Code	Criticalities Description
Montaggio	5	Supply boxes Kit	High	R	Average refilling frequency 2-3 times/shift, high variability in consumption, trolley capacity insufficient for lasting at least 1 shift and not correctly dimensioned, no procedure in the comunication with the waterspider, no visual management system for monitoring the level or checking the inventory, no respect of 5s in the storage of boxes, no information system for predicting the nuber of boxes required for a kit
Montaggio	10	Supply bubbles Kit	High	R	Average refilling frequency is 2-3 times per shift, high variability in consumption, waiting of operator when bubble case is over because the WS is not there or is busy, WS can't use the forklift inside working area, unnecessary transportation because the bubble machine is far from the main consumption points, lack of communication channel and procedure for warning the WS about the need of supply
Montaggio	15	Supply boxes Assembly	High	R	= task 5
Montaggio	20	Supply bubbles Assembly	Medium	R	=task 10
Mga	30	Supply 215x90	Medium	G	average refilling frequency is 1-2/shift, the supply point is too far and there is no safety stock, visual management tools or infrmative system for monitoring the stock. Only a temporary storage for doing the refilling. Stock capacity can be increased but it would complicate the operations for the picker and it could mean safety issues
Mga	50	Supply coperchi MGA 215x90	Medium	G	Storage can be inceased but it could be difficult to find space inside the warehouse
Mga	55	Supply temporary stock pallet Mga	High	G	The temporary stock area is limited and could be extended, but we need to find space. The covered area outside is not used as a temporary stock but just as a safety stock in case of rain
Mga	70	Supply Pedane in Spedizione	Medium	G	Pallets are left there after they are finished and they are not carried in outbound by the picker himself. it could be because of other packaging operations. This task could be done by the WS or by the picker but there are no criticalities. There is no simple and feasable improvements that can be done with our constraints
Inbound	75	Supply boxes GP	Medium	R	The water spider is wasting time in unnecessary transporting, the operator can do this task as they are very closed to the stock of boxes. Boxes storage in some workstation don't respect 5s. Operator are already using S1 recycled and covers S2-S3 recycled but they are using S2-S3-S9 NEW
Inbound	80	Supply Recycled Boxes GP	Medium	G	The task is not done constantly only when recycled S3 and S4 in lac are in eccess
Inbound	85	Supply boxes GV-GT-GS	High	R	The water spider is wasting time in unnecessary transporting, the operator can do this task as they are very closed to the stock of boxes. Boxes storage in some workstation don't respect 5s. Operator are already using S1 recycled and covers S2-S3 recycled but they are using S2-S3-S9 NEW
Picking	105	Cleaning	High	R	The water spider is doing unnecessary waiting during this operation. He remove the pallet then he has to wait for the cleaning operator and then he put the pallet again in position. He can't take away all the pallet in once because pickers are working in the corridor
Picking	110	Pallet management	High	R	Around 2 hours per shift are spent, low respect of 5s in the procedure of 80x60 management and 80x120 management. the generation of pallets is variable, there is no place in the corridors for placing 80x120. Many pickers have phisical limitationscfor moving 80x120, unnecessary transportation, no procedure in working. The job could be done unlimeted number of times
Picking	115	Remove pallet 80x60	High	R	No respect of 5s by the pickers. many times the pallets are out f their palce and the WS have to collect the pallets from the corridors
Picking	120	Supply boxes corr3	High	R	Average frequency is 2-3 times/shiftNo 5s (labels), no information about the correct storage in the shelfs, disorganization of throlley, new boxes are not necessary, abusing usage of the trolleys (pickers use throlley to do their supply, instead it coul be used just in case of need)
Picking	125	Supply Boxes corr55	High	R	Disorganization of throlley, the need to be satisfied is providing covers to the pickers to close the boxes at the end of the tour to avoid traffic, unnecessary new boxes supply as there
Picking	130	Supply Recycled Boxes	High	R	many recycled boxes thrown away in the bins instead of using them because of not enough space to store and collect them, no procedure and respect of 5s in putting the boxes in the correct shelf
Picking	135	Supply bubbles corr3	Medium	R	High refling frequency 2-3 times per shift. Unnecessary transportation, the back up case is very close to the consumption point
Picking	140	Unload to the floor	High	G	Necessary operation, but the WS unload the pallet when the other is not empty but there are at least 4-8 packs which are a lot of boxes, but they act like these because WS doesn't know about what happen next (load, unload trucks)
Dc	145	Monitoring	High	R	Unnecessary monitoring due lack of a working plan and checklist and communication system so the WS has to go there to see if they need something
Dc	150	Load/unload Trucks	High	G	No scheduling about arrivals, at the moment they ae totally random
Dc	162	Supply labels & ink & tape	High	G	No checklist and tacking of inventory

Table 4 Red and Green analysis

The activities which represented a quick win introducing standardization seemed to be the ones related to:

- Boxes supply whose main criticalities were represented by a not well-dimensioned inventory level of the trolleys, over-processing and unnecessary transportation.
- Bubbles supply whose main criticality was the unnecessary transportation from the location of the bubble machine to the consumption points due to the not proper position of the bubble machine.
- Pallet collection whose main criticality was over-processing meaning that whenever the Water Spider saw an empty pallet in the corridor he collected it.
- Supply recycled boxes whose main criticality was pollution. Despite being the only value-added activity, a lot of re-usable boxes were thrown to the waste bin.
- Monitoring whose main criticality was related to the lack of a standard working schedule which led the Water Spider to make too many empty rounds.

However, this was just a qualitative evaluation which didn’t take into account of the impact of every task in terms of time on the current consumable process. In order to get this information, it was necessary to gather data. Data were also necessary for establishing a baseline of current performances besides studying, analysing and benchmarking the potential solutions.

4.4.3 Gathering data

Once understood the status of the process and its main criticalities, the following step was defining the relevant variables to measure.

I identified three critical drivers for the success of the project which are:

- Time spent on carrying out the different activities in order to establish a baseline of current performances and identify the most time-consuming activities to optimise.
- Material consumption in order to estimate the frequency of every task and calculate the time spent but also to know the quantity supplied per shift to different consumption points and calculate the right inventory level of boxes and pallets.
- Productivity regarding performances of value-added processes and activities. This is relevant to check if by assigning some tasks related to consumables to other processes their performances decrease or keep being stable.

Then, for every category, I set the corresponding KPIs. For instance, material consumption was estimated calculating the average frequency per shift and the average quantity per shift in units or Unit Load (UL) for every supply activities. Productivity, instead, was assessed considering efficiency (Hr expected/Hr worked) and saving with regard to the consumption of recycled boxes.

The KPI tree displaying all the measures relevant to the project is shown below:

KPI tree		
Material Consumption/Supply	**Time Spent**	**Productivity**
Avg. Freq/Shift	Min/Freq	Hr expected/Hr worked
Avg.Qty/Shift	Min/Shift	Euro/Working Hr
UL/Avg.Qty	Hr/Shift	Euro/Piece
	Hr/week	

Table 5 Kpi tree

After establishing operational definitions, what came next was understanding how to gather data. Unfortunately, SAP couldn't provide the level of detail to calculate the metrics defined, so the only option was collecting data manually.

In the preparation of the template I tried to keep it simple and concise, however, due to the variety of consumables and consumption points it was split into two sheets one dedicated to boxes and one to pallets and other activities.

In these templates (see Table 6), basically, the Water Spider was asked to mark the replenishment quantity and time for boxes, bubbles and pallets supply activities. While for secondary activities it was asked only to take note of the occurrence. One relevant observation has to be made about the pallet collection activity which appeared soon really critical. Since the Water Spider was going to collect empty pallets as soon as they were generated, we couldn't ask him to indicate the time spent on every collection otherwise he couldn't do his work anymore. So, we decided to ask him to collect pallets only when there were at least 10 along the aisles and mark the starting and ending time. This could also become a potential solution but it was accepted only for the data collection. In fact, having pallets standing up on both sides of the corridors could create safety issues for the pickers because the aisles were narrow.

	Data					turno			nome				
Consumo pedane	pedane 215x100	pedane 215x90	pedane 150x80	pedane 120x80	pedane 80x60	coperchi MGA 215x90	Scatole grandi FTA	Coperchi grandi	scatole piccole	Coperchi piccoli	S7	Coperchi S7	Pedane in Rullivia
Ora													
Qtà movimentata													
Ora													
Qtà movimentata													
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Ora													
Qtà movimentata													

	Ora inizio	Ora fine
Scarico camion		
Carico camion		
Pulizia magazzino		
Raccolta pallet corridoi		

Indicare con una X quando si fanno le seguenti attività

Rimozione cartoni							
Rifornimento plutiball							
Rifornimento bobine bolle							
Rifornimento buste gialle							
Rifornimento buste nylon							
Rifornimento etichette							
Rifornimento reggette							
Rifornimento inchiostro							
Cancelleria							
Abbassamento pedane							

Consumo Scatole e coperchi		Data			turno		nome		
		Mont. corr. 0 (N)	Mont. (N)	Corr. 3 (N)	Corr. 55 (N)	Ent. Merci (R)	Corr. 20 (R)	Corr. 24 (R)	Corr. 55 (R)
S1	ora S1								
	QTA' S1								
	ora S1								
	QTA' S1								
	ora S1								
	QTA' S1								
	ora S1								
	QTA' S1								
S2	ora S2								
	QTA' S2								
	ora S2								
	QTA' S2								
	ora S2								
	QTA' S2								
	ora S2								
	QTA' S2								
S3	ora S3								
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S7	ora S7								
	QTA' S7								
	ora S7								
	QTA' S7								
	ora S7								
	QTA' S7								
COP. S1	Ora cop.S1								
	QTA' cop.S1								
	Ora cop.S1								
	QTA' cop.S1								
COP. S2-S3	Ora cop.S2-s3								
	QTA' cop.S2-S3								
	Ora cop.S2-S3								
	QTA' cop.S2-S3								
COP. S4-S7	Ora cop.S4-S7								
	QTA' cop.S4-S7								
	Ora cop.S4-S7								
	QTA' cop.S4-S7								
Bolle									

Table 6 Templates for data collection

The data collection duration was extended to 2 weeks for both shifts in order to get enough data for some statistical inference in case.

During this phase, I also carried out by myself the time measurement of every task on the list in order to calculate the total time spent. The total time of every task was separated into a fixed and a variable component that was dependant on the distance of the Water Spider to the point. The variable time was calculated based on the distance of every point from the centre of the warehouse.

The variation was calculated as the range between the minimum and the maximum measurements. On average it turns out to be 5% of the average time.

4.4.4 As-Is analysis

After data collection, it was finally possible to outline the current situation. In fact, knowing the average time spent on performing every single task, and the average frequency of occurrence per shift, it was estimated the total time simply multiplying these two factors.

Summing up all the activities the total time was estimated between 6,2 and 6,8 hours over 7,2 hours expected. But This variation was acceptable due to the assumptions on the variable time and the recommended way for carrying out pallet collection.

In order to identify the most time-consuming tasks and prioritize the action of improvements, I represented the data on a Pareto chart. But as shown in Figure 25 the ABC analysis revealed that only pallet collection and monitoring could be considered as significative activities. All the other tasks had more or less the same weight, thus it wasn't clear where to focus on improvement.

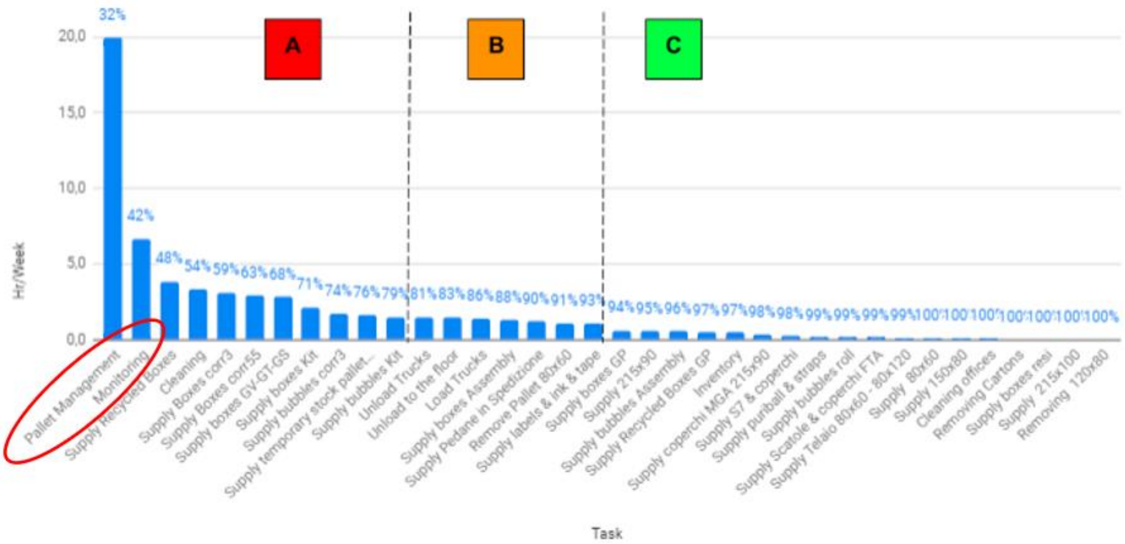

Figure 25 Pareto chart of the total time spent

Pallet collection was taking 20 hours a week that was 32% of the total time. This estimation was optimistic because the Water Spider was asked to perform pallet collection only once per hour spending 15-20 minutes per time, instead of doing it for all the time. However, this time slot was considered still too large because in some cases the presence of empty pallets on the sides of the corridors for a long time was creating safety issues. Optimising this task could represent a big opportunity for reaching the target but it wasn't easy at all because the most reasonable solution hadn't worked, the flow appeared totally chaotic and there were no data to support further analysis.

Monitoring, instead, was representing the 10% of the total time and was concerning the empty rounds the Water Spider was making because of the high variability and the lack of a fixed schedule. This waste in motion could be reduced providing a written working plan.

After this analysis, only monitoring seems to be a critical activity with a known and clear action of improvement.

As the situation was quite sluggish. I decided to filter the activities by task family and see if some new insights could be given. It came out that altogether the tasks related to boxes supply were representing a considerable amount of time, quite similar in terms of magnitude to pallet management. (See Figure 26)

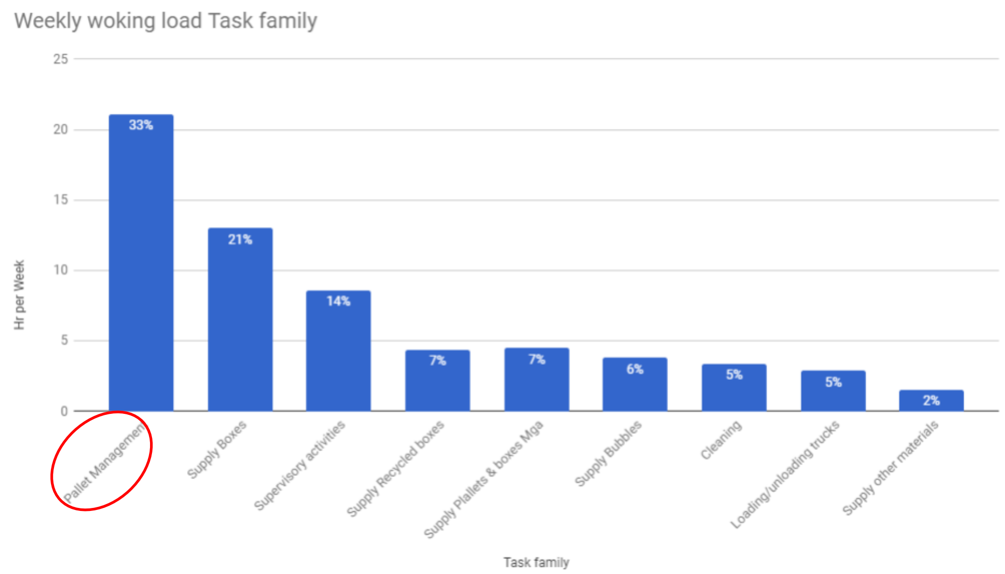

Figure 26 Total time per task family

Moreover, this analysis was relevant also because it showed that, even ignoring the pallet collection, the remaining group of activities identified in the R&G analysis as potential quick wins were all together representing almost 50% of the total consumables time. So, focusing on tasks related to boxes supply, monitoring activities, recycled boxes and bubbles supply, whose criticalities were known and actions of improvement seemed quite defined and feasible, could be very convenient also in terms of expected results.

However, this margin could not be enough to reach the target because these tasks would have been optimised and not removed. For this reason, since the pallet collection could be a good opportunity for achieving the goal, it was also included in the list of the critical activities to improve.

4.5 Do

4.5.1 Improvement1: boxes supply tasks

In the definition of the strategy for developing and implementing the solutions, I decided to concentrate first on the activities related to the boxes supply since they were the second most time-consuming after pallet collection.

The tasks linked to boxes supply were involving three different areas: the local adaptation centre, the inbound and the picking area.

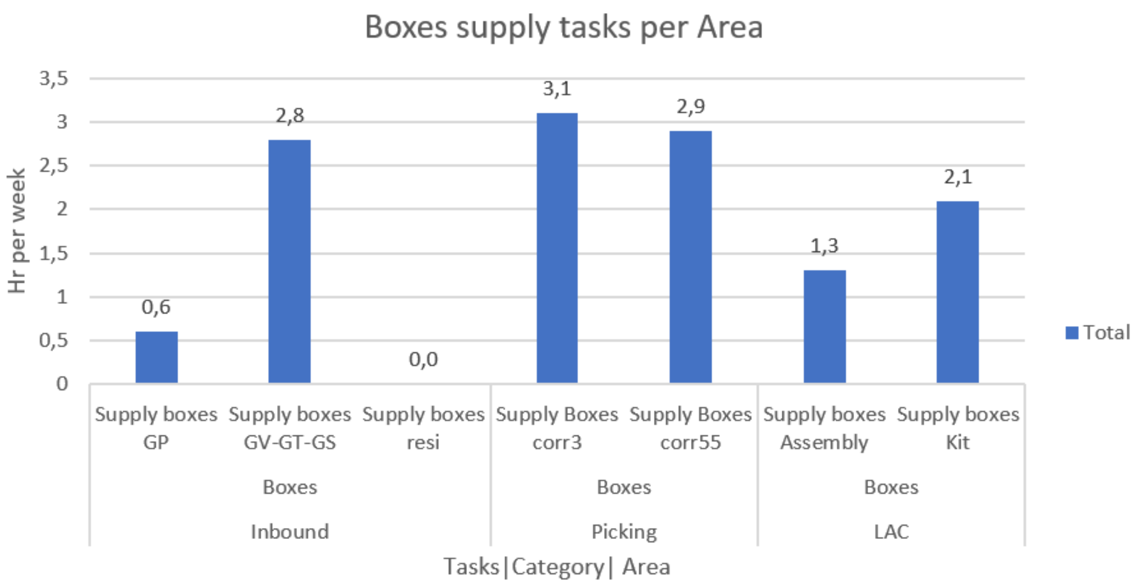

Figure 27 Boxes supply tasks breakdown

As there were several activities having to do with different areas, I decided to focus on each area separately in order to keep the root cause analysis simple.

