POLITECNICO MILANO 1863

SCHOOL OF INDUSTRIAL AND INFORMATION ENGINEERING

Master degree in management engineering

Analysis, evaluation and selection of the WAREHOUSE MANAGEMENT SYSTEM in a manufacturing company

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ABSTRACT

The master thesis is strictly related to the analysis required for choosing and implementing a new Warehouse Management System in a manufacturing company. Nevertheless, the approach used is focused on the issues which characterized the firm, never taking for granted that the WMS was the unique solution to be applied.

The project behind the report is structured on the A3 Model, the problem-solving procedure invented and standardized by Toyota. This approach was studied during the Industrial Management course and deepened in the book: J. FLINCHBAUGH, "A3 Problem Solving: Applying Lean Thinking". In the first project phases, the company's inefficiencies in terms of time and money wastes were identified and quantified. Afterwards, different analyses were carried out to define the direct causes of the problem, the root-causes that implied the previous ones and, starting from them, the countermeasures required to solve the general issue. In the end, the process of implementation of the identified countermeasures took place. In this phase of the A3 model, the comparison between the offers of different suppliers was carried out.

However, some action plans, parallel to the WMS implementation, were defined and consolidated, because of their significance, even though the decision of implementing them is out of the project's borders previously defined.

In each case, software changes, hardware changes and managerial ones always imply the necessity to adapt the people involved in them. For this reason, also the human factor, related to how the work of operators and employees changed, is discussed.

In the end, also the future steps is defined. They consist in the selection of the optimal proposal for Yanmar and in the following collaboration with the supplier chosen in order to fit his product to Yanmar's needs; the implementation of the information software; the test phase and the training for the workers involved.

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EXECUTIVE SUMMARY

1.1 The company

Yanmar Co. is a Japanese diesel engine manufacturer founded in Osaka, Japan in 1912. Yanmar manufactures and sells engines used in a wide range of applications, including seagoing vessels, pleasure boats, construction equipment, agricultural equipment and generator sets. It also manufactures and sells agricultural equipment, construction equipment, climate control systems, aquafarming systems, in addition to providing a range of remote monitoring services.

1.2 The Problem

The planning and logistic processes within the company are characterized by long execution time, idle time and time wastes. This directly affects the total time needed to pursue the company's business, but also the quality of the work of logistics operators and white collars within the offices.

1.3 The Goal

The goal of the whole project is to further the above mentioned processes by implementing procedural, informative and equipment changes. In this way, the corrective actions will increase the performances of the existing activities, introduce some value-added activities and reduce the non-value-added ones.

1.4 The Analysis

In this phase of the project, all the logistic processes carried out within the company were analysed. In order to pursue these analyses, three methods were implemented. Indeed, data were obtained through Gemba Walk with the logistic operators, through interviews of both white collars and warehouse workers and from the IT department. In this way, the actual performances were qualitatively described and judged.

Once identified the inefficiencies which affect each process, the following step was the time loss quantification. The entity of each loss was computed considering it in absolute terms or comparing it with an optimum as-is situation. In this step of the analysis, for example, to quantify one of the most significant inefficiency, the Spaghetti chart method was implemented. This approach aimed to track the path of the logistic operator during the picking mission for setting up the kit used to assemble a specific kind of motor (named Power Pack). Through this method, it was clear that the worker in question retraces sections of the warehouse already travelled in the same picking mission. This implies a time loss compared with the scenario in which he travels an optimized path.

The following step consisted in transform the losses expressed in terms of time into monetary losses.

After the entire process of inefficiencies quantification, a Pareto Analysis was carried out on them.

In this way, the impact of the most effective money losses was visibile.

In the third step of the analysis, the first tool used is the Ishikawa Diagram, with a brainstorming that helps to identify possible causes. Then, with the help of the know-how of our company tutor and other company employees, the main causes were identified. After this, a further analysis was done with the Five-Why's method until the real root causes were found. The nature of the identified root cause is extremely different. For example, they range from the technical error in creating a picking list of a certain type of mission to the implementation of an incorrect refuelling policy. In the corresponding section, they will be precisely explained.

In the final step, specific countermeasures were defined for each identified root cause.

1.5 The implementation

After the phase of countermeasure identification, the phase of implementation started. Since several root causes are related among them, the large part of the defined countermeasures could be carried out through the installation of a new Warehouse Management System, which is the main topic of this project. For this reason, the first steps of this phase were preliminary investigations about the possible suppliers of this information system. In order to communicate and collaborate with them, it was necessary to conclude a list of standard requests (features already available in the actual WMS); non-standard request (all the other features desired); the interfaces that the WMS must have with the other information systems within Yanmar Italy.

INTRODUCTION

Yanmar Co. is a Holding diesel engine manufacturing Company with HQ in Osaka-City, Japan. Founded in March 1912 by Magokichi Yamaoka. He was a poor guy who grew up during the second industrial revolution. Magokichi worked for various companies carrying out tasks of different nature: from managing machines in a knitting to taking part in the realization of oil pipelines. In 1912, he had the opportunity to start his own business, so he decided to found a gas distribution company. Magokichi soon realized that gas engine repair was the most successful activity of his small firm. For this reason, he decided to make it the company's core business.

Figure 1 – Magokichi Yamaoka Yanmar founder

Nowadays Yanmar Co. is dislocated all over the world in 104 companies, concentrated on the large part in Europe and in the south of Asia with almost 20 thousand employees.

The net sales of the holding in the FY 2018 were 6.38 billion euros, the net profit instead was about 17 million euros.

The business domain of Yanmar Co. is divided into six different divisions: marine, agriculture, construction, component, power solution, energy system.

Concerning the vision of Yanmar, these are the most significant words of Magokichi: *“I want to reduce the burden of the common laborer with the power of machines"*

After founding Yanmar, Mr. Yamaoka saw the enormous potential of the diesel engine as a safe next-generation, labor-saving, power source that provided a high-energy conversion rate. He was able to notice that commercially available diesel engines of the time were large and were not suited to the unique demands of agricultural applications, which required further improvements in portability.

He threw himself into the task of reducing the size of the diesel engine for practical use, a feat that was technically difficult and, after many failures, he succeeded in producing the world's first compact diesel engine. This was his first step in bringing his vision to fruition.

The modern vision of the company is based on two main pillars:

1. **An energy-saving society**:
   Greater access to energy. Waste-free, safe and affordable heat, work and power, at any time.
   Solution: Yanmar strives to realize both a comfortable society and a reduced environmental footprint by developing highly efficient and highly safe engine technologies and systems that optimally leverage different energy sources.
2. **A society where people can work and live with peace of mind**:
   Relief from harsh working conditions. People earn a secure living in safe and fulfilling work and live rewarding lives in harmony with nature.
   Solution: With mechanization and automation technologies, which enhance productivity while reducing worker burden, technologies that improve the safety and operability of machines and vehicles and support infrastructure and urban development, we seek to establish a better environment for all.

Focusing on Yanmar Italy s.p.a, which is located in Cassano Magnago, Varese, it was established in 1996 and it covers an area of more than 9000 square meters including offices, warehouses and the production site. In this pole, more than 120 people work.

The product portfolio of Yanmar Italy is composed of six typologies of motors:

- Air-Cool Single Cylinder Diesel Engine (L-series)
- Water-Cool Multi-Cylinder Diesel Engine (Power Pack & Local Dressing)
- Water-Cool Multi-Cylinder Diesel Engine (TNV Series)
- Generators & Welder powered by L Series Engine (YDG & YDW)
- Outboard marine engine (D-Torque 111)

From a general point of view, Yanmar Italy produces motors assembling purchased components (buying them from Yanmar Co. or from other suppliers); sells motors (internally assembled or produced by another Yanmar manufacturing site); customizes standard engines. Yanmar Italy also produces generators: they are assembled starting from a Yanmar Series L engine. Yanmar Diesel Generators (YDG) and Neander (brand name of the D-Torque 111 and used to identify it) are the last to product inserted within the company portfolio. They represent the attitude of the company to target new market segments switching also from a Business to Business market to a Business to Customer one.

Figure 2 - L Series Engine

After this overall description of Yanmar Co. and of Yanmar Italy Spa, could result useful to introduce, from a general point of view the concept of WMS.

The WMS (Warehouse Management System) is a software system that has the task of supporting the operational management of the physical flows that passes through the warehouse, from the control of the incoming goods during the acceptance phase to the preparation of shipments to customers. The main macro-processes that see his intervention are:

- identification of goods in transit in the warehouse;
- reception and control;
- the management of Loading Units (for example, the assignment of a specific package to a collection pallet);
- planting in the locations;
- internal transfers and lowerings from reserve locations to picking locations;
- the management of the warehouse map (using, for example, the rotation of stocks to determine in which locations it is advisable to plant/pick up a specific item);
- picking;
- shipments to customers (in the meaning seen above);
- the preparation of inventories or, more generally, of statistics regarding stocks and flows.

This system must be able to interface with the company management system (the so-called ERP: Enterprise Resource Planning), which instead deals with the administrative management and therefore with the activities concerning the warehouse from an accounting, fiscal and commercial point of view. In addition to the ERP, the WMS must also be able to interface with the software used by any automated storage and handling systems within the warehouse.

The WMS cannot be seen as a perfectly replaceable commercial product: the choice and the subsequent implementation require a specific project, of a duration that is anything but negligible, which also incorporates the related purchase process (nothing prevents, however, from "building" the own WMS at home, in this case, however, the implementation and start-up times will inevitably be longer).