So, starting from the picking area, considering the time analysis, it can be noticed that the absolute time for carrying out these activities was quite low, around 6 minutes, but the frequency was high, around 3 times a shift. This high frequency resulted in unnecessary transportation and a consequent waste of time, more than half-hour a shift (See Table 7).

Picking	Avg. Freq./Shift	Absolute Time Estimated (Min/ freq)	Time Estimated per Shift (Min/shift)	Time Estimated per Week (Hr/Week)	% Total Time (%)
Supply Boxes corr3	3	6,3	18,8	3,1	5%
Supply Boxes corr55	3	5,8	17,4	2,9	5%
Total	**6**	**12,1**	**36,2**	**6**	**10%**

Table 7 As-Is analysis boxes supply tasks in picking

The cause of the frequent supply of boxes in these points was clarified after comparing the estimated consumption per shift for every type of boxes and covers in each point against the trolleys capacity.

It appeared that these trolleys didn't contain the quantity of consumables proportional to the consumption per shift. In fact, as shown in Table 8, the As-Is inventory level set up in the trolleys for every type of boxes and covers didn't provide a homogeneous time between supplies in terms of shifts. For this reason, the supply operations resulted out of phase and asynchronous meaning that the Water Spider, instead of going just once to the point and supplying it with everything, was bringing different types of boxes and covers at a different time. Furthermore, this issue was aggravated by the fact that some type of boxes and covers, usually the ones with the lowest rotation, were overstocked or even unnecessary (like Vip covers) while the type of boxes with a higher consumption rate were understocked (See red cells Table 8).

Task	Type of boxes	Freq./shift per type of boxes	Avg. Freq. of supply/shift	Max consumption per shift (UL/Shift)	AS IS inventory Trolley (UL)	No. Shifts of autonomy (units)
Supply boxes corr.3	S1	0,2	2,8	1	6	6,0
	S2	0,7		2	6	3,0
	S3	0,8		2	3	1,5
	S4	2,1		2	2	1,0
	S7	1,8		2	2	1,0
	Covers S1	0,2		1	6	6,0
	CoversS2-S3	0,6		4	12	3,0
	Covers S4-S7	0,7		4	12	3,0
	Vip Covers S1	0		0,1	6	60,0
	Vip Covers S2-S3	0		0,1	6	60,0
	Vip Covers S4-S7	0		0,1	6	60,0
Supply boxes corr.55	S1	0,7	2,9	2	4	2,0
	S2	0,9		3	6	2,0
	S3	0,5		3	8	2,7
	S4	0,8		2	4	2,0
	S7	0,6		2	4	2,0
	Covers S1	1,3		8	8	1,0
	CoversS2-S3	2,3		11	6	0,5
	Covers S4-S7	1,1		3	6	2,0

Table 8 Analysis of boxes consumption in picking

So, once understood that the inventory level wasn't optimised, next step would be dimensioning the stock capacity of the trolleys to maximise their stock level, thus minimizing the frequency of supply, but keeping homogeneous the autonomy between the supplies. In this way, the Water Spider could have supplied all points just once per a fixed period.

As, according to Lean, inventory is waste, it was decided at first to dimension correctly the inventory level of the current trolleys and see the results, instead of replacing immediately those trolleys with bigger ones. In fact, it is true that by maximising the stock you minimize the frequency of supply, but we need to consider that:

- There were space issues for expansion so, a bigger trolley could not fit in that space.
- The loading capacity of the order picker truck was limited so, if the stock capacity of trolley exceeded the capacity of the order picker, the frequency wouldn't be minimized anymore and having a bigger trolley would be useless.
- Carrying big trolleys full of boxes and covers with an order truck could cause some safety issues

All these considerations will be taken into account for the design of the solution in every case.

In order to define roughly the maximum inventory level of every type of boxes and covers for every with respect to the trolley volume, keeping homogeneous the time between replenishment, I created a solver.

The assumptions I took were:

- No constraints about the shape of the trolley and its dimensions.
- No three-dimensional space constraints about the right disposition of Unit loads of boxes and covers in every shelf inside the trolley.

I took the results of the solver just as a baseline for future modifications to do on field. In fact, creating a solver able to determine the maximum quantity of boxes and covers, along with their optimum 3D orientation on the different shelves, the number of shelves and layers per shelf would have been too long to develop. No wonder there are specific applications that are designed just for this purpose for example 3D volumetric palletization of boxes.

Hereunder, it is reported the linear programming formulation of the problem.

Decision variables

S_j: Number of Unit Load Boxes j for j ϵ $\{S1, S2, S3, S4, S7\}$, ∀ S_j ϵ N^+

C_y: Number of Covers y for y ϵ $\{Covers\ S1, Covers\ S2S3, Covers\ S4S7\}$, ∀ C_y ϵ N^+

Parameters

D_{Sj}: Maximum consumption in Unit Loads of S_j

D_{Cy}: Maximum consumption in Unit Loads of C_y

V_{Cy}: Volume of every UL C_y in cm^3

V_{Sj}: Volume of every UL $S_j$in cm^3

V_T: Volume trolley not considering shelves in cm^3

A_{Sj}: Time between replenishment boxes j, $A_{Sj} = S_j / D_{Sj}$

A_{Cy}: Time between replenishment covers y, $A_{Cy} = C_y / D_{Cy}$

Objective function

Maximize $Z = \sum S_j + \sum C_y$

St

$\sum D_{Sj} + \sum D_{Cy} \leq V_T$

$A_{Sj} = A_{Cy}$

The results computed by the solver for trolleys in corridor 3 and 55 are represented respectively in Table 9 and Table 10 .

Type of boxes	Max consumption per shift (UL/Shift)	Volume per UL (cm3)	No.UL (units)	Total Volume (cm3)	Time between replenishment (shifts)	Volume trolley (cm3)
S1	1	9000	2	18000	2	1035000
S2	2	13500	4	54000	2	
S3	2	27000	4	108000	2	
S4	2	84000	4	336000	2	
S7	2	54000	4	216000	2	
Covers S1	1	9000	2	18000	2	
CoversS2-S3	4	1800	8	14400	2	
Covers S4-S7	4	9600	8	76800	2	
				841200		

Objective function: max Z	**36**

Table 9 Solver results for trolley corridor 3

Type of boxes	Max consumption per shift (UL/Shift)	Volume per UL (cm3)	No.UL (units)	Total Volume (cm3)	Time between replenishment (shifts)	Volume trolley (cm3)
S1	2	9000	4	36000	2	1560000
S2	3	13500	6	81000	2	
S3	3	27000	6	162000	2	
S4	2	84000	4	336000	2	
S7	2	54000	4	216000	2	
Covers S1	8	9000	16	144000	2	
CoversS2-S3	11	1800	22	39600	2	
Covers S4-S7	3	9600	6	57600	2	
				1072200		

Objective function: max Z	**68**

Table 10 Solver results for trolley corridor 55

In both cases, the solver returned a configuration of inventory that ensured a time between replenishment of two shifts. Ideally, this solution could be a very good improvement with more than 80% saving in time and the fact the volume saturation was respectively 82% and 69% made the results reasonable. But as the solver calculated the optimum solution only from a numerical point of view without considering the volumetric constraints, these results had to be verified on field.

After some trials, for the trolley in corridor 3, we came up with the layout shown in Figure 28 which respected the results of the solver.

Figure 28 Layout trolley corridor 3

This configuration ensured a time between replenishment equal to 2 shifts so the Water Spider would have had to supply boxes and covers just once a day with a time saving over 60%. The trolley replenishment could have occurred just once if the Water Spider would have carried the trolley with the order picker truck for doing the replenishment operations. About this, there weren't safety issues because the volume of the trolley was acceptable. The only requirement for implementing this solution would have been a maintenance activity to fix the bars for the forks insertion.

In this way, the Water Spider had to:

- Carry the trolley to the packaging storage.
- Do the replenishment there.
- Bring the trolley back to the initial point.

The same logic was applied also for the trolley in corridor 55. However, this solution will be subjected to further modifications when studying the recycled boxes process.

The results expected from the implementation of these solutions are reported below.

Picking	Avg. Freq. /Shift	Time Estimated (Min/ freq)	Time Estimated (Min/shift)	Time Estimated (Hr/Week)	% time saved (%)
Supply boxes corr.3	0,5	6,3	3,15	0,5	84%
Supply boxes corr.55	0,5	5,8	2,9	0,5	83%
Total	**1**	**12,1**	**6,05**	**1,0**	**83%**

Table 11 Expected results boxes supply in picking

Regarding the boxes supply in LAC, instead, the situation was illustrated in Table 12.

LAC	Avg. Freq. /Shift	Time Estimated (Min/ freq)	Time Estimated (Min/shift)	Time Estimated (Hr/Week)	% Total time (%)
Supply boxes Kit	3	5,9	12,9	2,1	3%
Supply boxes Assembly	2	4,7	9,4	1,3	2%
Total	**5**	**10,6**	**22,3**	**3,4**	**6%**

Table 12 As-Is analysis boxes supply in LAC

Again the frequency per shift was quite high, but conversely, to the previous cases, boxes supply in LAC was frequent because of the variability of the demand. In fact, as shown in Table 13, even though the inventory level was coherent to the average consumption, the coefficient of variation was between 0,75 and 1,33 for every type of boxes and covers. This meant that the system was characterized by a medium-high variability which caused the occurrence of picks in consumption of boxes and covers. The trolleys capacity in these circumstances was not sufficient, as a result the Water Spider or some times the operators themselves had to go and take the additional materials in the main packaging storage.

Task	Type of boxes	Freq./shift per type of boxes	Avg. Freq. of supply/shift	Avg. Consumption per shift (UL/Shift)	Sigma consumption per shift (UL/Shift)	Coefficient of variation	Max consumption per shift (UL/Shift)	AS IS inventory Trolley (UL)	No. Shifts of autonomy (units)	Extra stock (UL)
Supply boxes Kit	S1	0,6	2,6	1,8	1,8	1,0	4,0	3	0,8	2
	S2	0,6		1,7	2,1	1,2	4,0	3	0,8	2
	S3	0,8		2,1	1,9	0,9	4,0	3	0,8	2
	S4	1,3		2,4	2,6	1,1	5,0	3	0,6	5
	Covers S1	1,4		1,6	2,1	1,3	4,0	3	0,8	2
	CoversS2-S3	1,4		3,3	2,6	0,8	6,0	8	1,3	
	Covers S4-S7	2,1		2,8	2,3	0,8	6,0	4	0,7	5
Supply boxes Assembly	S1	1,3	1,5	2,1	2,3	1,1	5,0	3	0,6	3
	S2	0,9		1,8	1,9	1,1	4,0	3	0,8	2
	S3	1,3		1,5	2,0	1,3	4,0	3	0,8	2
	S4	1,3		2,4	2,5	1,0	5,0	3	0,6	3
	Covers S1	1,3		1,7	2,5	1,5	5,0	3	0,6	3
	CoversS2-S3	0,8		3,1	2,7	0,9	6,0	8	1,3	
	Covers S4-S7	1,1		2,2	2,3	1,0	5,0	5	1,0	

Table 13 Analysis of boxes consumption in LAC

At that moment the information system was not able to predict the consumption of boxes for the shift, so the only way to reduce this variability was by creating an extra stock in the LAC area. In this way, in case of peaks, the operators of the assembly or kitting zone, instead of warning the team leader about the shortage and wait for the Water Spider arrival, just had to take what they needed in a small storage internal to the LAC area (See Figure 29).

Figure 29 LAC Internal stock

The problem for implementing this solution was the research of the space for adding the safety stock because that area was overcrowded. The definition of this area is related to the implementation of another action of improvement concerning the bubble supply that we will see further. In fact, comparing the before and after situation (See Figure 29) it is clear that the extra stock was obtained removing the bubble cage and changing the orientation of the trolley.

The safety stock was calculated as follows:

(Maximum consumption – Trolley inventory)× No. shifts of coverage

This last factor depended on the capacity of the storage solution to be adopted. In the TO BE layout, based on the space available, the maximum number of trolleys that could be placed was 2. So, considering the installation of two trolleys with the same capacity of the existing ones, the period of coverage would be somewhere between 5 or 6 shifts see Table 14.

Task	Type of boxes	Max consumption per shift (UL/Shift)	AS IS inventory Trolley (UL)	Extra stock (UL)	No. Shifts of coverage
Supply boxes Kit	S1	4,0	3	2	5
	S2	4,0	3	2	
	S3	4,0	3	2	
	S4	5,0	3	4	
	Covers S1	4,0	3	2	
	CoversS2-S3	6,0	8		
	Covers S4-S7	6,0	4	4	
Supply boxes Assembly	S1	5,0	3	3	
	S2	4,0	3	2	
	S3	5,0	3	3	
	S4	5,0	3	3	
	Covers S1	5,0	3	3	
	CoversS2-S3	6,0	8		
	Covers S4-S7	5,0	5		

Task	Type of boxes	Max consumption per shift (UL/Shift)	AS IS inventory Trolley (UL)	Extra stock (UL)	No. Shifts of coverage
Supply boxes Kit	S1	4,0	3	2	6
	S2	4,0	3	2	
	S3	4,0	3	2	
	S4	5,0	3	5	
	Covers S1	4,0	3	2	
	CoversS2-S3	6,0	8		
	Covers S4-S7	6,0	4	5	
Supply boxes Assembly	S1	5,0	3	3	
	S2	4,0	3	2	
	S3	5,0	3	3	
	S4	5,0	3	3	
	Covers S1	5,0	3	3	
	CoversS2-S3	6,0	8		
	Covers S4-S7	5,0	5		

Duration safety stock (shifts)	Extra stock (UL)	
5	S1	6
	S2	4
	S3	6
	S4	8
	Covers S1	6
	CoversS2-S3	0
	Covers S4-S7	5
6	S1	6
	S2	5
	S3	6
	S4	9
	Covers S1	6
	CoversS2-S3	0
	Covers S4-S7	5

Trolley inventory X2
6
6
6
6
6
16
10

Table 14 Safety stock calculation

In Figure 29 the two trolleys are missing because they needed to be purchased, so as a temporary solution the stack of boxes and covers were placed onto pallets.

This solution would have reduced the total time spent in the LAC area for boxes supply by almost 50% as shown in Table 15

LAC	Avg. Freq. /Shift	Time Estimated (Min/ freq)	Time Estimated (Min/shift)	Time Estimated (Hr/Week)	% time saved (%)
Supply boxes Kit	1	5,9	5,9	1,0	53%
Supply boxes Assembly	1	4,7	4,7	0,4	70%
Supply extra stock	0,2	13	2,2	0,4	
Total	**2,2**	**23,6**	**12,8**	**1,8**	**47%**

Table 15 Expected results boxes supply in LAC

The last area to be improved was the inbound area.

As shown in Table 16 the most time consumign task was supply boxes to GT-GV-GS workstations in the unboxing area.

Inbound	Avg. Freq. /Shift	Time Estimated (Min/ freq)	Time Estimated (Min/shift)	Time Estimated (Hr/Week)	% Total time (%)
Supply boxes GP	1,3	2,9	3,8	0,6	1%
Supply boxes GV-GT-GS	2,1	8,0	16,8	2,8	4%
Supply boxes resi	0,2	6	1,2	0,2	0%
Total	3,6	16,9	21,8	3,6	6%

Table 16 As-Is analysis boxes supply in inbound

Here, the receiving pallets full of boxes with mixed items were processed by operators which separated the different items putting them in different boxes.

The Water Spider had to supply boxes and covers to these 5 unboxing work stations. But there were some elements, based on the work instructions, which suggested that this activity could be done by the operators themselves. In fact, at the end of their work of unboxing the operators would have to use an electric transpallet to remove the empty pallet, bring it to the deposit and finally take the new one to be processed from the receiving bay. As the deposit of the empty pallets was less than 5 meters from the boxes and covers storage, it was decided to add after task 150 which is “bring the empty pallet to the deposit” (task 150), a new task (task 150.1) concerning the boxes and covers supply in case of need (See Table 17). Regarding this activity, it was added also another task (151.1) before taking a new pallet to unbox, related to putting the materials in the correct slots in the working place.

Work instructions									
Numéro	Moyen utilisé	Code	Temps standard [s]	Kcal	Distance[m]	Fréquence	Coefficient de variation	Temps tolal [s]
127	girarsi verso la pedana	HOH	1,14	0,000	5	1,0000	1,10	1,3
128	depositare la scatola sulla pedana di messa stock	HMAD	1,71	0,000	1	1,0000	1,10	1,9
129	**impugnare il transpallet manuale**	HMAP	0,42	0,000	1	0,0365	1,10	0,0
130	sollevare la pedana con scatole pronta per messa a stock	HMPG	44,00	0,644	1	0,0365	1,10	1,8
131	partenza con pedana piena	HDDC	4,00	0,381	1	0,0365	1,10	0,2
132	spostamento verso deposito scatole per messa a stock	HDPC	1,67	0,134	5	0,0365	1,10	0,1
133	arresto nella zona deposito scatole messa a stock	HDAC	4,00	0,381	1	0,0365	1,10	0,2
134	deposito pedana piena	HMDG	29,00	0,644	1	0,0365	1,10	1,2
135	**staccare un bollino colorato**	HMAP	0,73	0,037	1	0,0365	1,10	0,0
136	camminare verso la pedana di deposito	HOH	1,14	0,000	3	0,0365	1,10	0,0
137	incollare il bollino colorato su pedana	HOP	0,66	0,028	1	0,0365	1,10	0,0
138	scrivere numero su bollino in base alla priorità	HAEM	0,95	0,000	1	0,0365	1,00	0,0
139	partenza verso fondo rullivia	HDDL	2,00	0,125	1	0,0365	1,10	0,1
140	spostamento con transpallet libero	HDPF	1,18	0,060	10	0,0365	1,10	0,0
141	camminare verso la pila di pedane vuote	HOH	1,14	0,000	6	0,0365	1,10	0,0
142	prendere una pedana vuota	HMCP	8,00	0,174	1	0,0365	1,10	0,3
143	camminare verso il fondo rullivia	HOH	1,14	0,000	6	0,0365	1,10	0,0
144	depositare la pedana vuota sulle pedane nailate	HMCD	6,00	0,058	1	0,0365	1,10	0,2
145	spostamento con transpallet libero	HDPF	1,18	0,060	3	0,0365	1,10	0,0
146	arresto nella zona deposito transpallet	HDAC	4,00	0,381	1	0,0365	1,10	0,2
147	ritornare verso fondo rullivia	HOH	1,14	0,000	3	0,0365	1,10	0,0
148	**prendere la pedana vuota**	HMCP	8,00	0,174	1	0,0313	1,10	0,3
149	camminare verso la zona deposito pedane vuote	HOH	1,14	0,000	5	0,0313	1,10	0,0
150	depositare la pedana vuota	HMCD	6,00	0,058	1	0,0313	1,10	0,2
150.1	**prendere scatole o coperchi se necessario e porle sul transpalle**		**25,00**		**5**	**0,0087**	**1,10**	**0,2**
151	ritornare verso la postazione di lavoro	HOH	1,14	0,000	5	0,0313	1,10	0,0
151.1	**posizionare i pacchi di scatole e coperchi nella postazione di lav**		**10,00**		**1**	**0,0087**	**1,10**	**0,1**
152	**partenza verso la zona di carica transpallet elettrico**	EDDL	2,00	0,000	1	0,00046	1,10	0,0
153	spostamento verso la zona di carica	EDL	1,20	0,000	10	0,00046	1,10	0,0
154	arresto in zona di carica	EDAL	2,00	0,000	1	0,00046	1,10	0,0
155	mettere il carrello sotto carica	HFB	115,00	0,000	1	0,00046	1,10	0,1
	Tempo ciclo totale per scatola							**100,3**

Table 17 Work instructions inbound

The time estimated for doing these two activities was estimated on average as 25 seconds and 10 seconds for task 150.1 and task 151.1 respectively, after some trials on field. The frequency of this operation, instead, was estimated based on the average consumption per shift against the inventory level of each station and it resulted in a maximum frequency of 2 times per shift as shown in Table 18.