This project aims to incorporate the operating logic of the warehouse it will be called upon to support within the WMS. For this purpose, it becomes of fundamental importance to carry out the so-called "macroanalysis" phase, which consists of specifying in a document the User Requirements of the software, i.e. the functions that the user final of the WMS is expected.

Once the solution provider has been established, it will be necessary to carry out the so-called "microanalysis" phase with him, during which a complete review of the software will be carried out in order to customize it based on the specific needs of the Company, without however distorting it in the logic of operation.

The software architecture of a WMS is of the client-server type (in the most recent solutions it can also be of the web-server type). The WMS server is connected to a host and, at a lower level, to access points located inside the warehouse to allow information to be exchanged in real-time via mobile devices (radio frequency terminals, Wi-Fi devices capable of reading barcodes or RFID tags and communicating the information to carry out activities via video/voice technology).

Figure 3 - Warehouse Management System Network

As studied in the book: G. RICHARDS, "Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse"; the main advantages that can be achieved with the introduction of a WMS are:

- Optimization of goods handling times (e.g. possibility to manage goods with a specific logic, previously identified, LIFO, FIFO, FEFO etc.);
- Reduction of order fulfillment times (e.g. by determining and suggesting to the operator the withdrawal round to be made);
- Rationalization of spaces, thanks to the possibility of storing any item in any location without the danger of forgetting where the goods were stored;
- Reduction of recourse to the historical memory of the operators, in fact at any time it is known exactly in which location or area of the warehouse the goods are;
- Reduction of paper supports (e.g. the picking lists are displayed directly on the terminal without the need to print them);
- Increase in the productivity of the operators;
- Possibility of consulting the stock data in real-time;
- Possibility of having updated statistics on the functioning of the warehouse;

- Reduction of errors due to manual management, thanks to the confirmation of the operation, and therefore a reduction of the related hidden costs (e.g. partial or total failure to fulfil the order).

PROBLEM BACKGROUND

Observing the company processes from a general point of view, could result easy to understand that the information flow and the activities linked to the materials flow are not always fluid and efficient.

In particular, every kind of inefficiency spotted is linked to the planning&logistic department and to the accounting one both for what regards the work of the white collars within the office and for the logistic operators within the three warehouses of Yanmar Spa. Their activities, observed through an eagle watch and not only locally, are characterized by long execution time, idle time, repetitions and time wastes.

This directly affects the total time needed to pursue the company's business, but also the quality of the work of everyone.

Going into detail, it is necessary to state that the nature of the problem is almost entirely linked to the information systems of the company, which directly influences the process methods to be put into practice and the respective execution times. Indeed, the pivotal issue of the entire project is the Warehouse management system of which Yanmar disposes.

This does not exclude that inefficiencies with a different nature (managerial and technical) exist.

Solving all these time inefficiencies would represent an increase of the company performance and a time saving, of both logistic operators and white-collar, which could be reinvested in existing value-added activities or in new projects.

PROBLEM BREAKDOWN

The environment in which the problem takes place concerns the entire set of logistic processes of the company. For this reason, before going into detail with the description of the individual processes affected by the problem, it is useful to describe the material flows within Yanmar Italy Spa from a general point of view.

The firm disposes of three warehouses, two of them are intended to store components; the third, instead, stores finish products. The first components WH directly refuels part of the ground locations and the Lamp Guide shelves near the production line. This warehouse is called Surplus 1 (SP1). The second components WH is located 100 meters far from the production site and it is intended to refuel the SP1. This warehouse is named Surplus 2 (SP2). The Lamp Guide shelves instead are location characterized by sensors and light signals useful to support the picker during the setting of the kit required by the production line. During the picking, the location containing the required component lights up, the picker notices it, clicks a proximity button and withdraws the component.

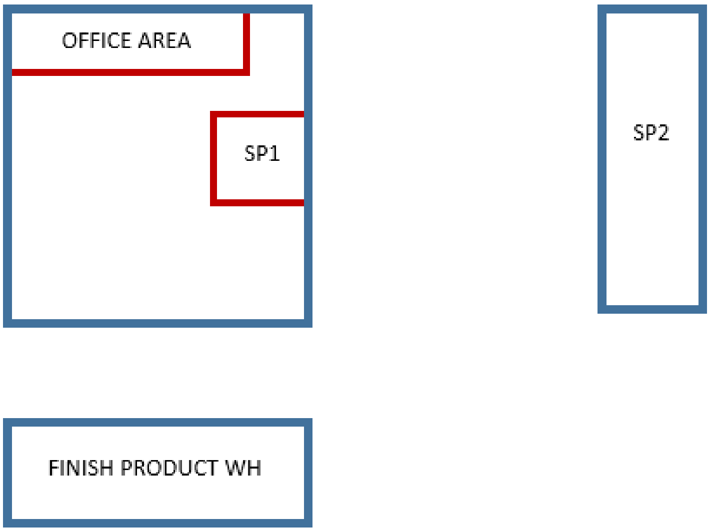


Figure 3 - Layout Yanmar Italy Spa - Scale 1:2500

Not all the components are stored inside the SP1, from a theoretical point of view only high volume SKU should be store in SP2, in practical terms also some components with small dimensions are stored in Surplus 2 because of logistic operators' habits and old incoming goods processes.

There are meanly eight different logistic processes within the company perimeter. They are divided in two different functional typologies: loading processes and picking processes.

For what concerns the loading processes they are typical of the kind of product interested (Series L, PP/LD, YDG, Neander)

LOADING PROCESS DESCRIPTION:

1) Loading process of Series L engine component:
    - Arrival of the carrier
    - Delivery notes check
    - Isolation of one pallet for each kind of product arrived in the WH
    - Moving of the isolated pallet to the quality control area (located within the factory)
    - If the goods passed the quality control check it could be directly used by the production line, it could remain in the Surplus 1 or it could be stocked in the Surplus 2
    - If the goods do not pass the quality control, the entire lot is rejected
    - Signature of the TD (Transport Document) / CMR (international transport document) and stamp of all the delivery notes, one per pallet (one per code). A copy of the delivery note is brought to the accounting department which loads it into their ERP (if it has already been uploaded into the WMS there is alignment). The other copy of the bills is sent back to the supplier attached to a copy of the TD
    - Photocopy of the delivery notes, one is for the QC
    - Manual typing of codes (which identifies the product) in order to load them into the WMS
    - Physical loading of goods on the shelves

    It is useful to specify that this process could be carried out both in the goods receipt area near Surplus 1 and in the receipt area of Surplus 2.

2) Loading process of PPLD components:
    - Goods receiving phase:
      Check delivery notes and check of goods consistency/integrity.
      Then the logistic operator brings the delivery notes into the office

- Access to WMS**:** selection of CKD icon, click on invoice; entry of day, month and year
- Upload of an Excel file received by mail from the planning and logistic department
- Loading unit creation and allocation of it in the 1800 cell in the WMS
- Printing of labels and placement of them on the packages
- Goods are physically taken in a fixed location
- Compaction of the goods stored from the fixed location to other locations in which this product is already stocked

3) Loading process of Neander and YDG components
   - Goods receiving phase:
     Check delivery notes and check of goods consistency/integrity.
     Then the logistic operator brings the delivery notes into the office
   - Access to WMS: selection of loading icon (one load for each chosen location)
   - Loading unit creation
   - Manual typing of the code which identifies the component to be loaded and the respective quantity
   - Printing of labels and placement of them on the packages
   - Goods are physically taken in the chosen location

4) Loading process of Finish Products (Bonded Warehouse)
   - Goods receiving phase:
     Check products integrity;
     The logistic operator brings the transit document to the office;
     Printing of labels with IM7 number (document required by customs rules) and placement of them on the package.
   - Up-load of an Excel file which is a pre-loading containing serial numbers, quantities
   - Access to WMS: searching of the pre-loading previously uploaded

- Scan of the barcode applied on goods through radiofrequency mobile terminals
- Loading unit creation
- Match between the serial number scanned and the ones reported in the pre-loading
- Loading of goods into the WMS
- Physical loading of the engines on the shelves

5) Loading process of Finish Products (nationalized)
   - Goods receiving phase:
     Check products integrity;
     The logistic operator brings the transit document to the office
   - Stock Upload of the WMS from the administration software (ACG and YGLS)
   - Scan of the barcode applied on goods through radiofrequency mobile terminals
   - Automatic loading unit creation
   - Loading of goods into the WMS
   - Physical loading of the engines on the shelves

Starting from the processes just described, would result easier to breakdown the problem for what concerns all the loading activities.

INEFFICIENCY 1: MANUAL TYPING OF CODES

The first inefficiency to be considered is the manual typing of code.

Before going into the detail of this time loss, it is useful to describe the typologies of code used by Yanmar Spa information system. The codes which univocally identify the components are alphanumeric and permanent. Indeed, once a component enters the company's data registry, a code is attributed to it and the following quantities loaded of these components will be recorded with the same code. Regarding finished products, the code is composed of the general model of the engine (first half) and a serial number (second half). In this way, the single motor is univocally identified.

During the loading of components which Yanmar Italy buys from a Local supplier (every supplier who is not Yanmar Co.Ltd. Japan), each code has to be typed manually in the radiofrequency terminals. Indeed, even if the package of the goods received has a label with the barcode of the code that Yanmar Italy has in his registries, often the mobile terminals are not able to scan it. It could not seem to be a trenchant inefficiency, but this situation implies that logistic operators have to use a very small keyboard to fill the voice "product" whenever they have to allocate a code to a location. In this way, could occur that a code is typed in the wrong way, so in future will be impossible to find it through the WMS, but only through the eyesight of the workers. The same happens with the entering of the quantity, but in this case, a wrong quantity entered will imply misalignment between the real stock and the WMS.

Another consequence that adversely impacts this loading process is the time directly required to press on the radiofrequency terminals about 15 digits instead of scan a bar code. Since the operation of loading a single pallet in a precise location is repeated approximately 35 times per day.

As shown in Table 1, this inefficiency affects the activities of two logistic operators. The first (DZ) manages the loading of Series L components which are sent by local suppliers; the second one (AL) instead, carries out the loading of YDG components. For both of them, the unitary loss is equal to half a minute, but the occurrence of the process to be carried out is different: (25 times a day for DZ and 10 for AL). As can be noticed in the higher part of the table, considering an hourly gross salary equal to 20 euros, the respective loss is equal to 4,2 and 1,7 euros per day. The lower part, instead, shows the errors which occur during an entire year caused by the manual entering of codes in the radio frequency terminals. An error committed implies the impossibility of the operators to find

Typing time	DZ	AL	Unit of m.
Average occurence	25	10	times/day
# of loading/year	6375	2550	
Unitary loss	0,5	0,5	min
Total loss	12,5	5	min/day
Daily monetary loss	4,2	1,7	€/day
Errors solving	**DZ**	**AL**	**Unit of m.**
Error Occurence %	0,5%	0,5%	
# of errors/year	32	13	
Total errors/year		45	
Error resolution		120	min
Total loss		5355	min
Monetary loss		1785	€
Daily monetary loss		7	€
Total annual loss		3080	€/year

Table 1 - Code manual typing inefficiency

a specific code required. Indeed, when a logistic worker types in the wrong way the digits of a code, the information available to the P&L department are different from the ones within the WMS. In this way, the picking list (created by P&L) become not executable. This kind of error occurs about in the 0.5% of the cases, data are shown in the managerial report of the company. This implies that on average the total number of errors committed in one year is equal to 45 (regarding the two processes taken into consideration).

Considering that, to solve a single error, about two hours on average are required (time necessary to find the missing components) the total monetary loss is equal to 1785€ per year (45 errors/year * 2 hours * 20€/hour).

Enlarging the focus to all the inefficiency the annual monetary loss is equal to 3080€ (1785€/year + (4,2+1,7) €/day * 5 days/week * 48 weeks/year).

INEFFICIENCY 2: BLUE BOXES

The second inefficiency, related to the different loading processes, regards the components of Neander engines (Outboard Marine DTorque 111). This activity relies on the replenishment of particular containers named blue boxes. Two boxes for each code are located near the production line; when the operator, assembling the motor, totally consumes the components within the first one, he takes it and poses it in a bigger wood basket. A logistic operator each day picks up this crate and brings it to the external components warehouse (Surplus 2). Over there he scans the QR code behind each box to be refuelled identifying the code to pick from the WH's shelves. The inefficiency occurs because some of these components have very small dimensions so, even if the consumption is very high, the rotation index of the package is contrarily very low. For this reason, all the pieces required to cover the internal demand for the next months could be in the box remained near the production line. Due to this fact, the MRP does not impose the necessity to send a new order to the supplier of the component considered. The logistic operator has not all this information and so he alerts himself starting troubling in search the missing code. In particular, he consults a very rarely updated file with the stock of the

Figure 4 - Blue Boxes

blue boxes codes extracted from the management software (ACG). Obtaining this info, AL can understand if the missing code has been recently ordered and so the required pieces are near the production line or if an error was committed and recovery actions have to be carried out. The overall time required to perform this check is on average equal to 20 minutes (precise average computed on 15 measurements during the Gemba Walks: 19 minutes and 32 seconds). The occurrence of this inefficiency is equal to 10 times per month (considering the month composed of 22 days).

So the annual monetary loss related to this waste of time amounts to 727 €/year. Indeed: Daily loss = 20 minutes * 10 times/month * 20 €/hour / (60 minutes/hour * 22 days/month) = 3.03 €

Annual loss = 3.03 €/day * 5 days/week * 48 weeks/year = 727 €

PICKING PROCESS DESCRIPTION:

1) Picking process of Series L engine component:
   - Delivery of a paper list of the requested codes
     (request to check of other code's stock)
   - Access to WMS:
     entering to the picking section
   - Picking number creation
     Picking list creation
   - Codes within the picking list removed by WMS (once for all codes through the selection of all the picking rows)
   - Physical picking of the codes

2) Picking process of PowerPack/Local Dress components:
   - Delivery of a paper list of the requested codes
   - Useless picking rows deleting
   - Barcode scanning
   - Code's location reached by the operator
   - Picking from the WMS of the specified quantity
   - Physical picking of the code
   -

   } Steps repeated for each rows within the picking

3) Picking process of Neander components
   - A shop floor operator throws the empty blue boxes into a wooden basket
   - A logistic operator brings the crate in Surplus 2
   - Access to WMS
     Scan of the QR code behind each blue box
   - Code's location reached by the operator
   - Physical picking of the code
   - Picking from the WMS of the specified quantity
     from the workstation

   } Steps repeated for each blue box to be refuelled

4) Picking process of Finish Products (nationalized)

- Sales contract delivery
- Access to WMS:
  Picking list creation starting from the sales contract received
- Selection of the picking list from the WMS of the workstation among the ones not yet fulfilled
- unloading of the entire list from the WMS
- Physical picking of the codes

INEFFICIENCY 3: NOT OPTIMUM PICKING PATH

The first inefficiency related to the picking processes regards the picking path, which is not optimum. Indeed, during the fulfillment of the picking missions, a part of the distance covered is avoidable. In particular, the picking of the components within the warehouses Surplus 1 and Surplus 2 are the processes in which this situation was spot. Going into details, the first process regards the kitting of PowerPack/LocalDressed motors. This picking takes place in the Surplus 2 whose layout was digitally recreated in an Excel file. In each mission are unloaded from the shelves all the components within the bill of

Code	Lane	Shelf	Ground	Distance travelled (m)	Distance cum (m)
119515-13200	3	3	1	12,62	12,62
119515-77900	7	19	2	38,66	51,28
119626-77220	5	1	1	29,88	81,16
119717-13110	3	3	2	10,48	91,64
119717-13550	7	26	1	46,12	137,76
119717-13600	3	3	2	46,12	183,88
119717-44740	3	1	1	2,48	186,36
119740-13100	7	6	1	18,84	205,2
119740-42350	6	16	1	32,36	237,56
119740-42290	11	7	1	28,74	266,3
121520-34820	3	3	2	18,74	285,04
129E00-13610	8	25	2	47,36	332,4
Centre	0	0	0	46,12	378,52

Table 2 - Travel distance computation

materials of the engine which has to be assembled by the dedicated workstation in the manufacturing site. Interviewing the logistic operator in charge to fulfill these missions (BD), very long execution times were noticed. For this reason, to deeply analyze the phenomenon, a Spaghetti Chart was carried out. The study had as object the picking of the twelve components of a model 4TNV88-BDYE2 engine. In the table below are shown the codes which identify univocally the components. In the other columns are reported the coordinates of the location in which the single code is sited, then the distance travelled to reach it during the picking mission. The first distance corresponds to the path required to reach the location of the first code starting from the centre of the warehouse. All the picking missions of this kind start from this point. It is shown in the last row because at the end of the picking mission BD comes back to it.

On the last column is reported the cumulated distance travelled during the process, so the last cell is the total path covered. In absolute terms, considering the not so wide area in