Inbound workstation single station GV-GT-GS										
Type	Avg./ shift (UL)	sigma (UL)	Max Cons./shift (UL)		Type	Capacity work station (UL)	Frenquency per shift	Avg. frequency	Maximum frequency
S1	1,0	0,7	2		S1	2	1	1	2
S2	1,5	1,3	3		S2	2	1,5		
S3	1,1	0,2	2		S3	2	1		
S4	0,7	0,3	1		S4	1	1		
Covers S1	0,2	0,1	1		Covers S1	2	0,5		
Covers S2-S3	1,5	0,3	2		Covers S2-S3	8	0,25		

Table 18 Frequency of task 150.1 and 151.1

Considering that the average consumption per every work station 31,1 boxes per hour, the frequency per box was calculated as 2/ (31,1 × 7,3)=0,0087. Multiplying the absolute time by the frequency per box we get the average time per box which was no greater than 0,2 seconds per box. (See Table 19)

So, the difference of the cycle time the between As-Is and To Be scenario is just of 0,4 seconds which at the end of the day resulted in 3 boxes lost. This loss is negligible also because it doesn't compromise the target, so the improvement action was accepted.

Target boxes/h	31,1	
Inbound unboxing	**AS IS**	**TO BE**
Cycle time sec/box	99,9	100,3
Boxes per day	541	538
Max Capacity boxes/h	38,1	37,9

Table 19 New cycle time inbound

This improvement contributed to reduce the 80% of the time spent by the Water Spider in the Inbound area, as shown below.

Inbound	Avg. Freq. /Shift	Time Estimated (Min/ freq)	Time Estimated (Min/shift)	Time Estimated (Hr/Week)	% time saved (%)
Supply boxes GP	1,3	2,9	3,8	0,6	0%
Supply boxes GV-GT-GS	0	0	0	0,0	100%
Supply boxes resi	0,2	6	1,2	0,2	0%
Total	**1,5**	**8,9**	**5,0**	**0,8**	**80%**

Table 20 Expected results boxes supply inbound

The overall expected outcomes of the improvement initiatives about the boxes supply tasks in comparison with the As-Is scenario are shown in Figure 30.

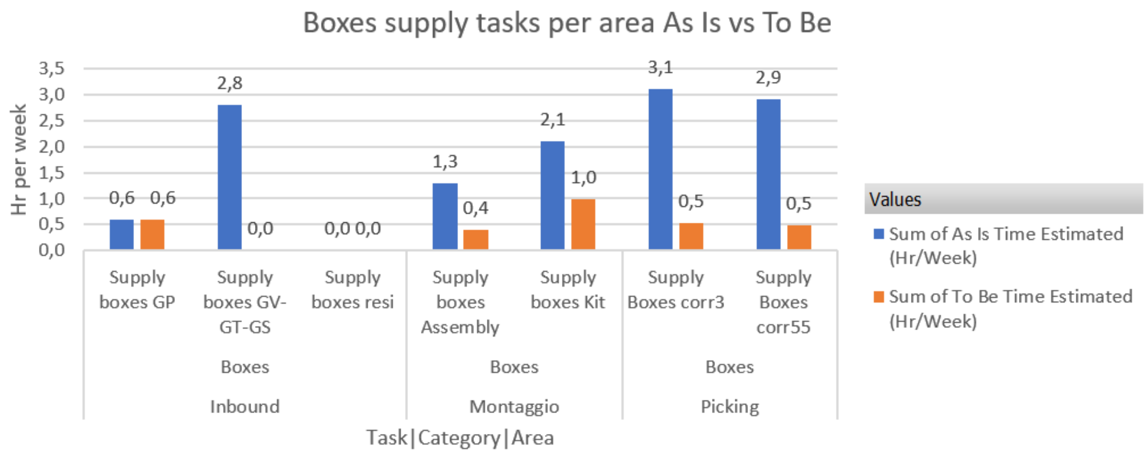

Figure 30 As-Is vs To Be Time analysis for boxes supply tasks

Summing up the impact of these actions of improvements, the total time per week spent by the Water Spider would be reduced by 15% as shown in Table 21.

Area	Task N.	Task	Category	As Is Time Estimated (Min/shift)	As Is Time Estimated (Hr/Week)	To Be Time Estimated (Min/shift)	To Be Time Estimated (Hr/Week)	Time saved per shift (min/shift)	Time saved per week (Hr/Week)	% time saved per shift (%)	% time saved per week (%)
Montaggio	5	Supply boxes Kit	Boxes	12,9	2,1	5,9	1,0	7,0	1,1	1,8%	1,8%
Montaggio		Supply Extra stock	Boxes	0	0	2,2	0,4	-2,2	-0,4	-0,6%	-0,6%
Montaggio	15	Supply boxes Assembly	Boxes	9,4	1,3	4,5	0,4	4,9	0,9	1,3%	1,4%
Inbound	75	Supply boxes GP	Boxes	3,8	0,6	3,8	0,6	0,0	0,0	0,0%	0,0%
Inbound	85	Supply boxes GV-GT-GS	Boxes	17,1	2,8	0	0	17,1	2,8	4,4%	4,4%
Inbound	95	Supply boxes resi	Boxes	1,2	0,2	1,2	0	0,0	0,2	0,0%	0,3%
Picking	120	Supply Boxes corr3	Boxes	18,8	3,1	3,15	0,5	15,7	2,6	4,0%	4,1%
Picking	125	Supply Boxes corr55	Boxes	17,4	2,9	2,9	0,5	14,5	2,4	3,7%	3,8%
Total time				**386,7**	**63,3**	**363,1**	**3,4**	**57,0**	**9,6**	**14,7%**	**15,2%**

Table 21 Overall time analysis after improvement 1

4.5.2 Improvement 2: recycled boxes

Another class of tasks critical to improve was the one related to the recycled boxes management. This activity should be optimised because it was the only value-added activity of the process. The goal was double:

1. avoiding that reusable boxes were thrown away in the waste bins
2. increasing the pickers' consumption of recycled boxes.

During the Gemba Walk, one of the most relevant examples of waste was related to the recycled boxes. In fact, inside the warehouse there were no written instructions regarding the re-usage of boxes used as containers for products with medium-low rotation.

These boxes were considered "recycled" because they were coming directly from the plants and they contained products to be sold individually. These boxes were stored in the shelving area, as shown in Figure 31, and were generated after the picker was picking the last item in the box.

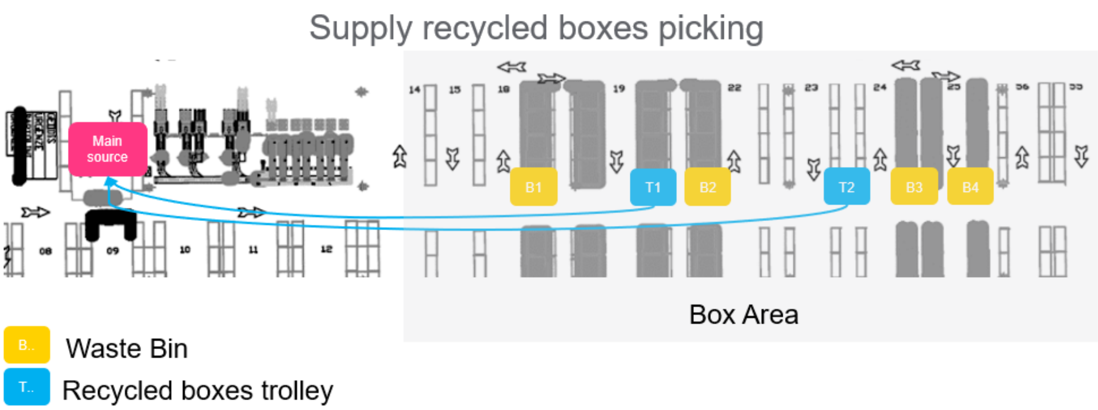

Figure 31 As-Is recycled boxes detailed flow

Despite the recommendation given to the pickers to put the recycled boxes in the 2 trolleys along the corridor or re-use them during the picking process, only some few ones were doing so. The majority were still throwing them away in the waste bins along the corridor.

The Water Spider task was to take these trolleys, when they were full, and bring them to the main area which was the starting point of the pickers, in order to encourage them to use recycled boxes instead of new ones for picking operations. However, the problem was that this activity at the moment was not optimized because in the waste bins there were still a lot of recycled boxes as shown in Figure 32.

Figure 32 Recycled boxes in the waste bins

This issue was analysed with the 5whys:

Problem: There are recycled boxes in the waste bins

Why?

Because operators are not putting them into the trolleys

Why?

1. Because some operators don't follow the istructions.
2. Because the two trolleys are full

Why?

  2.1. Because trolleys get full faster than the Water Spider frequency of emptying.
  2.2. Because pickers are slightly using recycled boxes in the box area

Why?

    2.1.1. Because the number of trolleys is insufficient
    2.2.1. Because pickers are taking new boxes from the trolley in corridor 55.

So, after the fourth why it was clear that this problem was due to three factors:

1. Pickers were not following the recommendation of putting the recycled boxes in the trolleys.
2. The number of trolleys was insufficient to collect all the boxes thrown away in the bins.
3. The consumption of recycled boxes was very low because it was limitated by the presence of new boxes in the trolley in corridor 55.

The first action to be implemented was increasing the number trolleys to collect the recycled boxes. Since the waste bins were containing mainly recycled boxes, it was decided to remove at least two of them and replace them with two trolleys (See Figure 33). In this way, pickers will be discouraged to throw away recycled boxes.

Figure 33 Trolleys for recycled boxes

Then, in order to increase the consumption of recycled boxes in the box area and reduce the frequency of the Water Spider for emptying these trolleys, it was decided to remove the S1, S2, and S3 from the trolley in corridor 55. In fact, considering that each of the four waste bins was containing at least 5 unfolded boxes of each type and that each bin was emptied at least 4 times a day, the total amount of recycled boxes per day appeared superior to the consumption of S1, S2, S3 of the trolley in corridor 55. (See Table 22)

Trolley Corridor 55	Max. Daily Consumption (UL)	Max Consumption (Units)
S1	4	80
S2	6	90
S3	6	60

No. Bins	Daily Frequency of emptying per bins
4	4

Waste bins	Avg. Units	Total units in boxes area
Rec.S1	8	128
Rec.S2	6	96
Rec.S3	4	64

Table 22 Consumption new boxes in corridor. 55 vs generation recycled boxes

Based on the same data it was established the inventory level of each trolley for each type of box multiplying each quantity per a coefficient equal to three since the capacity of these trolleys for containing unfolded boxes was more than three times the capacity of the bins. In fact, since boxes were simply thrown away without being folded the volume utilization of the bins was quite low.

As these calculations were based on data coming from few observations, these actions of improvement needed to be followed up with a session of monitoring and feedback given by the Water Spider and the team leaders of picking.

Nevertheless, trusting these rough data it appeared that there wouldn't be any need for the Water Spider to supply recycled boxes in the main source because production and consumption of recycled boxes would be balanced. However, it was estimated about 10 minutes twice a shift for the Water Spider to reorganize the trolleys and fold some boxes if they were full as the case in the figure below.

Figure 34 Trolley to reorganize

The final scenario at the end of the DO stage was represented in the figure below.

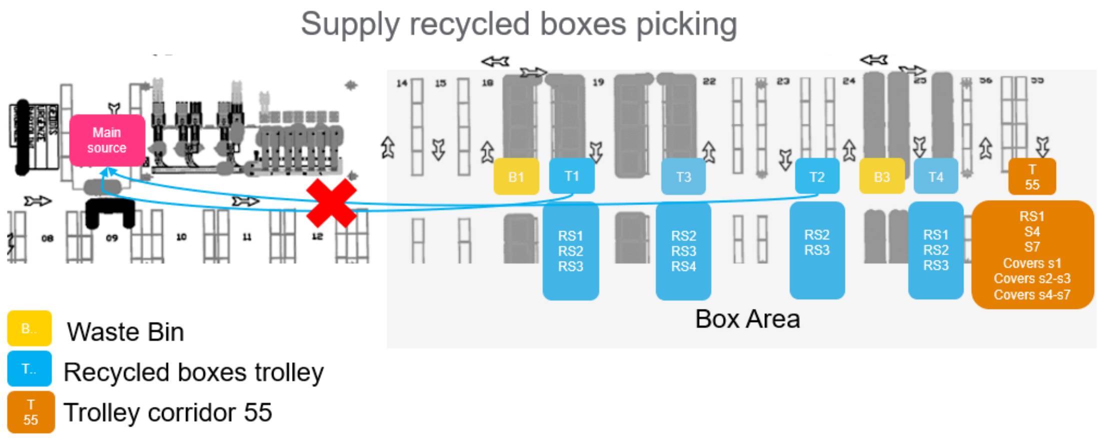

Figure 35 To Be recycled boxes detailed flow

In terms of time, the overall time was slightly reduced, but the saving was being made on the recycled boxes. In fact, their usage would contribute to reduce the cost of new boxes and also the cost of waste because they were not thrown away

Area	Task N.	Task	Category	As Is Time Estimated (Min/shift)	As Is Time Estimated (Hr/Week)	To Be Time Estimated (Min/shift)	To Be Time Estimated (Hr/Week)	Time saved per shift (min/shift)	Time saved per week (Hr/Week)	% time saved per shift (%)	% time saved per week (%)
Montaggio	5	Supply boxes Kit	Boxes	12,9	2,1	5,9	1,0	7,0	1,1	1,8%	1,8%
Montaggio		Supply Extra stock	Boxes	0	0	2,2	0,4	-2,2	-0,4	-0,6%	-0,6%
Montaggio	15	Supply boxes Assembly	Boxes	9,4	1,3	4,5	0,4	4,9	0,9	1,3%	1,4%
Inbound	75	Supply boxes GP	Boxes	3,8	0,6	3,8	0,6	0,0	0,0	0,0%	0,0%
Inbound	85	Supply boxes GV-GT-GS	Boxes	17,1	2,8	0	0	17,1	2,8	4,4%	4,4%
Inbound	95	Supply boxes resi	Boxes	1,2	0,2	1,2	0	0,0	0,2	0,0%	0,3%
Picking	120	Supply Boxes corr3	Boxes	18,8	3,1	3,15	0,5	15,7	2,6	4,0%	4,1%
Picking	125	Supply Boxes corr55	Boxes	17,4	2,9	2,9	0,5	14,5	2,4	3,7%	3,8%
Inbound	80	Supply Recycled Boxes GP	R.Boxes	3	0,5	3	0,5	0,0	0,0	0,0%	0,0%
Picking	130	Supply Recycled Boxes	R.Boxes	23,1	3,9	20	3,3	3,1	0,6	0,8%	0,9%
Total time				386,7	63,3	340,1	7,2	60,1	10,2	15,5%	16,1%

Table 23 Overall time analysis improvements 1, 2

4.5.3 Improvement 3: supply bubbles

The last improvement representing a quick win was the one related to the bubbles supply. As shown in Table 24, these three tasks were representing the 6% of the total time.

Bubbles	Avg. Freq. /Shift	Time Estimated (Min/ freq)	Time Estimated (Min/shift)	Time Estimated (Hr/Week)	% Total time (%)
Supply bubbles Kit	2	4,5	9	1,5	2%
Supply bubbles Assembly	1	6,8	6,8	0,6	1%
Supply bubbles corr3	4	2,6	10,3	1,7	3%
Total	**7,0**	**13,9**	**26,1**	**3,8**	**6%**

Table 24 As-Is analysis bubbles supply

In this case, the criticality was clear and was related to the fact that there was only one bubble machine serving 3 different points (See Figure 36).

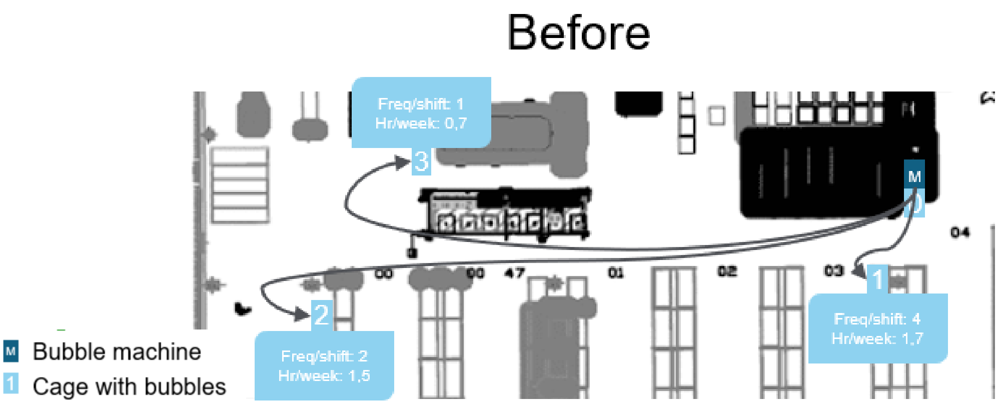

Figure 36 As-Is detailed bubbles flow

The easiest solution would have been to buy at least another machine and put it in LAC so that the area would be autonomous. However, this solution wasn’t possible because the number of machine was proportional to the consumption of bubbles according to the contract.

So, since the two most demanding points were far from the bubble machine, it was decided to move the bubble machine close to the LAC (See Figure 37). In this way, the Water Spider didn't have to supply bubbles there anymore because the operators could do this little task. In fact,like the case of boxes, the time lost for going and take the cage full of bubbles was inferior to the time of waiting for the Water Spider to do so.

As shown in Figure 37, in the new position, two cages were placed in front of the bubble machine. One was for the back up of the LAC station and the other was for the back up of the cage in corridor 3. In this way, both the Water Spider and the LAC operators didn't have to wait for the bubble machine to refill the cage. The frequency for supply bubbles in corridor 3 was halved because of a second cage was added as back up.