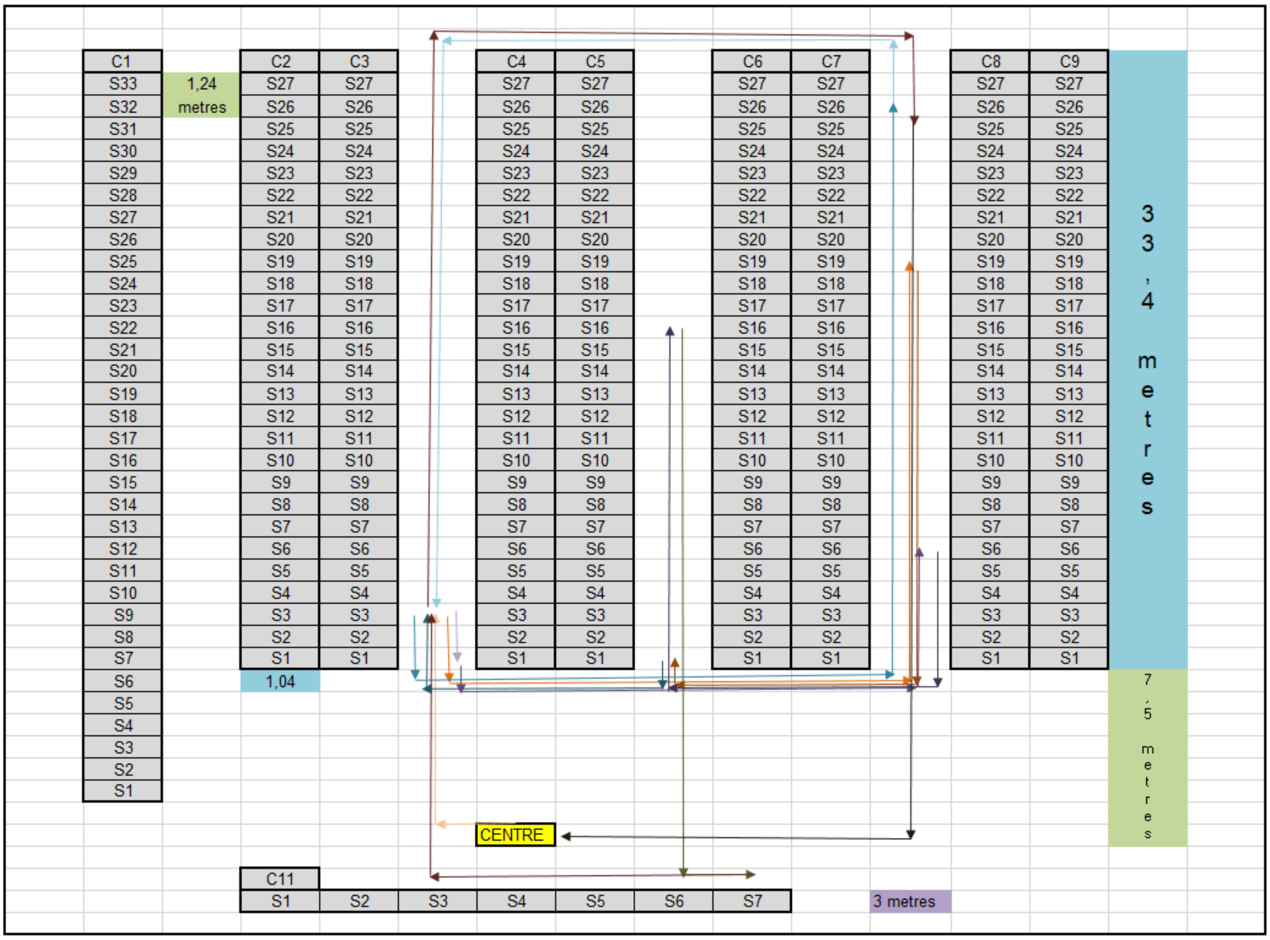


Figure 5 - Spaghetti chart on a sample mission

which the picking takes place and the low number of codes to be unloaded, a distance of almost 400 meters to be covered represents a waste of time. In Figure 5 the Spaghetti chart mentioned above is shown. As spotted from the overall analysis, the length of the total distance is not optimum because during the mission the same path is travelled more than once. The same analysis was repeated for all the assembly kit picked during the fourth week of July (from 20^{th} to 24^{th}). In that week, BD was supported by the work of another logistic operator (AL) on Monday and Thursday. As the following step, the process was measured also in temporal terms. It was deduced that the lead time can be split in a fixed part and in a variable one. Moreover, the percentage partition of these two components is not the same for the different kinds of engine. After this deep dive analysis, a registry with the percentages of fixed and variable time was created. The variable part of the lead time is strictly related to the distance travelled and to the speed of the forklift. Nevertheless, also the time spent to fulfill the different missions was every time measured and not computed from the speed of the forklift, which was not constant during the entire process. In conclusion, results that in order to pick the components of a single kit (often they are prepared more than one simultaneously) an average time of 26 minutes is required.

INEFFICIENCY 4: AUTHORIZED REVISIONS

The second inefficiency is linked to the picking process of Neander and YDG components and it regards the authorized revisions. Some Yanmar's suppliers have in their portfolio products with serial revisions: each engineering change implies a revision that will be identified with the code of the "father" plus two final digits. Instead, Yanmar generally manages the revisions as completely different SKUs. This because often they imply changes in the type of components with which the item revised is assembled. This misalignment results in mistakes made by the suppliers who send indifferently (often without specify the final digits) one of their revisions even if Yanmar has requested a specific code. When the wrong code arrives in Yanmar, the logistic operator cannot spot the mismatch, so he loads in the shelves and in the WMS the codes received. However, the problem arises when a picking list containing the precise code never arrived has to be fulfilled. At this moment, the error has to be rebuilt and the production has to adjust the bill of materials to make fittable the component ordered.

To manage this kind of emergency more or less an hour is required (average of 58 minutes based on the 5 measurements).). The occurrence of this inefficiency is equal to 3 times per month (considering the month composed of 22 days).

So the annual monetary loss related to this waste of time amounts to 640 €/year. Indeed:

Daily loss = 58 minutes * 3 times/month * 20 €/hour / (60 minutes/hour * 22 days/month) = 2.64 €

Annual loss = 2.64 €/day * 5 days/week * 48 weeks/year = 633 €

INEFFICIENCY 5: PAPER PICKING LIST

The third issue linked to the picking is related to the lists. Within Yanmar Italy, they are in the large part of the processes paper made. This is the main characteristic that affects their efficiency. The negative aspects of the paper are several. Firstly, it slows down the info flow because time is lost in printing and bringing it to the first operators who, if necessary, delivers it to a second one. Moreover, they can be physically lost both before and after the fulfillment of the mission to which the list is related. In the end, they are not a useful tool for the WMS which cannot exploit the info contained to speed up and optimize the picking process. In the following analysis is considered as time-loss all the time spent in managing paper lists in the different processes.

Paper picking lists					
Picking Process	Unit of m.	Creation	Printing	Delivery in	Delivery out
Series L comp.	minutes	5	0,2	0	10
YDG comp.	minutes	5	0,2	5	10
PP/LD comp.	minutes	10	0,2	5	10
K0 expedition	minutes	10	0,2	5	5
Total time	minutes	30	0,8	15	35
White collar time	min/day	45,8			
Operator time	min/day	35			
Total loss	€/day	31			

Table 3.1 - Paper Picking lists

Specifically, these losses can be divided into those related to the creation, printing and delivery of the lists and those related to the use of them within the warehouses. In the table above, data referring to the quantification of the first type of wastes are shown. The phase of creation consists in consulting the necessary info from the managerial software (ACG for Neander and YDG components; YGLS for the others) a convert them into an Excel file with a precise structure. The last two columns of the table respectively refer to the time required to bring the paper picking list from the office to the Surplus 1 centre workstation (delivery in) and from there to the warehouse where the picking process takes place (delivery out). In order to compute the time spent within the office, the first three columns have to be added, obtaining total daily time dedicated by the white collars involved. The delivery out phase instead absorbs logistic operators' time. Considering an hourly cost equal to 20 €/h for the manual workers and 25 €/h for the employees, the total daily loss is equal to:

45.8 min/day * 25 €/h / 60 min/h + 35 min/day * 20 €/h / 60 min/h = 30,75 €/day

Therefore, the annual loss will be equal to: 30,75 €/day * 5 days/week * 48 weeks/year = 7380 €/year

Regarding the second part of this inefficiency, three different logistic operators are involved. The first one (BD) carries out the setting of the kitting for PP/LD engines, the second one manages the YDG components picking and the third picks up the Series L components' pallets.

Paper picking list in the WHs				
Voice	Unit of m.	BD	AL	DZ
Unitary loss	min	2	2	2
Occurence	times/day	5	4	2
Total loss	min/day	10	8	4
Hourly cost	€/hour	20	20	20
total loss	€/day	3	3	1

Table 3.2 – Paper picking list

In all three cases, the main time losses are linked to the fixing of the paper to the forklift and, after the physical picking, to the inserting of the list in a ring binder (used as archive). The total daily loss is equal to 7 €/day, so the annual loss is 1680 €/day (7 €/day * 5 days/week * 48 weeks/year). Aggregating the computations proposed, the total annual loss linked to the paper-made picking lists amounts to 9060 €/year.

INEFFICIENCY 6: WMS/YGLS NOT ALIGNED

The following wastes of time regard more than one process that takes place within Yanmar Italy. Due to the computer nature of these issues, the inefficiency could be identified as the missing alignment between YGLS and WMS. In order to fully understand the logic behind the problems proposed, it could be useful to introduce the main structure of Yanmar's information system.

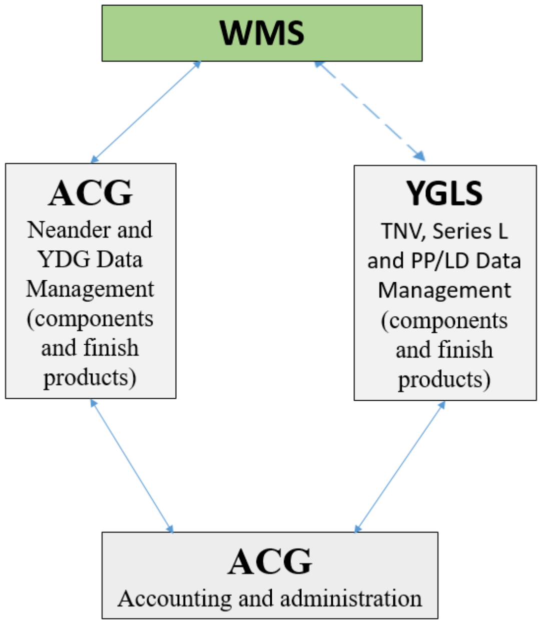


Figure 6 - Yanmar ERP

Yanmar's ERP is based on three different layers:

- ACG an accounting and administration software belonging to the TeamSystem holdings (ACG is the name both of the company and of the software solution offered)
- Another computer package of ACG that manages data related to Neander marine engines and YDG (generators). At the same level, there is another software: YGLS. It manages data referring to TNV, Series L and PP/LD engines. Both these two software contain data not only of the finished products but also of the components.
- On top of the structure the object of the project: the WMS. The link between the WMS and YGLS is outlined because the interfaces, which allow the connection, do not exist. Moreover, there is not the predisposition to install them. Instead, regarding ACG, the predisposition just mentioned exists, but not the concrete interfaces.

Coming back to the inefficiency before introduced, it is necessary to underline that the misalignment between WMS and YGLS is structured on four different wastes of time:

1. Use of pre-loadings and pre-delivery notes. A pre-loading is a list of engines that have to be stored within the finished product warehouse. This kind of digital document is used only for customs loading. Indeed, due to the in-force strict rules, each movement of each serial number has to be traced. The logistic operators (AA and GC) cannot load the motors received by the vector, because the WMS does not recognize the code attached to the engines' package. For this reason, a white-collar in charge of the customs warehouse (PG) has to upload the pre-loading in the WMS making the software able to accept the load of the just arrived engines. The concept of pre-delivery notes is very similar to the pre-loading one. Indeed, PG has to create a list containing the precise serial number of the engines required by certain customers. Without the upload of this file in the WMS, AA and GC can't unload motors from the shelves because they do not know which serial numbers have to be picked up. The annual loss is shown in the table, the computation has made considering an hourly cost of 25 €/hours for 5 days/week for 48 weeks/year.

Pre-loadings and pre-delivery notes		
White collar	PG	
Unitary loss	15	min
Occurence	0,6	times/day
Daily loss	9	min
Annual loss	900	€

Table 4.1 - WMS/YGLS not aligned

2. Necessity of a stock upload of the finished products. When the logistic operators have to store nationalized (not custom) engines, if the WMS is not predisposed, it will reject the attempt to load the motors. For this reason, the white-collar has to update in the WMS the engine stock previously downloaded by the YGLS software. The latter is already updated because contains the info related to the corresponding delivery note. In this way, the WMS will recognize

Up-load		
White collar	PG	
Unitary loss	15	min
Occurence	0,2	times/day
Daily loss	3	min
Annual loss	300	€

Table 4.2 - WMS/YGLS not aligned

the serial numbers of the motors received and the upload in the software will be possible.

3. Missing Upload. The issue just described absorbs time not only due to the computer process to be carried out, but also in the occurrence in which this upload is missing. As mentioned before the logistic operators, who manages the finished product warehouse, cannot load the shelves before the predisposition of the WMS, so happens that their activities remain in deadlock. Only one at the time of the two operators is involved in this process so, in the computation, values have not to be doubled. The annual loss is computed considering 5 days/week for 48 weeks/year.

Missing Upload		
Log. Operator	AA/GC	
Unitary loss	180	min
Occurence	0,2	times/day
Daily loss	36	min
Annual loss	3600	€

Table 4.3 - WMS/YGLS not aligned

4. The last part of this inefficiency involves the quality control department. Specifically, the QC makes requests that cannot be fulfilled. They consult info related to the received goods from the digital document inserted in YGLS software. However, this data does not yet describe reality; in this way, the QC falls in finding an already stored batch. The annual loss is computed considering 5 days/week for 48 weeks/year

QC has wrong info		
QC operator	RL	
Unitary loss	60	min
Occurence	0,2	times/day
Daily loss	12	min
Annual loss	1200	€

Table 4.4 - WMS/YGLS not aligned

Considering all the four components of this inefficiency, the total annual loss can be computed: 900 €/year + 300 €/year + 3600 €/year + 1200 €/year = 6000 €/year

INEFFICIENCY 7: WMS/ACG NOT ALIGNED

This inefficiency is very similar to the previous one. Indeed the nature of the problem is the same: a misalignment between the WMS and the managerial software. In this case, the information system under inspection is not YGLS but it is ACG. The latter contains data related to the receiving, the storing, the movements, the expedition and the accountability of Neander and YDG's components and finish products. Moreover, the quantification of the monetary loss is the same; however, the occurrence of the phenomena is different. As for the previous computations, was considered that the hourly

WMS/ACG not aligned				
	Pre-loadings/Pre-del. notes	UP-load	Missing upload	
Worker	PG	PG	AA/GC	
unitary loss	15	75	30	min
Occurrence	0,6	0,2	1	times/day
Total daily loss			16,25	€/day
Total annual loss			3900	€/year

Table 5 - WMS/ACG not aligned

cost of a white-collar is equal to 25 €/hour (PG), the hourly cost of a logistic operator is equal to 20 €/hour (AA/GC). In the end, the annual loss is computed considering 5 days/week for 48 weeks/year. Comparing the last two very similar inefficiencies could be spotted that, for what concerns the misalignment between WMS and ACG, the issue that affects the quality control does not exist. During the Gemba walk, the operators of the QC department were repeatedly questioned about this fact. Their explanation was based on two argumentations: the number of codes and batches managed by ACG is lower and the changes in the list of free pass code (products that bypass the QC by default) are rarer. These two factors bring the occurrence almost equal to 0%.

In the end, further observation can be done. The time required to carry out the upload from ACG to the WMS is higher than the one necessary from YGLS. After a more precise analysis, was inferred that the nature of ACG, intended as software, makes more cumbersome the download and the upload in the WMS, even if it was installed within the ERP more recently than YGLS.

INEFFICIENCY 8: WMS SP1/WMS SP2 NOT ALIGNED

Briefly summing up, in Yanmar there are two different components warehouses, the first one (Surplus 1) located near the production line, within the main building perimeter; the second one (Surplus 2) sited 100 meters away supports the first one. LM, logistic operators of the SP1, manages the goods required to be fulfilled by SP2. He prepares a file composed of three pages, the first two pages contain all the codes to be brought in SP1, the third instead reports one or two components not yet under the reorder point but near to it. This situation is managed through the expertise of the operator, his purpose is to check the stock in SP2 of the under investigation codes, to avoid emergencies during the following days in which the specified components will go down the threshold. Indeed DZ, the logistic operator of the SP2, withdraws the entire list, reads the codes of the third page and starts checking the stock in the SP2's WMS. After this process, DZ communicates the results of the check to LM not in a precise moment, but in the first casual meeting. As can be understood, this procedure, anything but standardized, implies significant wastes of time that are reported in the Table 6. The annual loss, based on a total daily waste of 15 minutes is computed considering 5 days/week for 48 weeks/year. It is necessary to add that this situation affects the quality of the info flow causing a not quantifiable damage neither in terms of time nor in terms of money. However pursuing the lean philosophy, has to be considered as an issue to be solved. Indeed, as explained in the book J. P. WOMACK, D. T. JONES, "Lean Thinking: Banish Waste and Create Wealth in Your Corporation", the continuous improvement is one of the three main prerequisites on the Lean Thinking (with standardization of the work and Heijunka). This philosophy was at the base of the analysis carried out during entire project and not adopted only for this inefficiency.

WMS SP1/WMS SP2 not aligned			
Logistic Operator	DZ	LM	
Unitary loss	7,5	7,5	min
Occurence	1	1	times/day
Daily loss	7,5	7,5	min
Total annual loss		1200	€

Table 6 - WMS SP1/WMS SP2 not aligned

INEFFICIENCY 9: RANDOM ALLOCATION OF GOODS IN THE WAREHOUSES

During the loading process both in the SP1 and in the SP2 the choice of where store the received goods is completely managed by the logistic operator who is carrying out the activity. In particular, they do not follow a specific logic; they identify an empty location and load in it the pallet that they are moving. The inefficiency occurs during the loading but affects the picking making it longer to be carried out if compared with a structured disposing logic of components within the warehouse.