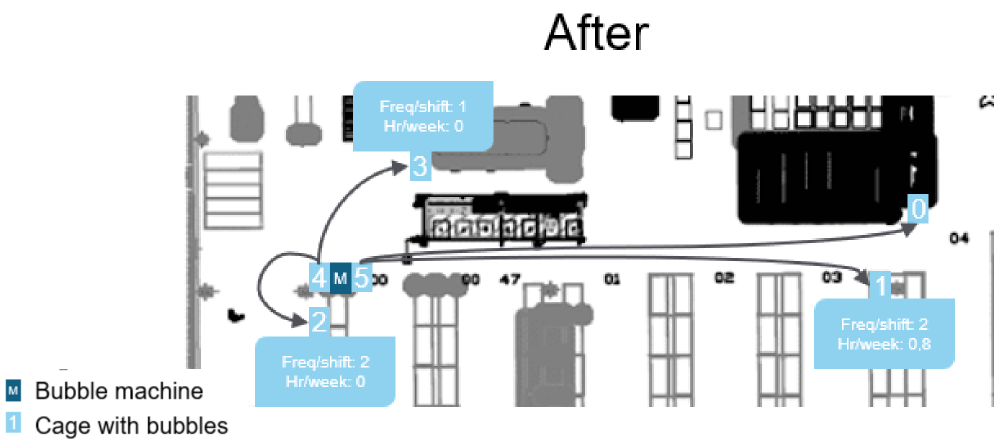

Figure 37 To Be detailed bubbles flow

Figure 38 shows the change in the layout concerning the bubble machine.

Figure 38 As-Is vs To Be bubble machine layout

The graph below shows the expected results before and after the improvement initiative.

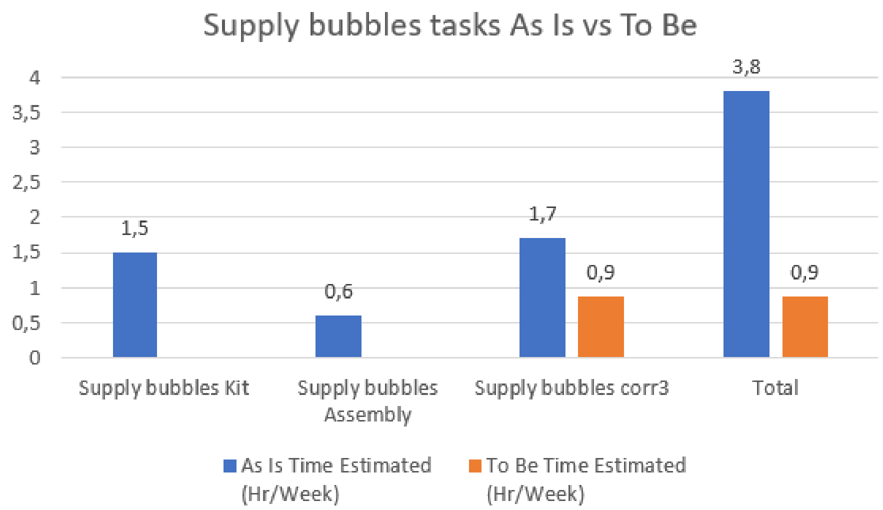

Figure 39 As-Is vs To Be time analysis for bubbles supply

Taking into account of this improvement the percentage of time saved was ranging between 18% and 24% of the overall time taking into account of the standard deviation. Considering that the activity with the highest variability, pallet colletion, kept being unchanged, it was quite useless introducing a working schedule because the it couldn't prevent the Water Spider from making empty rounds. In fact, the Water Spider still had to handle all the tasks related to pallet which were random.

For this reason, the optimization of the pallet collection was absolutely necessary for achieving the target and standardize the consumable process.

4.5.4 Improvement 4: pallet collection

Pallet collection was the most time-consuming activity of the whole consumable management process taking around 2 hours per shift, and it was also the one with highest variability.

As said before, pallet collection consisted of collecting the pallets 80x120 across the corridors of the pallet racking storage and bringing them or in a consumption point like outbound and LAC and main area or outside the warehouse in case of overstock, as shown in Figure 40.

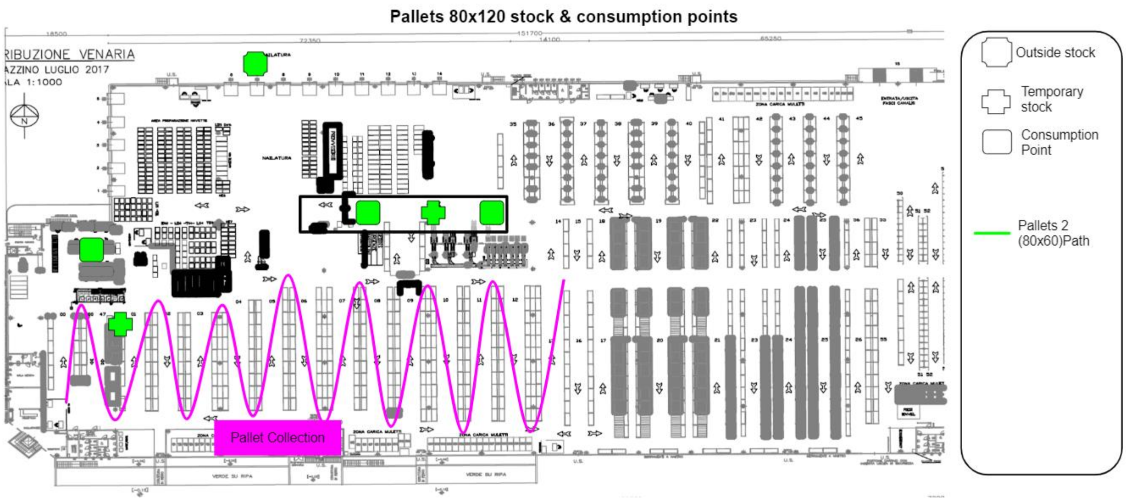

Figure 40 Pallets 80x120 detailed flow

The data collection only measured the time spent for this activity, but it didn't provide precise information about the exact number of pallets collected. It was estimated looking at the number of replenishment during the day, in fact, when a pallet is finished it has to be replaced in 15 minutes. As shown in the graph below

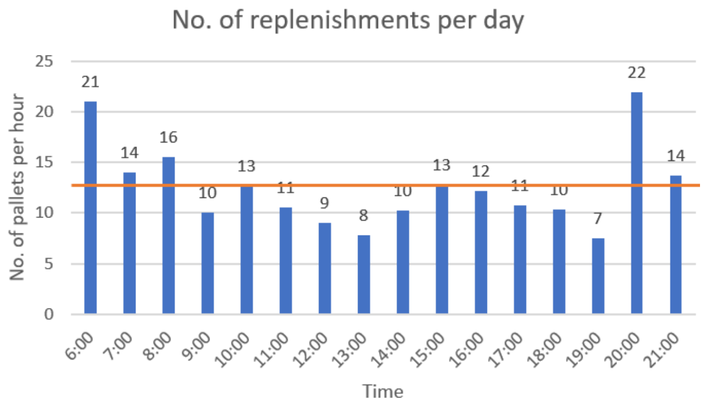

Figure 41 Number of replenishments per day

This graph shows that on average every hour there are across the corridors around 13 pallets to collect.

Particularly, as shown in Figure 42 and Figure 43, pallets concentrate in corridors 0 and from corridor 6 to 13 where it is generated at least one pallet per hour for the whole day.

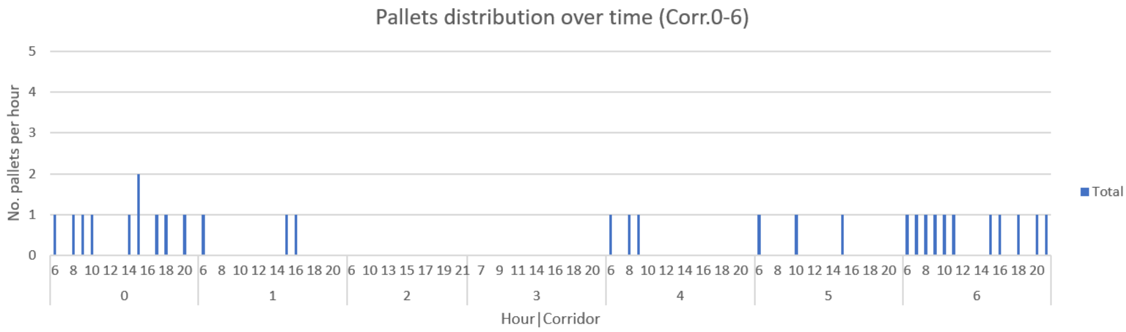

Figure 42 Pallet distribution over time corridor 0-6

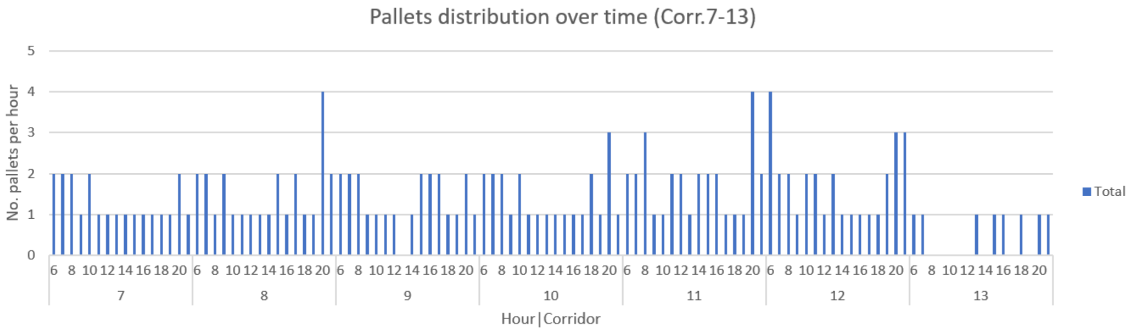

Figure 43 Pallet distribution over time corridor 7-13

This means that the Water Spider every hour has to spend at least 10 minutes to collect around 13 pallets from corridor 6 to 13 probably and at certain hours there were 2 pallets or more per corridor which could represent a safety issue. Furthermore, the time in which these pallets were generated was absolutely random so, it wasn't possible to predict when, during every hour, the Water Spider should have collect these pallets.

This issue was impeding the Water Spider to be employed in other activities because potentially every time he should have stopped doing his work for collecting pallets.

So, in order to reduce the lead time of the consumable process it was absolutely crucial to reduce the variability of this task. In fact, once defined clearly when to do this activity it would be possible to standardize the process and identify some time slots in which the Water Spider could be available for doing something else. Otherwise, the previous improvements just would have the effect of increasing useless motion and the empty rounds of the Water Spider.

One solution as said before was the one of limiting the pallet collection just at certain moments like at the end of each hour, but since there was high variability in the generation with picks of 5 pallets per hour in a corridor (See Figure 44 and Figure 45), there might be safety issues.

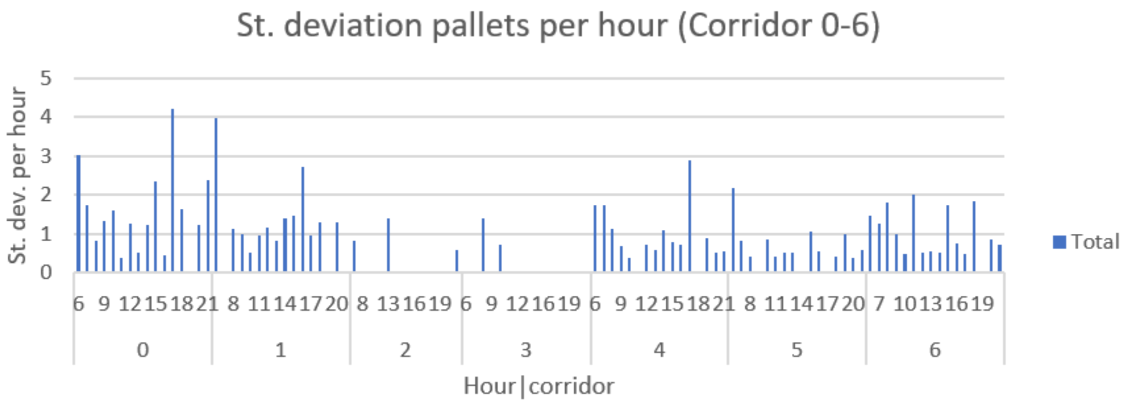

Figure 44 Standard deviation per hour corridor 0-6

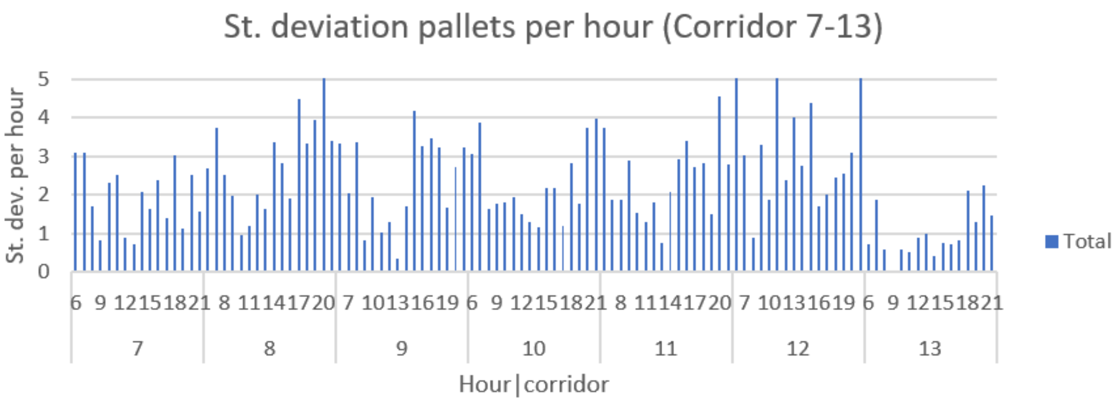

Figure 45 Standard deviation per hour corridor 7-13

The solution proposed aimed at removing the empty pallets in the same moment they were generated bringing them directly to the consumption points without the need of the Water Spider. Pickers and replenishment operators should have done this task.

In particular, when a picker was taking the last item from a pallet, instead of putting it vertically in one side of the corridor, he/she should have overlapped their shipment pallet to the empty one as shown in Figure 46 before moving to the next picking.

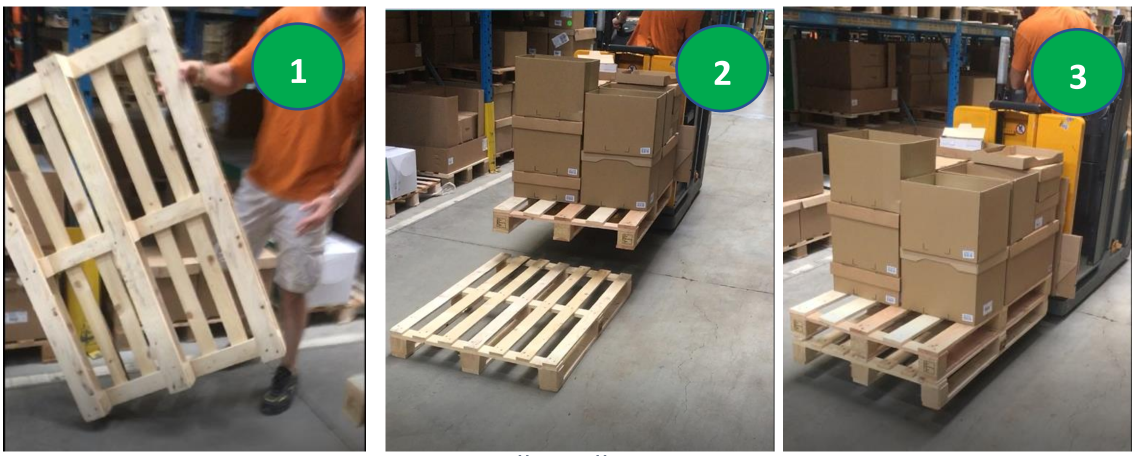

Figure 46 New pallet collection instructions

Once the picker had taken the empty pallet, he/she could proceed to the next picking location. In case of generation of another empty pallet, the picker should have left the pallet there because he would be handled by the replenishment operators.

When the picker had finished the picking order, he/she would have brought the double layer pallet to the outbound area as usual. The advantage of this solution was that once the two pallets were separated the extra pallet could be used by the shipping operators or by the picker themselves to start a new picking order, without the needing the Water Spider to bring it there. The Water Spider should intervene just when the buffers of the empty pallets were full. In this case, the pallets should have been taken outside of the warehouse because there was overstock.

Regarding the replenishment operators, they could carry up to three pallets during their empty round and they should have left them in the buffers of the consumption points.

In this way, the Water Spider just had to remove the pallets when the buffers were full. But this would occur a limited number of times considering that on average 170 pallets were being shipped every day from the centre and around 200 were generated.

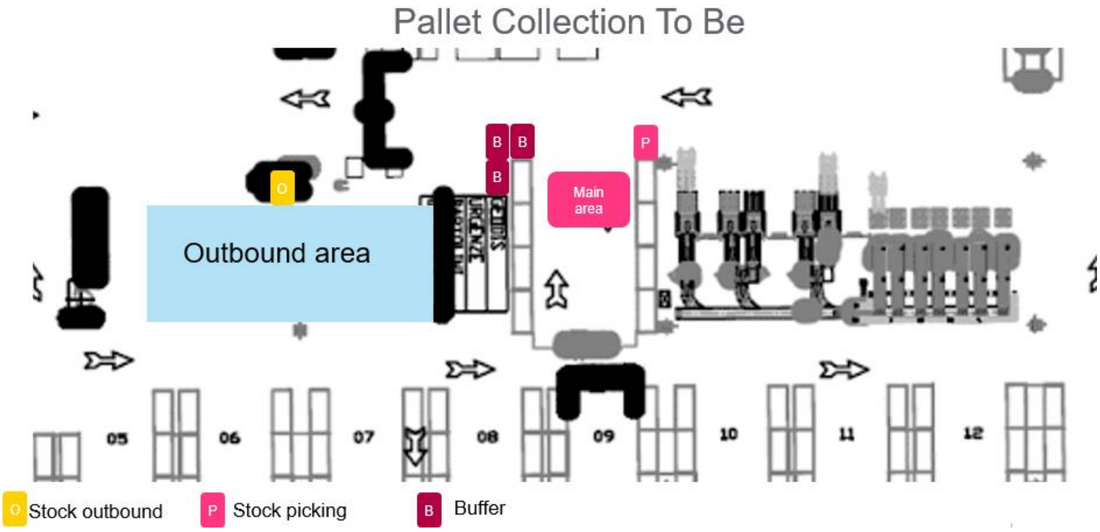

Figure 47 To Be pallet collection layout modifications

Even though each picker could carry maximum one empty pallet, the solution was feasible considering that:

- the average number of replenishment per day was 200 during the high season,
- the pickers per shift were 25,
- every picker processed at least 6 shipment pallets per shift.

The time analysis, as shown in Table 25, revealed that even considering the worst-case-time by pickers for loading the empty pallets (45 seconds), this solution could bring an overall saving of 1,2 hours a day regarding the consumable process in addition to reducing the Water Spider time of 1,8 hours a shift.

Analysis	Pickers/repl.oper.	Water Spider	Overall Saving
Time for taking the empty pallet [sec]	45		
No. of shipment pallets per picker [u]	6		
No.of pickers per day [u]	50		
Total time spent per operator [min/day]	3		
Total time pallet collection As Is [hr/day]		4	
Total time pallet collection To Be [hr/day]	2,5	0,3	1,2

Table 25 Time analysis To Be pallet collection

Moreover, as every operator was spending maximum 3 minutes per shift for doing this task probably their productivity won't be affected because this time could be confused with other variables like traffic, unplanned breaks or chatting.

Now the lead time of the consumable process would be reduced by more than 40%.