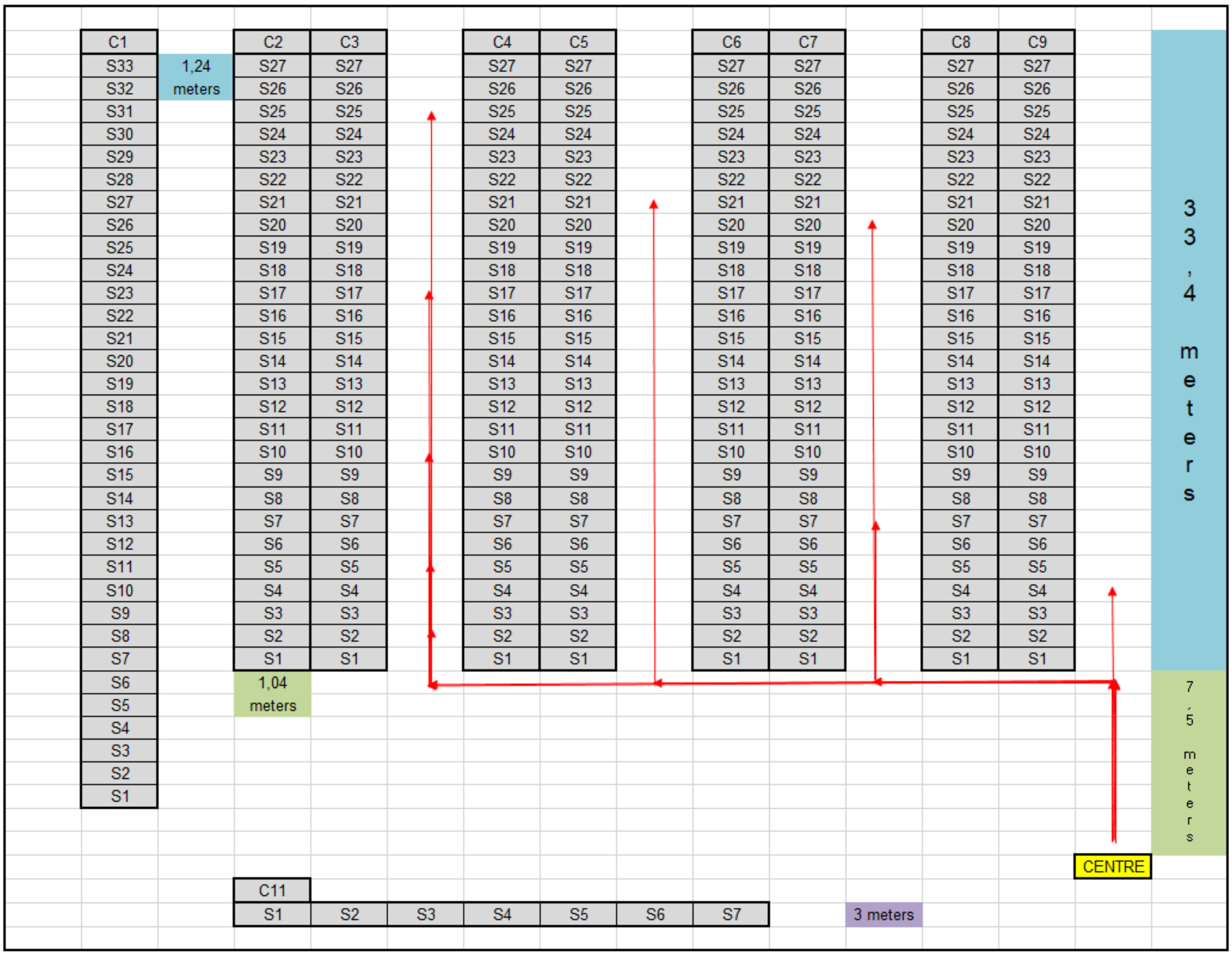


Figure 7 - Random products allocation

The figure above reports a layout of Surplus 2. The red arrows correspond to the path required to load and then pick a sample of nine codes. The processes analysed are related to the components of the Series L engines.

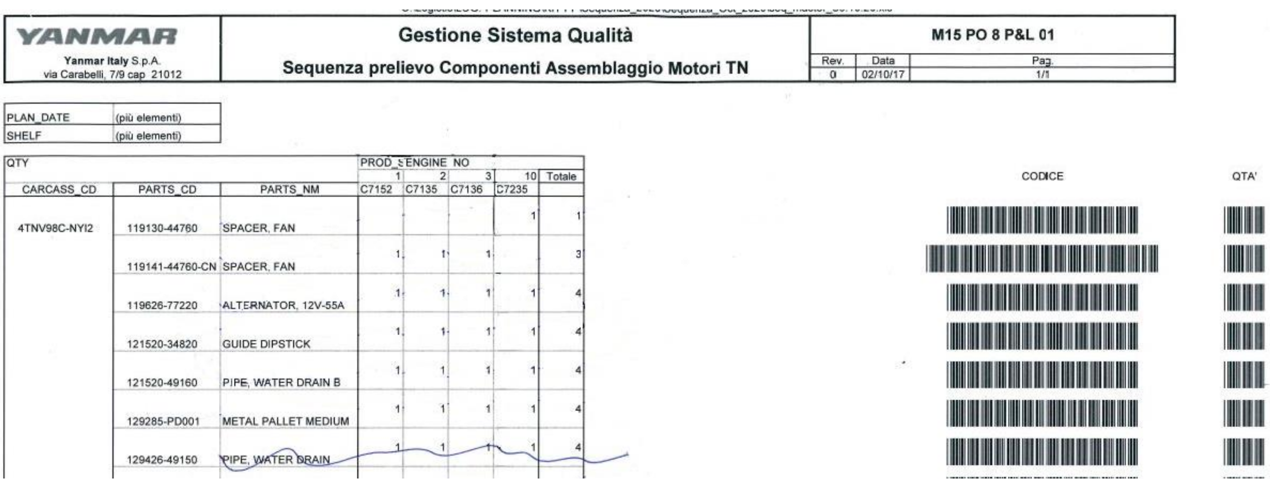
Location			Path (m)
Lane	Shelf	Floor	
4	10	4	33,6
10	4	3	11,8
6	21	2	42,2
3	17	6	42,3
7	7	1	21,3
3	2	6	23,7
8	20	2	37,4
4	5	5	20,0
4	25	3	52,2

Table 7 - Sample location

The logistic operator engaged (DZ) manages only entire pallets of the same code, the forklift, according to the company policies, can move at most one heavy pallet at a time. For this reason, every time a pallet is loaded or unloaded, the worker comes back to the centre of the mission, which does not coincide with the centre of the entire warehouse, as for the last layout proposed, but it is on the right low area. From the Spaghetti chart, can be inferred that the random allocation of goods implies a long picking/loading path to be travelled. This stretches the time required and creates waste. In order to quantify the loss in monetary terms, should be set up a comparison with an optimum scenario in which an allocation logic is in force. However, it will be possible only in the countermeasure identification phase. In Table 7 are reported the specific location attributed at the codes of the sample, each location is univocally identified by three coordinates: lane, shelf and floor. Observing the path results that almost 600 meters (comprehensive of forward and backward) are necessary to stock or pick up only nine codes.

INEFFICIENCY 10: PICKING ROWS DELETING

This inefficiency regards the picking process of the kit for the PP/LD engines. As we can see in the figure below, a picking row has been deleted manually with a pen. This does not mean that the row has been fulfilled, but that the component taken into consideration


YANMAR
Yanmar Italy S.p.A.
via Carabelli, 7/9 cap 21012

Gestione Sistema Qualità
Sequenza prelievo Componenti Assemblaggio Motori TN

M15 PO 8 P&L 01

Rev.	Data	Pag.
0	02/10/17	1/1

PLAN_DATE	(più elementi)
SHELF	(più elementi)

QTY			PROD_ENGINE_NO				
			1	2	3	10	Totale
CARCASS_CD	PARTS_CD	PARTS_NM	C7152	C7135	C7136	C7235	
4TNV98C-NYI2	119130-44760	SPACER, FAN				1	1
	119141-44760-CN	SPACER, FAN	1	1	1		3
	119626-77220	ALTERNATOR, 12V-55A	1	1	1	1	4
	121520-34820	GUIDE DIPSTICK	1	1	1	1	4
	121520-49160	PIPE, WATER DRAIN B	1	1	1	1	4
	129285-PD001	METAL PALLET MEDIUM	1	1	1	1	4
	129426-49150	PIPE, WATER DRAIN	1	1	1	1	4

CODICE
QTA'

Figure 8 - PP/LD components picking list

is not stored in the warehouse in which the process is carried out. Indeed the refuel logic of some codes is different. In this specific case, the component 129426-49150, a water pipe, has a ground-location near the assembly bay in which PP/LD motors are realized. This location is refuelled with KIPPU logic only by the SP1 (strategy explained below). Nevertheless, this info is not available to the logistic operator, so he loses time in searching the code through the radio-frequency terminal, checking that it is not stored in the SP2, deleting the referred picking list.

The occurrence of this phenomenon varies from 2 to 5 rows in each list. The picking lists of this kind, fulfilled by the logistic operator are 75 per month. The time necessary to scan, check and delete is equal to about 36 seconds (10 measurements done during the Gemba walks). Considering an average value of occurrence for each list equal to 3,5 ((2+5)/2), can be computed that the annual loss is:

3,5 rows to be deleted/list * 75/22 lists/day * 36/3600 hours * 20 €/hour * 5 days/week * 48 weeks/year = 573 €/year

INEFFICIENCY 11: DOUBLE IM7

The IM 7 is a document in which are reported the specific serial numbers of the engines that have to be stored in the customs warehouse. The customs trading of a motor allows the payment of the duties and VAT after-sale; in this way, it is necessary a smaller investment for its purchase and the company liquidity is minimally affected.

To describe this issue, an event that happened during the project is proposed.

On 13/07/20: a GDL courier has arrived. Usually, the logistic operators have to unload from the vector engines belonging to the same CKD (container). In this case, it was a normal truck containing motors belonging to two different invoices. However, this information was not directly visible to AA and GC, who paradoxically should check the serial numbers, one by one, comparing them with the serial numbers contained in the pre-loads already uploaded in the WMS. It happened that they scanned the engines from the first to the last without bringing the TR to the cradle (action required to fulfill the custom loading); in this way, the WMS considered everything as a single non-existent pre-loading. Naturally the WMS' matching attempt failed. As a result, all the records scanned from the beginning of the process were lost and the loading had to be doing all over again.

This kind of inefficiency occurs once a month and absorbs on average one hour, considering a work cost of 20 €/hour the annual loss is equal to 218 €/year (1/22 hours/day *20 €/hour * 5 days/week * 48 weeks/year).

INEFFICIENCY 12: WMS BREAKDOWN

On 21/07/2020 the WMS was completely unusable. Events like this happen once a year. The inefficiency consists of the impossibility to carry out any type of operation that involves the WMS. The unit loss is equal to 240 minutes. So the annual loss is equal to 80 €/year (240 minutes/time * 20/60 €/hour)

TARGET SETTING

Subsequently, to have identified and quantified twelve inefficiencies, it is necessary to set a target that can be reached once the project is completed. However, two of the issue above explained cannot be traduced in monetary terms. Indeed, in this specific step of the model, possible countermeasures were not yet developed. Because a comparison between the AS-IS situation and the TO-BE one cannot be carried out, a possible money-saving cannot be sized. These inefficiencies are the random allocation of the SKU within the warehouses and the not optimum picking path, all the other problems amount to a total annual loss equal to 23791 €/year. Starting from this info a “must-have” and a “nice to have” target was set.