Area	Task N.	Task	Category	As Is Time Estimated (Min/shift)	As Is Time Estimated (Hr/Week)	To Be Time Estimated (Min/shift	To Be Time Estimated (Hr/Week)	Time saved per shift (min/shift)	Time saved per week (Hr/Week)	% time saved per shift (%)	% time saved per week (%)
Montaggio	5	Supply boxes Kit	Boxes	12,9	2,1	5,9	1,0	7,0	1,1	1,8%	1,8%
Montaggio		Supply Extra stock	Boxes	0	0	2,2	0,4	-2,2	-0,4	-0,6%	-0,6%
Montaggio	15	Supply boxes Assembly	Boxes	9,4	1,3	4,5	0,4	4,9	0,9	1,3%	1,4%
Inbound	75	Supply boxes GP	Boxes	3,8	0,6	3,8	0,6	0,0	0,0	0,0%	0,0%
Inbound	85	Supply boxes GV-GT-GS	Boxes	17,1	2,8	0	0	17,1	2,8	4,4%	4,4%
Inbound	95	Supply boxes resi	Boxes	1,2	0,2	1,2	0	0,0	0,2	0,0%	0,3%
Picking	120	Supply Boxes corr3	Boxes	18,8	3,1	3,15	0,5	15,7	2,6	4,0%	4,1%
Picking	125	Supply Boxes corr55	Boxes	17,4	2,9	2,9	0,5	14,5	2,4	3,7%	3,8%
Inbound	80	Supply Recycled Boxes GP	R.Boxes	3	0,5	3	0,5	0,0	0,0	0,0%	0,0%
Picking	130	Supply Recycled Boxes	R.Boxes	23,1	3,9	20,0	3,3	3,1	0,6	0,8%	0,9%
LAC	10	Supply bubbles Kit	Bubbles	9,0	1,5	0,0	0,0	9,0	1,5	2,3%	2,4%
LAC	20	Supply bubbles Assembly	Bubbles	6,8	0,6	0,0	0,0	6,8	0,6	1,8%	0,9%
Picking	135	Supply bubbles corr3	Bubbles	10,3	1,7	5,2	0,9	5,1	0,8	1,3%	1,3%
Picking	110	Pallet Management	Pallet	120,0	20,0	20,0	6,7	100,0	13,3	25,9%	21,1%
Total time				**386,7**	**63,3**	**205,8**	**14,8**	**181,0**	**26,4**	**46,8%**	**41,7%**

Table 26 Table 23 Overall time analysis improvements 1, 2, 3, 4

This solution could really help to standardize the consumable process and define a working schedule to optimise the process because the major source of variability would have been massively reduced. In addition, with this new process, pallet collection lost its criticality because there wouldn’t be any more safety issues which required the immediate intervention of the Water Spider.

4.5.5 Improvement 5: monitoring

This activity was representing about 10% of the overall time. The reason why this activity was so time-consuming was related to the high variability but also to the fact that there was no working plan and no standard to support the Water Spider tasks. As an analysis of the consumption of consumables had never been done, the Water Spider couldn't predict when the material would be required or keep track of the work done, therefore he had to increase monitoring.

Thanks to the data collection it was possible to estimate the average frequency of each task. Based on that information and the analysis on the improvements it was possible to define the following working schedule.

To Be		Monday		Tuesday		Wednesday		Thursday		Friday	
Task	Activity	Shift 1 [min]	Shift 2 [min]	Shift 1 [min]	Shift 2 [min]	Shift 1 [min]	Shift 2 [min]	Shift 1 [min]	Shift 2 [min]	Shift 1 [min]	Shift 2 [min]
Supply boxes Kit	5	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9	5,9
Supply bubbles Kit	10										
Supply boxes Assembly	15	4,5		4,5		17,5		4,5		4,5	13
Supply bubbles	20										
Supply 215x100	25		5					5			
Supply 215x90	30	3	3	3	3	3	3	3	3	3	3
Supply 150x80	35							4			
Removing 120x80	40		3						3		
Supply 80x60	45		3,5						3,5		
Supply coperchi MGA 215x90	50	3	3	3	3	3	3	3	3	3	3
Supply temporary stock pallet Mga	55	10	10	10	10	10	10	10	10	10	10
Supply Scatole & coperchi FTA	60				5				5		
Supply S7 & coperchi	65	3		3		3		3		3	
Supply Pedane in Spedizione	70	3	3	3	3	3	3	3	3	3	3
Supply boxes GP	75	3,8	3,8	3,8	3,8	3,8	3,8	3,8	3,8	3,8	3,8
Supply Recycled Boxes	80	20	20	20	20	20	20	20	20	20	20
Supply boxes GV-GT-GS	85										
Removing Cartons	90	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5	2,5
Supply boxes resi	95	6						6			
Supply Telaio 80x60 - 80x120	100				8						
Cleaning	105	40		40		40		40		40	
Pallet Management	110	20	20	20	20	20	20	20	20	20	20
Remove Pallet 80x60	115		13,3		13,3		13,3		13,3		13,3
Supply Boxes corr3	120		6,3		6,3		6,3		6,3		6,3
Supply Boxes corr55	125		5,8		5,8		5,8		5,8		5,8
Supply Recycled Boxes	130	20	20	20	20	20	20	20	20	20	20
Supply bubbles corr3	135	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2	5,2
Unload to the floor	140	8,9	8,9	8,9	8,9	8,9	8,9	8,9	8,9	8,9	8,9
Monitoring	145	10	10	10	10	10	10	10	10	10	10
Unload Trucks	150			30		30					30
Load Trucks	155		33,1				33,1			33,1	
Cleaning offices	160				10						
Supply puriball &	161				10						
Supply labels & ink & tape	162	10	10		10		10		10		10
Supply bubbles roll	163				10						
Inventory	165								30		
To Be totale Hr/shift		3,0	3,3	3,2	3,2	3,4	3,1	3,0	3,2	3,3	3,2

Table 27 To Be weekly scheduled

This theoretical weekly schedule was used to balance the working load and create a simpler and more flexible working plan to be followed by the Water Spider.

The working plan had to be organized in order to maximise the time slot in which the Water Spider could be available for doing something else. But because of variability about consumption and the fact that some activities still had a frequency greater than once a shift, it was decided to compact all the consumables activities in two-time slots, at the beginning and at the end of the shift. The central part of the shift around 3,5 hours, instead, should be dedicated to performing more productive activities in the inbound department.

In the figure below it is represented the weekly working plan.

Indicare con una spunta le attività generiche svolte, la quantità per la fornitura di scatole e coperchi nuovi, l'ora di inizio e fine attività e ora arrivo per carico e scarico camion															
Time Slot		Piano di lavoro Water spider		Settimana n°		Water spider Turno 1:					Water spider Turno 2:				
						Lunedì		Martedì		Mercoledì		Giovedì		Venerdì	
T1	T2	Attività		Materiale	Qtà	Turno 1	Turno 2	Turno 1	Turno 2	Turno 1	Turno 2	Turno 1	Turno 2	Turno 1	Turno 2
6:00	14:00	Inizio turno	Ricognizione			h:	h:	h:	h:	h:	h:	h:	h:	h:	h:
20 min break		Stock Centrale	Controllo e/o Fornitura stock	120x80	------										
				Scatole	------										
		MGA	Distribuire Pallet (Tutte le postazioni)		Pieno										
		Montaggio	Fornitura scatole e coperchi extra stock, kit, assembly	S1 (Pack.)	6|3|3	| |		|		| |		|		|	
				S2 (Pack.)	4|3|3	| |		|		| |		|		|	
				S3 (Pack.)	6|3|3	| |		|		| |		|		|	
				S4 (Pack.)	8|3|3	| |		|		| |		|		|	
				Cop. S1 (Pack.)	6|3|3	| |		|		| |		|		|	
				Cop. S2-S3 (Pack)	0|8|8	| |		|		| |		|		|	
				Cop. S4-S7 (Pack)	5|4|5	| |		|		| |		|		|	
		Picking	Corridoio 3	S1 (Pack.)	2	------		------		------		------		------	
				S2 (Pack.)	4	------		------		------		------		------	
				S3 (Pack.)	4	------		------		------		------		------	
				S4 (Pack.)	4	------		------		------		------		------	
				S7 (Pack.)	4	------		------		------		------		------	
				Cop. S1 (Pack.)	2	------		------		------		------		------	
				Cop. S2-S3 (Pack)	8	------		------		------		------		------	
				Cop. S4-S7 (Pack)	8	------		------		------		------		------	
			Bolle Corri. 3	1 cesta	Pieno										
		Corr. 16 A 55	Fornitura (corr. 55)	Cop. S1 (Pack.)	16	------		------		------		------		------	
				Cop. S2-S3 (UL)	22	------		------		------		------		------	
				Cop. S4-S7 (UL)	6	------		------		------		------		------	
				S7 (Pack.)		------		------		------		------		------	
			Sitemare grigliati scatole	RS1/ RS2/ RS3/RS4	Pieno										
			Cesta coperchi a entrata merci	S2-S3	Pieno										
		Picking	Rimozione pallet	80x60	------										
		Altro	Controllo e/o Fornitura Etichette/ Pluriball/Barcode/ Inchiostro/ Reggette/Bobine bolle/etc		Pieno	------		------		------		------		------	
9:00	16:30	Altro	Attivita Extra o Urgenze (*)		------										
30 min lunch		Disponibilità per altre attività				h:	h:	h:	h:	h:	h:	h:	h:	h:	h:
12:50	20:50	Fine Turno	Ricognizione			h:	h:	h:	h:	h:	h:	h:	h:	h:	h:
10 min break		Picking	Pulizia magazzino		------	------		------		------		------		------	
		Altro	Altre attività (**)		------		------		------		------		------		------
		Spedizione	Fornitura pallet	80x60	Pieno										
		Stock Centrale	Controllo e/o Fornitura	120x80	------										
				Scatole	------										
		MGA	Scorta sicurezza Mga		Pieno										
		Corr. 16-55	Piegare grigliati scatole riciclate	RS1/ RS2/ RS3	Pieno										
		Corr.3	Bolle Corr. 3	3 ceste	Pieno										
14:00	22:00	Spedizione	Cartoni tama	1 pallet	------		------		------		------		------		------
		*	Scarico Camion	ora arrivo	------										
		*	Carico Camion	ora arrivo	------										
		**	Inventario		------										
		**	Scatole mga		------										
		**	Urgenze		------										

Commenti	1° turno	2° turno
lunedì		
martedì		
mercoledì		
giovedì		
venerdì		

Figure 48 Weekly working plan

The beginning of the shift was the longer time slot in which the most crucial activities were carried out. So, here we find boxes, pallet and bubble supply, but also the pallet removal task and the load/unload truck activity. This last activity caused a lot of variability because the arrival day of the trucks was not fixed or scheduled. So, the working load could vary of at least 30 minutes a shift depending on this factor. In the last part of the shift, instead, there were the secondary activities like cleaning or refilling the safety stock for MGA pallets, but also those activities with a frequency greater than one like bubbles supply in corridor 3.

The working plan was developed considering the maximum workload for the first and second shift. They were rounded up to 3,5 hours for approximation requirements. The main source of variability in this schedule, at that moment, was related to the truck arrivals because there was no scheduling about that. This criticality still had to be improved by operations. So, in the short term, the Water Spider working plan had to be adjusted on a daily basis by the inbound team leader with the information about the truck arrivals.

Comparing the scheduling before and after the improvements, it appeared that these initiatives could lead to 60% reduction of the operating time as shown in Figure 49.

As Is vs To Be scenario	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Hr/week
As is total Hr/shift	6,5	6,2	6,7	6,2	6,7	6,0	6,4	6,1	6,7	5,9	63,4
To be total Hr/shift	3,0	3,3	3,2	3,2	3,4	3,1	3,0	3,2	3,3	3,2	31,8
Delta Hr/shift	3,8	4	4	4	4	3,7	4	4	4	4	39,6
%	**46%**	**66%**	**60%**	**73%**	**56%**	**62%**	**60%**	**73%**	**55%**	**59%**	**60%**

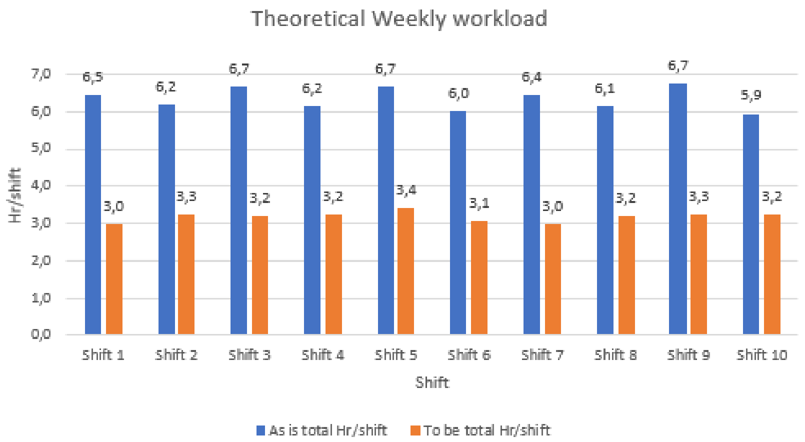

Figure 49 Weekly schedule As-Is vs To Be

The overview of all the improvements undertaken is shown in Table 28.

Area	Task N.	Task	Category	As Is Time Estimated (Min/shift)	As Is Time Estimated (Hr/Week)	To Be Time Estimated (Min/shift)	To Be Time Estimated (Hr/Week)	Time saved per shift (min/shift)	Time saved per week (Hr/Week)	% time saved per shift (%)	% time saved per week (%)
Montaggio	5	Supply boxes Kit	Boxes	12,9	2,1	5,9	1,0	7,0	1,1	1,8%	1,8%
Montaggio		Supply Extra stock	Boxes	0	0	2,2	0,4	-2,2	-0,4	-0,6%	-0,6%
Montaggio	15	Supply boxes Assembly	Boxes	9,4	1,3	4,5	0,4	4,9	0,9	1,3%	1,4%
Inbound	75	Supply boxes GP	Boxes	3,8	0,6	3,8	0,6	0,0	0,0	0,0%	0,0%
Inbound	85	Supply boxes GV-GT-GS	Boxes	17,1	2,8	0	0	17,1	2,8	4,4%	4,4%
Inbound	95	Supply boxes resi	Boxes	1,2	0,2	1,2	0	0,0	0,2	0,0%	0,3%
Picking	120	Supply Boxes corr3	Boxes	18,8	3,1	3,15	0,5	15,7	2,6	4,0%	4,1%
Picking	125	Supply Boxes corr55	Boxes	17,4	2,9	2,9	0,5	14,5	2,4	3,7%	3,8%
Inbound	80	Supply Recycled Boxes GP	R.Boxes	3	0,5	3	0,5	0,0	0,0	0,0%	0,0%
Picking	130	Supply Recycled	R.Boxes	23,1	3,9	20,0	3,3	3,1	0,6	0,8%	0,9%
LAC	10	Supply bubbles Kit	Bubbles	9,0	1,5	0,0	0,0	9,0	1,5	2,3%	2,4%
LAC	20	Supply bubbles Assembly	Bubbles	6,8	0,6	0,0	0,0	6,8	0,6	1,8%	0,9%
Picking	135	Supply bubbles corr3	Bubbles	10,3	1,7	5,2	0,9	5,1	0,8	1,3%	1,3%
Picking	110	Pallet Management	Pallet	120,0	20,0	20,0	6,7	100,0	13,3	25,9%	21,1%
Dc	145	Monitoring	Other	40,0	6,7	8,0	1,3	32,0	5,4	8,3%	8,5%
Activities not improved				93,9	15,6	93,9	15,6				
Total time				**386,7**	**63,3**	**173,8**	**16,1**	**213,0**	**31,8**	**55,1%**	**50,2%**

Table 28 As-Is vs To Be time analysis after improvements 1, 2, 3, 4, 5

4.6 Check

The follow-up of the improvements was carried out through the working plan, see Figure 48.

In fact, it was asked the Water Spider to fill in the working plan:

1. ticking the frequency of every activity scheduled
2. marking the UL supplied for the boxes and covers supply tasks
3. taking note of the starting and ending time for the consumables management process
4. writing feedback especially regarding the recycled boxes

From the first 2 points, it was possible to verify the estimated inventory of the trolleys and the frequency of each task.

Table 29 shows that the activities related to boxes supply in LAC and picking were correctly dimensioned.

Area	Task	Type	Avg. Freq. of supply/day	Max UL supplied/day	Target Avg. Freq./day	Trolley capacity (UL)	Status
Picking	Supply boxes corr.3	S1	1	4	1	2	
		S2	1	3		4	
		S3	1	3		4	
		S4	1	3		4	
		S7	1	3		4	
		Covers S1	1	4		2	
		CoversS2-S3	1	7		8	
		Covers S4-S7	1	3		8	
	Supply boxes corr.55	S1	1	0	1	0	
		S2	1	0		0	
		S3	1	0		0	
		S4	1	0		0	
		S7	1	3		4	
		Covers S1	1	13		16	
		CoversS2-S3	1	21		22	
		Covers S4-S7	1	5		6	
LAC	Supply boxes Kit	S1	1	2	1	3	
		S2	1	2		3	
		S3	1	2		3	
		S4	1	3		3	
		Covers S1	1	2		3	
		CoversS2-S3	1	6		8	
		Covers S4-S7	1	3		4	
	Supply boxes Assembly	S1	1	2	1	3	
		S2	1	2		3	
		S3	1	2		3	
		S4	1	3		3	
		Covers S1	1	2		3	
		CoversS2-S3	1	5		8	
		Covers S4-S7	1	3		4	
	Extra stock	S1	0,2	4	0,2	6	
		S2	0,2	3		4	
		S3	0,2	5		6	
		S4	0,2	7		8	
		Covers S1	0,2	3		6	
		CoversS2-S3	0,2	0		0	
		Covers S4-S7	0,2	4		5	

Table 29 Benchmarking improvement 1 results

Table 30 reports the frequency of the other tasks in the plan.

Area	Task	Type of boxes	Avg. Freq. of supply/day	Target Freq./day	Status
Picking	Supply bubbles corr.3	Bubbles	5	4	
	Fold Rec.boxes	R.Boxes	2	2	
	Organize Rec.boxes	R.Boxes	4	2	
	Cleaning	-	1	1	
	remove pallet 80x60	Pallets	2,5	2	
	Remove pallet 80x120	Pallets	3,4	3	
	Pallets to shipping	Pallets	2	4	
DC	Supply labels, straps etc	other	1	1	
	Supply cartons	other	1	1	
MGA	Safety stock MGA	Pallets	3,2	4	
	Supply pallets MGA	Pallets	2,4	2	
	Supply boxes MGA	Boxes	1	1	
Extra	Inventory	-	0	0,1	
	Loading trucks	Pallets	3	3	
	Unloading trucks	Pallets	7	3	

Table 30 Benchmarking frequency of main activities

It can be noticed that bubble supply was a bit underestimated because instead of occurring 4 times a day it was occurring 5.

But also the recycled boxes management needed some improvements because according to the comments of the Water Spider pickers were not putting the boxes correctly in the shelves of the trolleys, so he had to organize trolleys more frequently. Moreover, still there were recycled boxes in the waste bins, so it was necessary to remember the pickers to follow the instructions.

The activity of removing pallet 80x120 was slightly greater than expected but acceptable.

In terms of operative time, the results were quite positive as shown in Table 31. In fact, they showed that the target was achieved, but the overall time per shift was about 0,7 hours per shift larger than the estimated duration. This was partly connected to the fact that some activities that were not subjected to improvements were actually executed with a higher frequency than the one expected. (See Table 30).

As Is vs To Be scenario	Shift 1	Shift 2	Shift 3	Shift 4	Shift 5	Shift 6	Shift 7	Shift 8	Shift 9	Shift 10	Hr/week	% delta Hr/week	Avg. Time per shift Hr/shift
As is total Hr/shift	6,5	6,2	6,7	6,2	6,7	6,0	6,4	6,1	6,7	5,9	63,4		6,3
To be total Hr/shift	3,0	3,3	3,2	3,2	3,4	3,1	3,0	3,2	3,3	3,2	31,8	50%	3,2
Effective total Hr/shift	3,8	4,2	4,0	3,8	4,1	4,0	3,7	3,9	4,0	3,8	39,3	38%	3,9

Table 31 Benchmarking As-Is vs To Be vs Effective total time

For example, the activity of loading and unloading trucks was estimated with a frequency equal to 6 times per week, instead, it turns out to be equal to 10 meaning that every shift about 30-35 minutes had to be added to overall time. Regarding this issue, it is important to specify that 3 of these deliveries were anticipations for covering the periods of holiday closure of the consumable suppliers. So, ignoring this noise factor the results were quite similar to the ones expected.

In order to validate the results, there were still two checking to do concerning the pallet collection. In fact, it has to be verified that:

1. there weren't too many pallets in the corridors
2. this activity didn't affect the productivity of the pickers and replenishment operators.

The first point was accomplished through daily monitoring of how many pallets were present in the corridors every hour. This data collection (see Figure 50) revealed that in the pallet racking area there had never been any more than 4 pallets per corridor and there was only 1 case in which there were 3 pallets in the same corridor. Moreover, the total number of pallets in the warehouse had never overcome the total of 5 and they were around in the 80% of the time were maximum 2. These results were strongly positive.

Probability to find a pallet in a corridor during the day														
Corridor	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
0 pallets	22%	89%	100%	100%	89%	100%	89%	89%	89%	89%	78%	78%	78%	78%
1 pallets	44%	11%	0%	0%	0%	0%	11%	0%	11%	11%	22%	22%	22%	22%
2 pallets	22%	0%	0%	0%	11%	0%	0%	11%	0%	0%	0%	0%	0%	0%
3 pallets	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4 pallets	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
5 pallets	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Probability total no pallets in the picking area during the day						
Tot. No. pallets/time	0	1	2	3	4	5
9:30	20%	40%	20%	0%	20%	0%
10:30	0%	40%	60%	0%	0%	0%
11:30	0%	60%	40%	0%	0%	0%
12:30	20%	40%	40%	0%	0%	0%
13:30	20%	20%	20%	40%	0%	0%
14:30	20%	20%	40%	0%	0%	20%
15:30	40%	20%	20%	20%	0%	0%
16:30	20%	60%	20%	0%	0%	0%
17:30	20%	40%	20%	0%	20%	0%
Avg prob.	**18%**	**38%**	**31%**	**7%**	**4%**	**2%**

Figure 50 Probability of finding empty pallets

In order to check the effect of the change in the pallet collection in the performances of the pickers, it was decided to apply a paired sample T-Test. So, it was chosen as a sample the average performances of the pickers of the 2 weeks before (U1) and after (U2)the improvement. The T-Test revealed that from a statistical point of view the two samples couldn't be considered diverse.

T-Test			
H0	U2=U1		
H1	U1-U2>0		
n°	66		
D	-0,56%		
Sigma D	24%		
T	-0,18953		
T_lim5%	1,67	Pvalue	37%

The Null Hypothesis can't be rejected because there is 37% chance that performances would be the same with 95% of confidence.

intervallo di confidenza	
inf=	-0,0547
sup=	0,04355

Avg.Before	94%	Sigma before	4%
Avg.after	95%	Sigma after	4%

Figure 51 T-Test on operators' performances

Before concluding it is important to remark that this project contributed not only to reduce the consumable time by 38% but it also enables to increase the effectiveness of performances and reduce the operating costs.

Figure 52 shows that in Venaria DC because of the low efficiency and the variability of the demand during low and high season, it is often necessary to work overtime. Since the bottleneck of the process is the picking process, the consumable and the Water Spider Master project aim at reducing the operating time of non-profitable processes and invest it in the picking area to reduce the operating costs and avoid to work on Saturday.

Water Spider Master Project scope

As Is	Operating time [Hr/shift]	Consumable management [Hr/shift]	Waste management [Hr/shift]	Picking [Hr/shift]	Productivity [OT/Hr]	Output [OT/shift]
Water Spider1	7,2	7,2	0	0	0	0
Water Spider2	7,2	7,2	0	0	0	0
Operator A	7,2	0	5	2,2	24,5	53,9
Operator B	7,2	0	5	2,2	24,5	53,9
Total	**28,8**	**14,4**	**10**	**4,4**	**49**	**108**

Water Spider Master Project	Operating time [Hr/shift]	Consumable management [Hr/shift]	Waste management [Hr/shift]	Picking [Hr/shift]	Productivity [OT/Hr]	Output [OT/shift]
Water Spider1	7,2	3,2	4	0	0	0
Water Spider2	7,2	3,2	4	0	0	0
Operator A	7,2	0	0	7,2	24,5	176,4
Operator B	7,2	0	0	7,2	24,5	176,4
Total per day	**28,8**	**6,4**	**8**	**14,4**	**49**	**353**
Delta picking [Hr/day]				10		

Consumable Project	Operating time [Hr/shift]	Consumable management [Hr/shift]	Waste management [Hr/shift]	Picking [Hr/shift]	Productivity [OT/Hr]	Output [OT/shift]
Water Spider1	7,2	3,9	0	3,3	24,5	80,85
Water Spider2	7,2	3,9	0	3,3	24,5	80,85
Operator A	7,2	0	5	2,2	24,5	53,9
Operator B	7,2	0	5	2,2	24,5	53,9
Total per day	**28,8**	**7,8**	**10**	**11**	**98**	**270**
Delta picking [Hr/day]				6,6		

DC performances

Target high Season [OT/day]	Operating time picking [Hr/day]	Avg. Productivity [OT/day]	Avg. Output [OT/day]	Overtime per day [Hr/day]	Expected time [Hr/day]	Efficiency [%]
9648	366	24,5	8962	28	268	68%

Target low Season [OT/day]	Operating time picking [Hr/day]	Avg. Productivity [OT/day]	Avg. Output [OT/day]	Overtime per day [Hr/day]	Expected time [Hr/day]	Efficiency [%]
7500	270	26	7032	18	208	72%

Target high Season [OT/day]	Operating time picking [Hr/day]	Avg. Productivity [OT/day]	Avg. Output [OT/day]	Overtime per day [Hr/day]	Expected time [Hr/day]	Efficiency [%]	Saving high season* [Euro]
9648	376	24,5	9207	18	267,8	68%	**10350**

Target low Season [OT/day]	Operating time picking [Hr/day]	Avg. Productivity [OT/day]	Avg. Output [OT/day]	Overtime per day [Hr/day]	Expected time [Hr/day]	Efficiency [%]	Saving low season* [Euro]
7500	280	26	7292	8	208	72%	**16560**

Target high Season [OT/day]	Operating time picking [Hr/day]	Avg. Productivity [OT/day]	Avg. Output [OT/day]	Overtime per day [Hr/day]	Expected time [Hr/day]	Efficiency [%]	Saving high season* [Euro]
10680	373	24,5	8900	21,4	267,8	68%	**6831**

Target low Season [OT/day]	Operating time picking [Hr/day]	Avg. Productivity [OT/day]	Avg. Output [OT/day]	Overtime per day [Hr/day]	Expected time [Hr/day]	Efficiency [%]	Saving low season* [Euro]
7500	277	26	7204	11,4	208	72%	**10930**

* The cost per hour is considered the minumum working rate by law equal to 9 Euro per hour. It doesn't take into account of the cost of machine, overheads, etc.

Figure 52 Economic evaluation consumables project

The consumable project added 6,6 hours per day to the picking operating time. This would have permitted to reduce the cost of overtime in picking by more than 16K Euros per year keeping the investment costs to 0.

The margin would have risen to more than 26K Euros per year thanks to the results of the Water Spider Master project. However, the investment cost required was around

20K Euros (for buying a tow tractor with some trailers for carrying waste bins in addition to some IoT devices and sensors).

Comparing the two projects with the method of the Net Present Value and assuming a discount rate of 10%, it turns out that the Water Spider Master project is more profitable than the consumables project even though the latter has no investment cost. (See Table 32)

Net present value					
				A	Consumable project
Discount rate	10%			B	Water Spider master Project
Periods	5				
A Initial investment in year 0 [Euro]	0				
B Initial investment in year 0 [Euro]	20000				
Year	1	2	3	4	5
Discount factor	0,91	0,83	0,75	0,68	0,62
Undiscounted inflows	17761	17761	17761	17761	17761
Discounted inflows A	16146	14678	13344	12131	11028
Undiscounted inflows	26910	26910	26910	26910	26910
Discounted inflows B	24464	22240	20218	18380	16709
NPV A [Euro]	**67327**				
NPV B [Euro]	**82010**				

Table 32 Net present value method

4.7 Act

This last stage is about preparing documentation for formalizing and standardize the improvements, but also identify future actions.

Regarding the documentation, besides the working plan which had to be completed every day by the Water Spider, it was also provided a document with an integral description of how to do all the activities in the plan. (See Figure 53)

Time Slot		Attività		Materiale	Qtà	Decrizione
6:00	14:00	Inizio turno	Ricognizione			Giro perlustrativo tra tutte le aree interessate per capire se ci sono urgenze e definere l'ordine di priorità delle attività di inizio turno. In linea generale le attività con priorità sono la fornitura di scatole e pallet in stock centrale, montaggio e MGA.
20 min break		Stock Centrale	Controllo e/o Fornitura stock centrale	120x80	------	Controllare che ci siano almeno 20 pallet (2pila) 80x120 e 80x60 nelle varie postazioni. Se ci sono più di 20 pallet (2 pile) rimuovere i pallet in eccesso
				Scatole	------	Controllare per ogni tipologia scatola che ci siano almeno 1 layer per S1,S2,S7, 3 layer per S3 e 2 layer per S4 disponibili sui pallet, in caso contrario abbassare un'altra pedana e posizionare le scatole in eccesso nei grigliati sul lato opposto
		MGA	Distribuire Pallet (Tutte le postazioni)		Pieno	Distribuire nelle apposite ubicazione i pallet MGA (215x90,215x100,150x80) e i coperchi MGA. La qtà sono 19 unità ca per i pallet e 10 unità ca per i coperchi. In caso di shortage sarà l'operatore a dover riferire al team leader che potrà decidere o di chiamare il water spider o di risolvere il problema internamente
		Montaggio	Fornitura scatole e coperchi extra stock, kit, assembly	S1 (Pack.)	6|3|3	Ogni 5 turni riapprovvigionare il LAC nell'area extra stock di scatole e coperchi nuovi nella quantità definita. In caso di shortage sarà l'operatore a dover riferire al team leader che potrà decidere o di chiamare il water spider o di risolvere il problema internamente. Fare rifornimento negli orari di pausa montaggio per poter entrare con il mezzo nell'area kit. Riapprovvigionare l'Assembly una volta al giorno e i kit una volta al turno
				S2 (Pack.)	4|3|3	
				S3 (Pack.)	6|3|3	
				S4 (Pack.)	8|3|3	
				Cop. S1 (Pack.)	6|3|3	
				Cop. S2-S3 (Pack)	0|8|8	
				Cop. S4-S7 (Pack)	5|4|5	
		Picking	Corridoio 3	S1 (Pack.)	2	Approvigionare il grigliato al corridoio 3 di scatole e coperchi nuovi nelle quantità indicate. In caso di shortage l'operatore dovrà riferire al Team leader del reparto che che potrà decidere o di chiamare il water spider o di risolvere il problema internamente
				S2 (Pack.)	4	
				S3 (Pack.)	4	
				S4 (Pack.)	4	
				S7 (Pack.)	4	
				Cop. S1 (Pack.)	2	
				Cop. S2-S3 (Pack)	8	
				Cop. S4-S7 (Pack)	8	
			Bolle Corri. 3	1 cesta	Pieno	Rimpiazzare uno alla volta i grigliati vuoti con quello pieno disponibile al montaggio nel corridoio 0. Fare in modo che al termine dell'operazione i 3 grigliati del corridoio 3 siano pieni. In caso di shortage sarà l'operatore a dover riferire al team leader che potrà decidere o di chiamare il water spider o di risolvere il problema internamente
		Corr. 16 A 55	Fornitura (corr. 55)	Cop. S1 (Pack.)	16	Approvvigionare il grigliato di coperchi e scatole nuovi della tipologia indicata e nella quantità indicata. In caso di shortage sarà l'operatore a dover riferire al team leader che potrà decidere o di chiamare il water spider o di risolvere il problema internamente
				Cop. S2-S3 (UL)	22	
				Cop. S4-S7 (UL)	6	
				S7 (Pack.)		
			Sitemare grigliati scatole riciclate	RS1/ RS2/ RS3/RS4	Pieno	Sistemare le scatole nei ripaini corretti dei trolley se sono fuoriposto
			Cesta coperchi a entrata merci	S2-S3	Pieno	Se la cesta è vuota rimpiazzarla con una piena nell'area corr. 16-55
		Picking	Rimozione pallet	80x60	------	Rimuovere i pallet 80x60 dalle apposite ubicazioni e depositarli o nelle aree apposite al corr.5 o corr.2 o, se sature, fuori nell'area di stoccaggio esterna. In caso di shortage o overstock l'operatore dovrà riferire al Team leader del reparto che provvederà a chiamare il waterspider
		Altro	Controllo e/o Fornitura Etichette/ Pluriball/Barcode/ Inchiostro/ Reggette/Bobine bolle/etc		Pieno	Provvedere al rifornimento di etichette, pluriball, reggette, barcode, inchiostro,bobina bolle, al montaggio, rullivia spedizione, entrata merci e picking
9:00	16:30	Altro	Attivita Extra o Urgenze (*)		------	Svolgere le attività urgenti o non ordinarie come carico o scarico camion. Appuntare l'ora di arrivo del camion
30 min lunch		Disponibilità per altre attività				
12:50	20:50	Fine Turno	Ricognizione			Giro perlustrativo tra tutte le aree interessate per capire se ci sono urgenze e definere l'ordine di priorità delle attività di fine turno. In linea generale le attività con priorità sono la fornitura di scatole e pallet in stock centrale, montaggio e MGA.
10 min break		Picking	Pulizia magazzino		------	Rimuovere i pallet per permettere alla signora delle pulizie di pulire il vano. Solo al primo turno dalle 12:00 alle 12:30
		Altro	Altre attività (**)		------	attività poco frequenti come inventario, fornitura scatole MGA. Solo al secondo turno
		Spedizione	Fornitura pallet	80x60	Pieno	Se il numero di pallet 80x60 è < 10 (1 pila) in spedizione aggiungere una pila.
		Stock Centrale	Controllo e/o Fornitura	120x80	------	In entrata merci mantenere il numero di pallet 80x120 e 80x60 <= 30. In caso di eccesso rimuovere o di shortage rifornire.
				Scatole	------	Controllare per ogni tipologia scatola che ci siano almeno 1 layer per S1,S2,S7, 3 layer per S3 e 2 layer per S4 disponibili sui pallet, in caso contrario abbassare un'altra pedana e posizionare le scatole in eccesso nei grigliati sul lato opposto
		MGA	Scorta sicurezza Mga		Pieno	Approvvigionare lo stock tempoaneo di canalis di una pila di pallet 215x90 e coperchi o di una pila di pallet prossimi allo shortage
		Corr. 16-55	Piegare grigliati scatole riciclate	RS1/ RS2/ RS3	Pieno	In caso di sovraffollamento di scatole nei grigliati piegare la metà delle scatole
		Corr.3	Bolle Corr. 3	3 ceste	Pieno	Rimpiazzare uno alla volta i grigliati vuoti con quello pieno disponibile al montaggio nel corridoio 0. Fare in modo che al termine dell'operazione i 3 grigliati del corridoio 3 siano pieni. In caso di shortage sarà l'operatore a dover riferire al team leader che potrà decidere o di chiamare il water spider o di risolvere il problema internamente
14:00	22:00	Spedizione	Cartoni tama	1 pallet	------	A fine turno portare in spedizione i cartoni che il personale Tama ha smistato in prossimità dei container

Figure 53 Tasks description

The pallet collection process explained in the DO phase was formalized with a flow chart representing all the activities and the actors involved, see Figure 54.

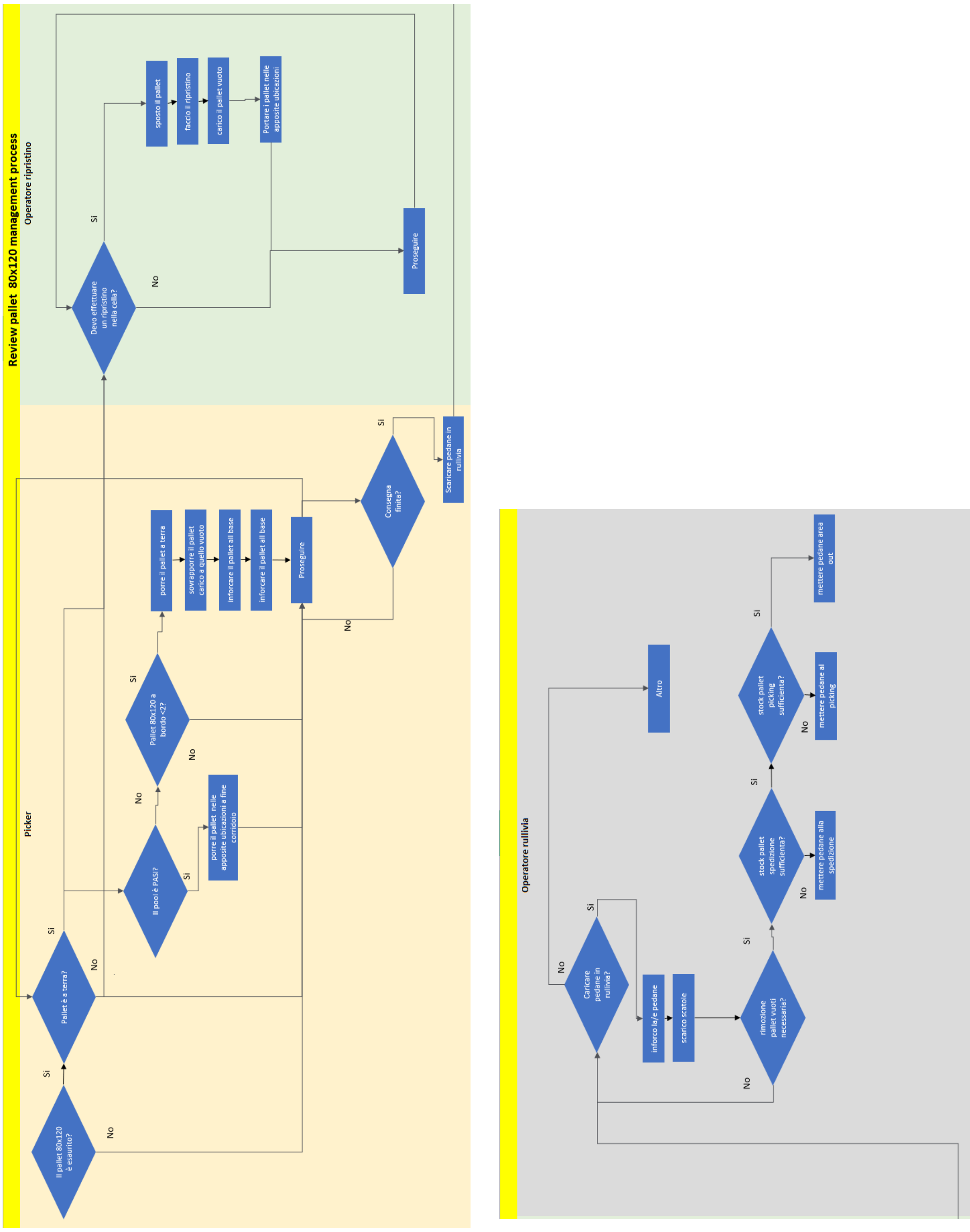

Figure 54 Pallet collection process mapping

Finally, it was also created a responsibility matrix for every department involved in the consumable process specifying their role in every activity.