- Must-have: elimination of the 40% of the monetary loss (involving the not yet quantified part)
- Nice to have: elimination of the 80% of the monetary loss (involving the not yet quantified part)

Often the link between non-value added activities and a monetary saving is not so concrete.

Nevertheless, in Yanmar, the team of logistics operators is very flexible. Indeed, each operator can perform the tasks of the others in almost completely interchangeable ways. For this reason, the company's top management can evaluate whether to reduce the total number of workers in the warehouses.

Furthermore, Yanmar is always performing an enlargement of the firm’s portfolio, pursuing this approach the trading business can increase. Indeed, without overloading the production capacity of the plant, the workforce, released by reaching the target, can be channeled into the logistic management of other engine lines.

ROOT CAUSE ANALYSIS

The Root-cause Analysis is a method of problem-solving useful to identify the most upstream cause of a problem. Removing it prevents the problem from recurring. To make the analysis more visual, there is a tool called Ishikawa Diagram that graphically shows all the original causes. Then, each potential cause could be traced back to find the Root-Cause, using the Five Whys technique.

As explained in the first part of the report, the analysis is focused on the identification of the causes that imply time losses and inefficiencies in the company processes.

For each of the four frameworks in the Fishbone (Management, Man, Machine, Method, and Measurement) different causes were identified. This phase exploited brainstorming as the main tool, in particular, was considered each info obtained from the office and from the Gemba Walks.

The result is shown in the next figure:

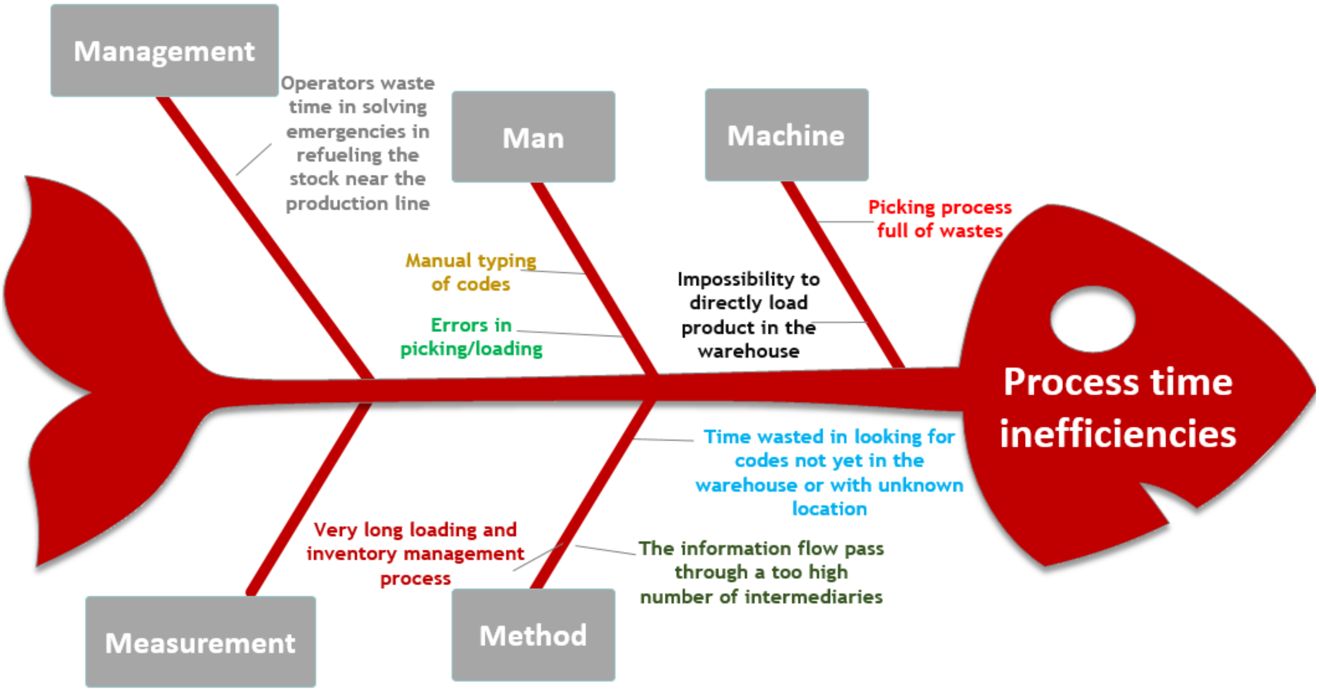


Figure 9 - Ishikawa Diagram

Starting from the left, the first framework analysed is the one referred to management. Problems may derive from incorrect managerial choices taken by the white collars of the company. Going into details, only one cause was identified within the management boundaries:

- The stock near the production line is consumed by the assembly operators. The replenishment of the components used by them is based on a KIPPU logic. This strategy implies that a Kanban label (named KIPPU) is inserted between the packages on the shelves. When the operator, consuming the component, notices that the KIPPU came at the shelving board, the label is withdrawn from the location and brought back together with the number of packages indicated by itself. The quantity to be refuelled is fixed at the beginning of the fiscal year basing on the forecasted demand and reported on the kanban labels. In other words, a KIPPU is a physical reminder of the Reorder Point. However, due to the demand variability, this logic could result too much static. Indeed, at the end of the work shift, happens that there is yet one package before the KIPPU, so the stock is not refuelled, this implies an emergency in the following day.
  This dynamic characterizes also the goods flow between SP1 and SP2 even if the replenish logic is not based on KIPPU but on a reorder point strategy. If the stock of a code is near the threshold and, imminently, the production line is going to consume it, an emergency will occur.

"Man" is the second framework of the analysis. It is comprehensive of all the causes directly related to human attitude and error. Two causes were identified within the Man boundaries:

- Manual typing of code. As explained in the problem breakdown, logistic operators have to type manually the codes which identify the products within the WMS. This situation directly affects the efficiency of the overall company both stretching the logistic processes lead time and causing errors due to the wrong typing of codes. To have more precise information; it is suggested to consult the inherent problem breakdown section.
- Errors in picking and loading. As in each activity, wrong execution could be carried out. Indeed can occur that:
  - a code is stored in a location different from the one typed in the WMS
  - the code entered in the WMS is wrong (previous cause)

    - the quantity entered in the WMS is wrong (both in the picking and in the loading process)
    - the picked product is wrong

The third framework regards "Machine" causes. The causes within these boundaries refer to the "physical" characteristics of the tools necessary to fulfill the different logistic processes. Two causes were identified:

- Picking process full of wastes. The computer nature of the WMS implies following precise and cumbersome procedures that directly affect the process lead time of the processes considered.
- Impossibility to directly load products in the warehouse. Once again, the WMS has a control tool that could consists also in a structural hurdle: it needs to be predisposed for the loading of new serial numbers. Without this predisposition, engines cannot be stored in the finished product warehouse. Also for this cause, it is recommended to consult the inherent problem breakdown section.

The last framework is related to the "Method". In its boundaries are contained all the causes which refer to a wrong process. Three causes were identified:

- Time wasted in looking for codes not yet in the warehouse or with an unknown location.
- The information flow passes through a too high number of intermediaries. In the large part of Yanmar's processes analysed, information required never gets directly to the person or system that needs it. This means that the information flow is characterized by non-valued added rebounds.
- Very long loading and inventory management process. Both two procedures are cumbersome due to different reasons. The first one will be better analysed subsequently in the Five Whys Analysis. The second one instead is referred to a specific phenomenon named compaction. It consists in moving components already stored from their location to another one in which the same code is loaded in higher quantity. In this way, a single product does not result scattered all over the warehouse in different locations. The purpose of this procedure is value-adding, but it becomes necessary downstream an inefficient activity: a not optimized loading process.

To carry out a more precise and deeper investigation about the causes that imply wastes of time, the Five-Whys method could be applied. Indeed, starting from the direct causes identified with the Ishikawa diagram, the casual-effect chain could be built to find the root causes for each inefficiency. The method was implemented six times, not on all the causes, but only on the more complex ones.