Matrice responsabilità montaggio				
#	Attività	WS	Team Leader	Operatore
1	Controllo stock scatole		R	S
2	Controllo inventario altri materiali		R	S
3	Comunicazione con WS		R	
4	Fornitura scatole LAC	R		
5	Fornitura etichette, inchiostro,nastro, reggette	R		
6	Fornitura pluriball	R		
7	Fornitura bolle Assemblaggio			R
8	Fornitura bolle Kit			R
9	Fornitura starordinaria scatole Assemblaggio, kit			R
10	Gestione scatole riciclate			R
11	**Shortage materiale (scatole, bolle, pallet, coperchi, etichette etc...)**		**R**	**S**

Matrice responsabilità entrata merci				
#	Attività	WS	Team Leader	Operatore
1	Fornitura S2-S3-S9 a postazioni entrata merci			R
2	Fornitura coperchi a postazioni entrata merci	R		
3	Fornitura S1 riciclate a postazioni entrata merci	R		
4	Fornitura grigliato 1-2 riciclate	R		
5	Fornitura cesta coperchi	R		
6	Controllo e fornitura materiale secondario (etichette, inchiostro, nastro, barcode)	R		S
7	**Shortage materiale (scatole, bolle, pallet, coperchi, etichette etc...) o accumulo pallet 80x120, 80x60, cassonetti, cartoni**		**R**	**S**

Matrice responsabilità spedizione				
#	Attività	WS	Team Leader	Operatore
1	Depositare il pallet o i 2 pallet nell'area di stock adiacente			R
2	Shortage pallet (solo se c'è disponibilità di pallet in entrata merci)			R
3	Trasferire cartoni per i top dei pallet da entrata merci a spedizione			R
4	**Shortage materiale (scatole, bolle, pallet, coperchi, etichette etc...) o eccesso pallet**		R	S

Matrice responsabilità Picking				
#	Attività	WS	Team Leader	Operatore
1	Riporre correttamente le scatole riciclate negli appositi grigliati			R
2	Riporre correttamente i coperchi S2-S3, S4-S7 nelle apposite ceste			R
3	Usare le scatole riciclate			R
4	Usare i coperchi riciclati nelle determinate condizoni			R
5	Riporre i pallet 80x60 nelle apposite ubicazioni			R
6	Raccogliere i pallet 80x120 nelle modalità indicate			R
7	Supervisone attività 1, 2, 3, 4, 5, 6		R	S
8	Comunicazione con WS		R	
9	Rimuovere pallet 80x60 dalle apposite postazioni	R		
10	Fornitura pallet 80x120 in stock centrale	R		
11	Fornitura grigliato corridoio 3	R		
12	Fornitura grigliato corridoio 55	R		
13	Fornitura bolle corridoio 3	R		
14	Svuotamento e organizzazione grigliati scatole riciclate	R		
15	Rimuovere e ordinare ceste coperchi S2-S3,S4-S7	R		
16	Controllo e fornitura materiale secondario (etichette, inchiostro, nastro, barcode)	R		
17	Pulizia corridoi	R		
18	Shortage materiale (scatole, bolle, pallet, coperchi, etichette etc...) o eccesso pallet nei corridoi (>=3 pallet per corridoio)		R	S

Legenda		
#	Ruolo	Descrizione
R	Responsabile	Responsabile dell'esecuzione dell'attività
S	Supporto	Colui che deve fornire supporto informativo e/o operativo nello svolgimento della attività del responsabile

Figure 55 Responsibility matrix

The purpose of this matrix was to clarify who is involved in every task and what is their degree of participation.

In order to standardize the communication channel, it was decided that the Water Spider should follow just the instructions of the team leader of each department avoiding that chaos which was occurring before where basically everyone was telling the Water Spider what to do. So, the team leader had to become responsible for supervising the consumable need of his/her department. Regarding this point a future action would be implementing a kanban system for managing the supply of each consumable type. The operators of each department should have supported the team leader in the supervising activities referring if some consumable material was in shortage.

The Water Spider was intended only as responsible for the supply of consumables for the quantity established in the working plan. In case of shortage, it should have been the team leader to manage the situation.

Further improvement actions were identified as:

1. Implementing an automatic inventory in SAP of the secondary consumables like straps, labels, barcode labels, ink, etc in order to know real-time the inventory and the location of these materials. In fact, till that moment there was no tracking and only the Water Spider knew this information.
2. Implementing a kanban system for telling exactly the Water Spider what to supply and in which quantity.
3. Moving from a static system of supply to a dynamic one developing a “call-action system” thanks to the help of a smartwatch. In this way, the Water Spider would intervene only when it was required. This solution could be very important for the integration of the consumable process with the waste management process. In fact, in this way it would be possible to establish which waste bin to empty without monitoring every time. In addition, this technology could have facilitated the communication between team leaders and Water Spider.

However, these improvements which are more related to the” Step up” stage should have been anticipated by the standardization of the waste management process.

5 Project 2: Zebra TC8000 commissioning

5.1 Context

Project 2 is completely different because it is not about standardizing a process but just updating it with technological solutions that will make possible future smart initiatives. This project focuses on updating the main tools which enable all the warehouse operations, the handhelds.

Before focusing on the project some more details will be given about what a handheld computer looks like, what it is used for and what are the features of the Zebra TC 8000

Up to the project start, the fleet of handhelds used by warehouse operators in Venaria DC was counting around 30 Motorola MC9090, the older ones, and 20 Motorola MC9190, some year younger. (See Figure 56)

Figure 56 MC9090 and MC9190[59]

Through these devices, operators are told what to do so that the WMS can manage and control the correct execution of any warehouse operations from put-away to shipping.

[59] (Zebra, n.d.)

In fact, on these terminal computers is running SIM+, a Terminal Emulation app of SAP, which is the Venaria DC WMS. SIM+ emulates on the handheld display a series of “black & yellow screens” from SAP with input/output fields that the operator has to type-in or read.

As shown in the pictures, these models are very similar, and they are both quite old dating back 2012-2013. Both of them are using Windows mobile as enterprise operative system which is not going to be updated anymore by Microsoft.

These devices, being quite old, are characterized by a low level of technology and hardware components. They are very basic mobile computers with only a display, a keyboard, a barcode scanner, a battery and a processor for connecting wireless to the server and running SIM+. They have no camera or any other smart application, which limited the use of these devices only to the function of displaying the picking list and scanning items. These features make these devices incompatible for the use of any modern App and more in general for the integration to any IoT system.

While Zebra TC 8000 (see Figure 57) is an Android-based touch computer that, with an innovative ergonomic design and an advanced technological package, is able to boost workers by 14%.

Figure 57 TC 8000[60]

TC 8000 are Android next-generation handhelds that have very similar functionalities to smartphones, but they are augmented. In fact, they have high-resolution camera, longer

[60] (Zebra.com, n.d.)

band Wi-Fi, advanced touch screen, Bluetooth 5.0 and NFC technology. In addition, they are equipped with high performing hardware components like triple shift battery, 8 core processor, flawless barcode scanning, hands-free proximity scanning mode to speed up normal picking operations. Being Android devices, they have also access to Google Mobile Services (GMS).

This was the most urgent project in the schedule because it was, actually, a backlog for the previous year. In fact, between 2017 and 2018, the Venaria DC bought from DSM Group, an information technology solutions provider, 20 next-generation handhelds called Zebra TC 8000, in order to start the upgrade of its fleet. But till March 2019 they had remained unused essentially because of a lack of expertise and know-how.

This stalemate situation was damaging the company both from the economic and operational side.

On the one hand, there was the need to amortize the cost of an investment done more than one year ago which was still not commissioned. But also, the company had to deal with the lack of maintenance support for the oldest models whose spare parts were out of production and the waste of time for the warranty of the new devices since they were not taking any advantage.

Furthermore, due to recent new hirings in the warehouse department, there could be a risk of a shortage of computer handhelds for managing warehouse operations. In fact, remaining with the same fleet of devices whose availability was decreasing, could have meant, in case of failures, being in serious troubles.

On the other hand, not commissioning TC 8000 would have also stopped opportunities for developing future "4.0" projects and technologies like E-tracking which was part of the 2019 Venaria Smart DC program and it will be further briefly described.

All these facts led to the conclusion that it was imperative to get the 20 TC 8000 in operations by the end of June in order to settle the budgetary issue, be ready for the pick of production and start-up further planned projects.

But in order to understand the scope of the project, there is another point to clarify.

In fact, the retirement of Microsoft's mobile operating system implies that, when replacing old handhelds with next-generation devices, such as in this specific case, it is necessary to migrate all Terminal Emulation (TE) apps to Android, the new enterprise operating system of the devices.

In order to simplify this issue, the Zebra devices have pre-loaded and pre-licensed All touch Terminal Emulation (TE) programs that allow, without any backend modification or coding expertise required, to easily turn the traditional Windows 'green screens' into interactive and intuitive touch screens.

The conversion and customization of the screens to enhance the TE app that manages warehouse operations in Venaria DC, with modern Android touch interfaces was the key goal of the project.

However, the project involved also the physical installation of these devices in the warehouse to get them fully in operation.

So to summarise, the project goal was carrying out the complete commissioning of 20 TC 8000 both by migrating the SAP Terminal Emulation app, SIM+, to Android and by managing installation on field of the devices.

5.2 Action plan

As seen the project goal is quite extensive not only in terms of tasks but also in terms of actors involved.

The players involved in this project are internal to the company but also employees of external companies regarding the IT part.

In particular, they were:

- Maintenance concerning the physical installation of devices
- Fujitsu the outsourcing company responsible for the functioning of the devices
- Capgemini the outsourcing company responsible for the WMS solution development.
- Methods for the working instructions
- DSM Group the smart solution provider which was involved for the troubleshooting.

When dealing with innovation projects with different external companies involved, the first difficulty is in the project definition stage because it is not always very clear the extent to which each part is responsible for.

Anyway, the project, as shown in Figure 58, was structured in 4 phases:

1. Mapping: concerning the massive screen conversion of SIM+ to Android touch interfaces and customization of keyboards.
2. Testing & validation: concerning verifying the correct functioning of the touch version of SIM+
3. Implementation: concerning everything related to the installation and commissioning of the 20 devices in warehouse operations
4. Follow up: concerning the monitoring of the outputs of the project.

The activities in red form the critical path.

As we can see from durations, the testing and validation phase was the longest one, as an indication of the importance of IT in the project. Despite some problems, the project was closed respecting the deadline.

ACTION PLAN INSTALLAZIONE TC8000								Durata progetto [gg]		93
Fase	Sottofase	Task	Data inizio	Data fine	Durata [gg]	Resposnsabile	Collaboratori	done	work in progress	to do
1	1	Traduzione massiva schermate registrate	04/03/2019	27/03/2019	23	Capgemini	Emanuel, Capgemini	X		
2	1	Fase di Test e perfezionamento progetto	28/03/2019	15/05/2019	48	Capgemini	Emanuel, operatori	X		
	3	Incontro con DSM Aggiornamento TC8000 #1	17/04/2019	17/04/2019		Emanuel	Manutenzione, Fujitsu, Capgemini, Team laders Metodi, DSM	X X X X X X X		
	4	Risoluzione anomalie tastiere	18/04/2019	08/05/2019		Emanuel	Team leaders, operatori, DSM	X		
	5	Aggiornamento TC8000 #2	17/04/2019	15/05/2019		Fujitsu	Emanuel	X		
3	1	Training capi turno + operatori	08/05/2019	09/05/2019	28	Emanuel	Team leaders, operatori selezionati	X		
	2	Training massivo operatori	13/05/2019			Team Leaders	operatori selezionati		X	
	3	Sistemazione carica batterie	16/05/2019	16/05/2019		Manutenzione	Team leaders	X		
	4	Sostituzione parziale terminali	17/05/2019	17/05/2019		Manutenzione	Emanuel, team leaders	X		
	5	Monitoraggio affidabilità TC8000	17/05/2019	23/05/2019		Emanuel	Emanuel, team leaders, operatori	X		
	6	Sostituzione Totale terminali	24/05/2019	24/05/2019		Emanuel	Fujitsu, Emanuel, team leaders, Manutenzione	X		
	7	Analisi supporti tc8000 sui mezzi	08/05/2019	09/05/2019		Manutenzione	Metodi	X		
	8	Controllo idoneità prototipo	17/05/2019	17/05/2019		Manutenzione	Emanuel, manutenzione, team	X		
	9	Installazione supporti	20/05/2019	05/06/2019		Manutenzione	Team leaders, manutenzione	X		
4	1	follow up funzionamento pistole	17/05/2019	05/06/2019	19	Emanuel		X		
	2	follow up regolazioni supporti	20/05/2019	05/06/2019		Emanuel		X		
	3	Aggiornamento istruzioni operative	17/05/2019	05/06/2019		Metodi		X		
	4	Chiusura progetto		05/06/2019	93			X		
5	1	studio applicazioni future					metodi, team leaders, DSM			

Figure 58 Action plan TC 8000 commissioning

5.3 Mapping

This phase was the most complicated because it involved the use of an emulation software that allowed to convert and customize the “black & yellow” screens into touch interfaces.

But in order to edit the screens, it was necessary to import them. The success of the project really depended on this task because if all the screens had not been converted, in the end, the operator would not be able to work because he/she could not interact with SIM+. In fact, if a screen is not mapped you can’t move the cursor and type anything, so you are unable to continue the transaction. In this phase it was fundamental the contribution of the SAP specialist in importing as many screens as possible by simulating all the possible transactions especially those concerning errors by the operator.

The mapping phase and the functioning of the software can be explained using as reference Figure 59.

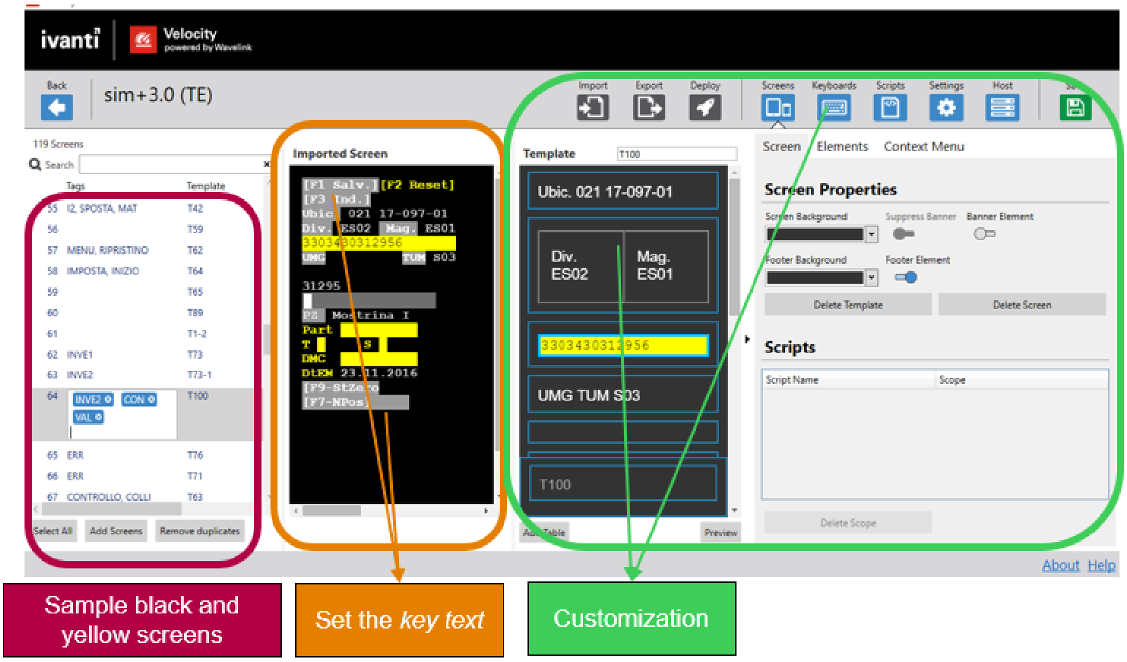

Figure 59 The mapping procedure

In input we have a sample of all the different types of analogical screens. Then by defining the key text for every screen, you set the match criteria that will allow to associate any related screen to that template. Finally, you can focus on customizing the templates.

The most important thing regarding the mapping process was understanding and establishing the matching criteria used by the software to convert automatically all the similar "black &yellow" screens into the template designed.

Once understood that the software uses key text as a matching criterion, it was sufficient to mark properly the key text of every analogical screen of the sample to get in output the right template representing that screen.

Once the screens were imported and matched, they could be converted. The emulation software basically allows to redesign the graphic layout of "black & yellow screens" into touch interfaces by adding for example buttons, menu, labels, dedicated keyboard.

Some examples of the result of the work done with the software are seen in the figures below.

For example, Figure 60 shows how a "black & yellow" screen representing a Menu, where the user had to type a number + ENTER to select an instance, was converted in a more user-friendly touch menu with the use of buttons. An important element that will be very useful in the test and debug phase was the label in the footer of each touch screen to identify immediately the problematic screen.

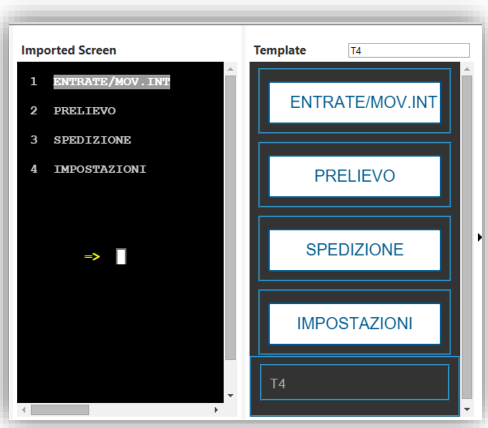

Figure 60 "Black & yellow" vs touch entry menu

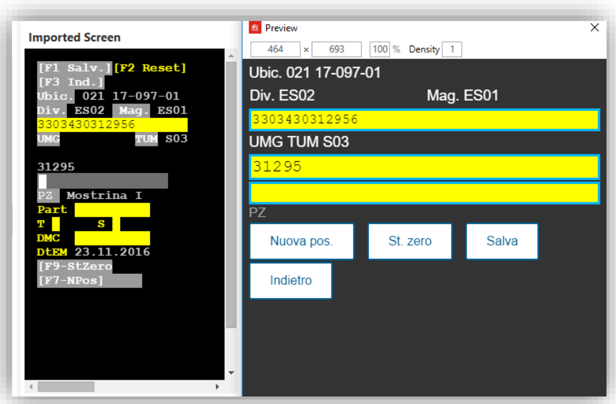

Figure 61, instead, shows again the use of buttons reproducing some function keys, but also how you edit screens by deciding what to display or not.

Figure 61 Personalized screen

Figure 62 instead is an example of the 12 personalized keyboards I created, that should appear according to the transaction the operator is working on. For example, if in an input field of a particular screen the operator should only type numbers then he will be showed just a keyboard with numbers and the allowed commands when clicking on that field.

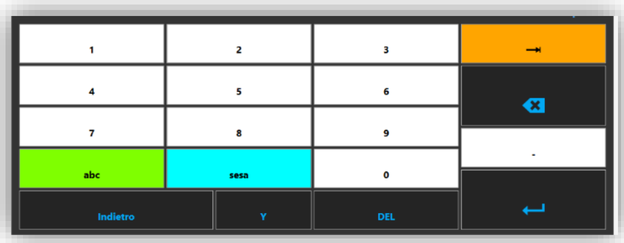

Figure 62 Numeric keyboard

The customization of keyboards was the most “value-added” functionalities of this software. In fact, the act of assigning the proper keyboard with only the allowed digitable keys to every input field would have made the digital experience of operators more friendly, especially for the new ones.

Figure 63, was the most favourite keyboard by the operators because it reported already all the possible container codes they should insert when creating a package, rather than recall them by heart.

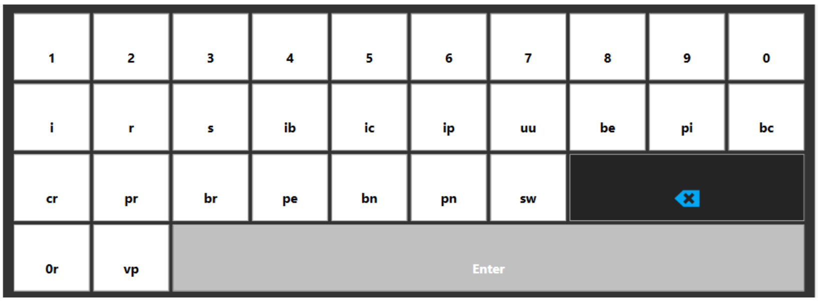

Figure 63 Containers code keyboard

5.4 Testing and validation

When you have completed the mapping phase, you have created the matrix of conversion for the migration of all the SIM+ transactions. So, you export all these settings in a file that has to be uploaded in the emulation app installed on the TC 8000. At this point, you ask one operator in the warehouse to run the program on one TC 8000 and to test and verify with him/her if all the screens and keyboards mapped are matching, if there are some mismatches or if there are some screens that were not mapped.

This is what testing and validation are all about.

In this stage was fundamental listening to the feedback of the operator in order to make some corrections or identify some problems.

The main problem reported by the operator was the reason why this phase was so long. Basically, operators reported that at a certain point, the app did not display anymore the correct keyboards for the specific templates.

In order to solve this issue, I tried in first person to understand the problem and with the help of operators and the TC 8000 seller we found out the cause of the failure. Essentially, it was a bag of the application and it could be solved, according to the software provider, by checking if with previous versions of the emulation app the problem disappeared.

After the trial of 5 versions, and two weeks of testing, finally, the problem was solved.

Therefore, at this stage, the task regarding the migration of the WMS TE app to Android was completed. It was then the time to think about the necessary measures to put in operation the devices not only for replacing the older ones but especially for creating future smart opportunities.

Regarding this last point, I thought it was important upgrading the devices from a Not Google Mobile Services (NGMS) software package to a Google Mobile Services (GMS) package enabling the Play Store and opportunities for developers. The NGMS version was a default version with only the Zebra applications and the Zebra app store.

Also, cybersecurity measures were taken. In fact, it was necessary to limit the access to the various apps of these handhelds which were similar to smartphones now.

So, I organized a workshop with the solution provider to arrange all 20 devices on these two points: GMS upgrade and installation of an access administrator application.

This ambiguity could become a critical factor especially in case of unforeseen events or extra workload because it could not be included in the contract so another offer would be required with a consequent waste of time.

5.5 Implementation

This phase consists of all the tasks related to physically install and use the devices in the warehouse. Regarding this matter, there are two main things that could be considered critical. The first one is the training to operators and the second one is the design and installation of mounting accessories suitable for the order pickers.

Given the criticality of the operation, it was decided to allocate the majority of the devices to the picking department and to give just one or two devices to all the other sector in order to get familiar with those.

But replacing, all at once, almost half of the old devices with next-generation devices could represent a problem without a minimum session of training especially because the technological attitude of the operators wasn't so high. So, in accordance with the team leaders it was decided to proceed gradually. In the first phase for sure team leaders had to be trained so that they could assist operators in case of need. Then, we decided to put in operation just 5 TC 8000 and encourage all 25 pickers per shift to try it for one day with the supervision of the team leaders. After one week, we collected the feedback and still some little adjustments were done. Finally, after team leaders' approval, the rest of the TC 8000 was installed.

About the mounting accessories, instead, I designed a prototype with Solidworks and since in the warehouse there was 3D printing it was decided to manufacture the accessories in this way.

In fact, this solution was more convenient than other offerings. The only drawback was time because it took about 8 hours to manufacture one piece. However, in two weeks all cases would have been installed on the order pickers, so it was acceptable.

In Figure 64 is shown the 3D view of the prototype. Designing the prototype was quite easy also because I took inspiration from the idea of one operator.

I just made some adjustments in terms of ergonomics.

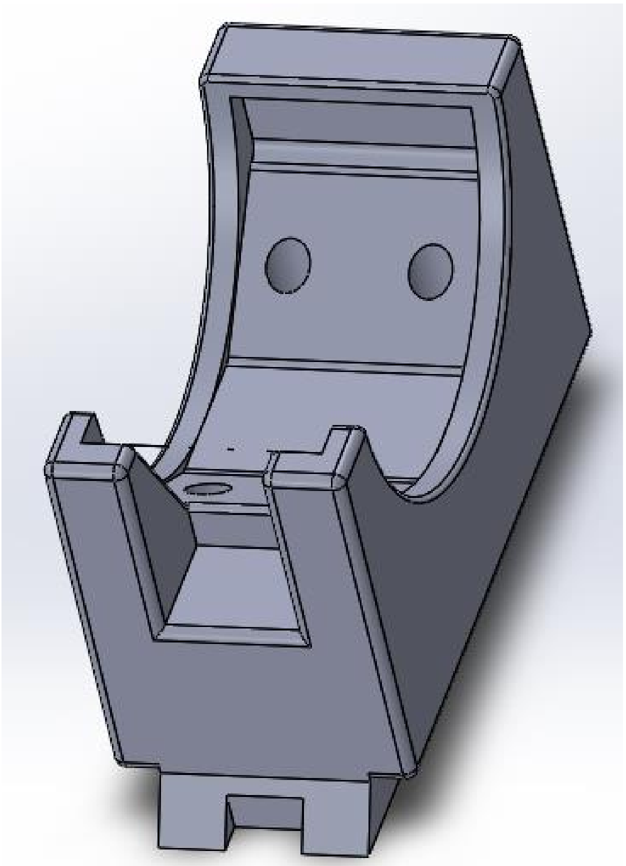

Figure 64 TC 8000 mounting accessory prototype

Figure 65 and 66 show the final result of the implementation phase.

Figure 65 Mounting accessory

Figure 66 mounting accessory-TC 8000

Before closing the project, I set a follow-up phase for a week to monitor the functioning of the TC 8000 and the production of the cases. Moreover, I realized a procedure to migrate future screens from SIM+ to Android.

5.6 Analysis of the improvement

This technological upgrade also brought some little benefits in terms of efficiency. In fact, TC 8000 handhelds were more performing in barcode scanning, more durable and more ergonomics than old devices. But also, the customization of screens and keyboards has allowed gaining some seconds per pick.

In the Figure below we can see the time spent to complete every instruction involving handhelds, before and after.

Numéro	Moyen utilisé	Code	As-Is Temps standard [s]	To Be Temps standard [s]
11	leggere sul palmare la prima ubicazione	HALC 3	5,34	3,81
12	appoggiare il palmare	HMAD F4	1,00	1,00
13	partenza con carico pesante	EDDC	3,00	3,00
14	spostamento tra ubicazioni	EDC	0,90	0,90
15	arresto con carico pesante	EDAC	3,00	3,00
16	prendere una scatola	HMAP F4	0,73	0,73
17	comporre la scatola (se nuova)	CRONO	15,00	15,00
18	applicare etichetta barcode su scatola	CRONO	3,60	3,60
19	prendere il palmare	HMAP F4	0,73	0,52
20	scanner etichetta barcode	HSCAN	2,00	1,00
21	appoggiare il palmare	HMAD F4	1,00	0,50
22	posare la scatola sulla pedana	HMAD F4	1,00	1,00
42	prendere il coperchio	HMAP F4	0,73	0,73
17	comporre il coperchio	CRONO	15,00	15,00
43	chiudere la scatola	HMAD F4	1,00	1,00
44	leggere sul palmare ubicazione successiva	HALC 3	5,34	2,21
45	**MONO:** alzare il carrello per picking alto	EOLC	7,00	7,00
46	prendere il palmare	HMAP F4	0,73	0,52
47	scanner codice prodotto	HSCAN	2,00	1,00
48	appoggiare il palmare	HMAD F4	1,00	0,50
49	movimento del corpo verso l'ubicazione	HDH	1,14	1,14
50	prelievo della scatola	HMPP 21	4,00	4,00
51	posizionamento della scatola sulla pedana	HMPD 21	3,00	3,00
52	prendere il palmare	HMAP F4	0,73	0,52
53	scanner etichetta barcode	HSCAN	2,00	1,00
54	applicare etichetta barcode su scatola	CRONO	3,60	3,60
55	conferma quantità sul palmare	HAC1	1,56	1,20
56	appoggiare il palmare	HMAD F4	1,00	0,48
57	abbassare il carrello	EOBC	6,00	6,00
58	scendere dal carrello	HDD	3,00	3,00
59	prendere il palmare	HMAP F4	0,73	0,52
60	scanner codice prodotto	HSCAN	2,00	1,00
61	appoggiare il palmare	HMAD F4	1,00	0,48
62	prelievo della scatola	HMPP 11	8,00	8,00
63	posizionamento della scatola sulla pedana	HMPD 11	6,00	6,00
52	prendere il palmare	HMAP F4	0,73	0,52
53	scanner etichetta barcode	HSCAN	2,00	1,00
54	applicare etichetta barcode su scatola	CRONO	3,60	3,60
64	conferma quantità sul palmare	HAC1	1,56	1,20
65	salire sul carrello	HDM	3,00	3,00
	Tempo ciclo [s/pz]		118,41	106,47
	Saving [s/pz]			11,94

Figure 67 As-Is vs To Be picking processing time

In the table below, instead, it is provided a brief economic evaluation of the immediate returns coming from the outcomes of the project. This economic evaluation takes also into account of the risk that this technological upgrade might not reduce the picking cycle time because there are operators which have not a technological orientation and so they work better with the analogic devices. In this case, it has been calculated by measuring some operators that the positive effects were balancing the waste in time of operators due to difficulties in managing the touch device, so the net time saved is 0. The probability of success in reducing the cycle time has been estimated counting how many operators are technologically skilled over the total. It is noteworthy the fact that the expected return of this investment is influenced also by the future outcomes of the smart projects that will be involving TC8000 devices, but at the moment they cannot be estimated.

Economic evaluation							
D_y	Expected items per year [K units]	1221,22					
ΔCt	Time saved per item [s/pc]	11,94					
T_y	Expected time saved per year [h]	4050					
ER_y	Expected return per year* [Euro]	36.453 €					
IC	Investment cost [Euro]	41.900 €					
$P_{success}$	Probability (ΔCt=11,94) [%]	70%					
$P_{failure}$	Probability (ΔCt=0) [%]	30%					
P	Periods in years [u]	5					
i	Discount rate [%]	10%					
Year		**0**	**1**	**2**	**3**	**4**	**5**
Discount factor		1	0,91	0,83	0,75	0,68	0,62
Undiscounted outflows		41.900 €	0 €	0 €	0 €	0 €	0 €
Undiscounted inflows			36.453 €	36.453 €	36.453 €	36.453 €	36.453 €
Discounted inflows		0 €	23.198 €	21.089 €	19.172 €	17.429 €	15.844 €
	Expected Net Present Value	**54.831 €**					

* ER_y has been calculated considering the minimum wage rate per hour established by law equal to 9 Euro

Table 33 Economic evaluation TC800 impact in picking process

5.7 Future states

This project was a milestone because it brought to a technological upgrade in the warehouse that would lay the basis for future innovations.

One of these innovations was already identified at the end of this project and consists of an app that allows the verbal communication between team leaders and operators in case of problems. This app could be installed on the smartphone of team leaders and on TC 8000 and will avoid the operator to go every time in the team leader office when he/she has to report something.

Being a pre-installed app in the devices I tested it to see if it was working but unfortunately there are some problems of protocols and capacity of broadband. Therefore, another project should be started for implementing this solution.

Another opportunity would be using the TC 8000 to do E-training and make available all the job breakdown sheets to the operators so that in case of doubt in some procedures they could have the answer on their devices.

Then, certainly, there is the Augmented Reality as a big opportunity for inventory management and receiving.

At the moment, the project dependant on TC 8000 commissioning was E-tracking.

Briefly, E-tracking is an application that should be installed on smart mobile devices used by pickers that calculates the theoretical time for completing the picking list and in case the effective time spent is superior to the expected one, it will display a drop-down menu where selecting the possible cause of delay. This application, when it will be in place, will be very important because it will allow giving more detailed insights about picking performance significant factors. E-tracking will help to understand how to design effective improvements in the picking area in order to speed up operations by giving immediate feedback on the effects of the action taken.

6 Conclusions

The two projects carried out during my internship are part of the Smart DC plan of the Schneider Electric distribution centre of Venaria.

A DC is conceived to serve the customers efficiently and meet their requirements sending to the right products in the right quantity, in the right place and at the right time. Its purpose is broader than simply store finished goods to create inventory after a production like classic warehouses.

Warehousing in DCs is based on seven processes that form a cycle. It begins with goods receiving which consists of unloading the trucks, control the quality of the cargo, labelling and sorting the unit lads. Then there is the put-away process where goods are put in the proper storage locations depending on the reference features. Picking is the most labour-intensive process and it is about fulfilling the customer order. Finally, there is packing and shipping. In case of errors there could also be the returns to manage.

The last frontier of warehousing is Smart DC which is the application of Industry 4.0 technologies in logistics. IoT solutions, big data and analytics, automatic identification technologies like RFID or VRT, Augmented Reality, robots and cobots are changing the paradigm of warehousing, increasing automation and reducing the impact of human labour. For example, Amazon with the Kiva system has automated the picking and put-away process moving from a picker to good logic to a good to picker logic. In Schneider Electric this concept is enriched with the implementation of smart solutions of its portfolio like the EcoStruxure technology.

After describing logistic operations in Venaria DC and the features of a Smart DC including Schneider Electric flagship DC, it is clear that the centre has still the characteristics of a traditional DC. This means that the environment is not yet completely mature for applying the technologies of a Smart DC because there are some gaps to close and requirements to be met.

The two projects are going to tackle some of these gaps for making Venaria DC leaner and potentially smarter in accordance with the goal of the implementation plan.

The first project points out that the lack of standardization impede any project of improvement because it is impossible to improve a process that is not under control and has no information or data for analysing it. For this reason, the ambitious Water Spider master project was confined, at the beginning, to the standardization of the consumable and waste management processes.

Despite the Schneider Electric philosophy of innovation is focused on “Think Big” when facing operational problems, standardization is always the first milestone to achieve; standardization is the baseline for continuous improvement.

Standardisation is about providing a clear work sequence of tasks to be performed in an efficient way specifying the time and the materials required to complete the process.

Standardisation is linked to reducing inefficiencies and waste. In order to achieve this, it is convenient to use structured and data-driven approaches like the PDCA method and keep in mind the lean principles like the 8 Mudas.

Through these tools, it has been possible to systematically identify the main criticalities, design and test improvement initiatives.

Generally, when approaching to continuous improvement it is useful to do a Gemba walk to see and understand in first person the entity of the problems to solve. This practice is crucial especially when data are missing because it allows doing a preliminary screening of the main criticalities of the process. However, data are essential for making decisions about what to improve and how, but also to understand if the improvement has been effective. Process mapping, Pareto chart, root cause analysis, paired sample T-Test are useful tools for this purpose.

The project contributed to reducing by almost 40% the consumable process operating time while providing standards in the way to perform the most critical activities. A work sequence of the main tasks has been defined specifying the frequency and the quantity of material to supply. In addition, a responsibility matrix clarified the involvement of every department in the activities of the consumable process and a flow chart formalized the most complex and critical activity of the process, pallet collection.

The time saved in the consumables management process was used by the Water Spider to do productive activities in the shorter term, while in the longer term will be used to perform the waste management process after it will be standardized. A good solution for integrating the two flows could be the introduction of sensors sending signals to the smartwatch of the Water Spider telling him which activity had the priority.

At the end of the project there were still activities to improve, for example, loading and unloading trucks were introducing a lot of variability because there was no scheduling for the consumables cargo arrival. It was necessary to plan specific arrival time slots in order to balance the daily workload of the Water Spider. Also, minor activities like the supply of labels, straps, ink, barcode labels needed to be measured and tracked.

While the first project made the DC leaner, reducing waste through standardization, the second one about TC 8000 commissioning would have turned the DC to be smarter.

In order to implement Industry 4.0 technologies like AR or IoT solutions, in Venara DC it was necessary to undertake a technological upgrade of the handhelds used to perform warehousing operations.

When passing from analogical to touch devices it is necessary to transform all the WMS apps interfaces into touch interfaces. To do that, I used an open-source software that allowed to redesign every interface adding graphic elements like buttons, customized keyboards.

This digital transformation made SIM+, the WMS app in Venaria DC, more intuitive and faster and allowed to reduce the cycle time for picking.

This project is an example of how leading continuous improvement projects requires transversal competences. If the first project was closer to my core competencies the second one was a little bit challenging because it was more related to IT aspects, I am not familiar to, but it also required project management skills in coordinating the tasks of everyone.

This project was a milestone for the implementation of E-Tracking. This app installed on these next-generation handhelds will calculate the theoretical time spent for picking and will compare it with the effective time providing a set of options for explaining the cause of delay.

These projects show the first step for a traditional DC to become a Smart DC is achieved standardization and technological adaptation.

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