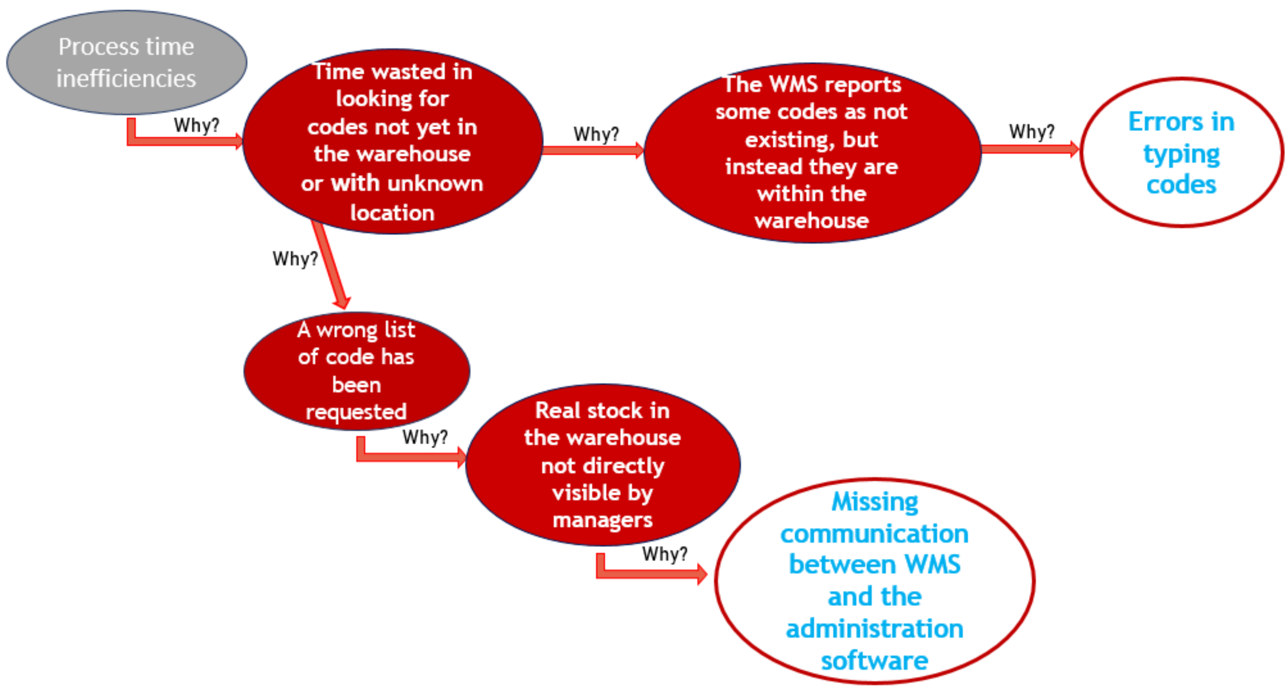


Figure 10 - "Method" Cause 1

The first cause investigated belongs to the Method framework, it regards the time inefficiencies implied by the search of codes doomed to failure (Figure 10). Indeed, in this case as previously explained, the wanted products are not yet in Yanmar's warehouses, or they have an unknown location. This happens because of two reasons. Or a wrong list of codes has been requested or the WMS reports some code as not existing, instead they are within a warehouse. The first reason refers to each picking list that is fulfilled in any logistic process, they often are created by a white-collar within the office who could not realize that what he is asking has no sense, not because of him, but since the real stock in the warehouse is not directly visible by managers.

This situation is implied by the final root-cause, which consists in the missing communication between the WMS and the administration software. So the branch in the lower part of the above figure is completed. Coming back to the other branch, the root cause of not existing but requested codes are implied by the errors committed in the typing of codes during the loading phase.

Applying this method, a direct cause was exploded with the aim of finding the root one. However, it has been ascertained that the latter is another direct cause.

The second "Method" cause is related to the loading process from a general point of view. As already described, it is affected by different wastes, the causes of them are two. The

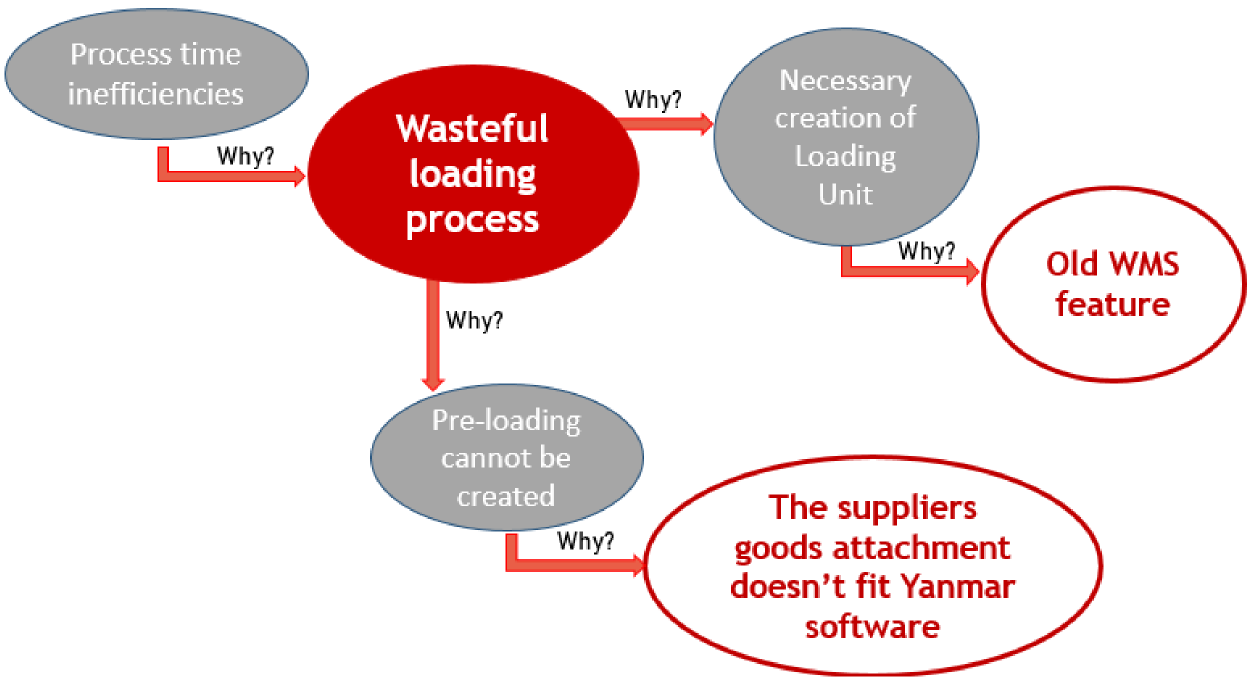


Figure 11 - "Method" Cause 2

first is the impossibility to create a pre-loading in each occasion. A pre-loading always significantly reduces the process lead time. Indeed, the operator can carry out the computer procedure once for the entire document and not one for each product.

In turn, a pre-loading cannot be always created because the suppliers' attachments do not fit Yanmar ERP. Indeed, a pre-loading takes origins from a specific file format managed by Yanmar Japan, the Head Quarter creates and sends a “tailored” Excel file which can be read by Yanmar Italy’s WMS.

The second cause of the wastes in the loading process is the necessity to create a Loading Unit. It is a digital container in which codes are located. It can contain only one code (single-code) or more than one (multi-code). Each loading unit is assigned to a physical location and subsequently can be moved to another one. This computer entity has to be manually typed every time a loading process is done, so the lead time results a little bit stretched. The necessity to create the LU in this way is an old WMS feature (root cause).

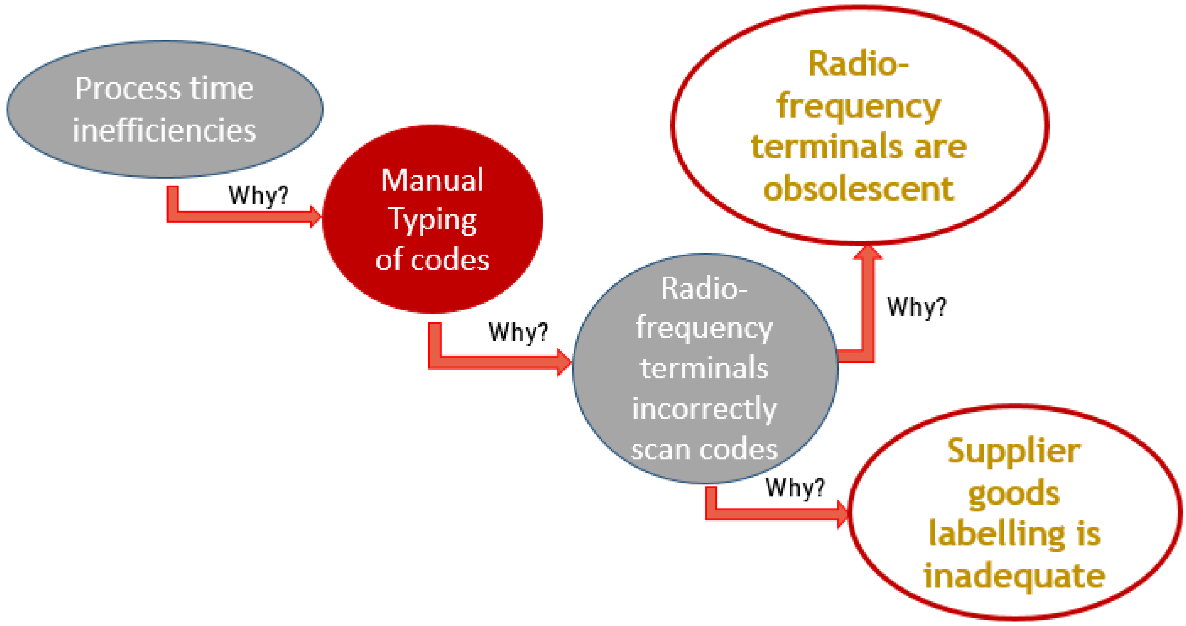


Figure 12 - "Man" Cause

This cause belongs to the “Man” framework. How it affects Yanmar’s logistic process, has been precisely described in the problem breakdown phase.

Codes are manually typed in the Radio-frequency terminals because the latter are not able to correctly scan them from the packages.

Proceeding with the method implementation, the last Why was exploded in other two causes.

The first one refers to the age of the hardware; indeed the radio-frequency terminals are obsolescent. The second one instead regards suppliers. Each not Japanese company which satisfies Yanmar's requirement attaches a different kind of label to packages sent. The large part is inadequate to be scanned.

Figure 13 represents the cause-effect chain of the issue belonging to the management framework. The situation in which logistic operators wastes time in solving emergencies linked to the replenishment of the stock near the production line is implied by two different reasons.

The first one directly regards the assembly line. Indeed, happens that the materials required by the production are not available to the assemblers. Proceeding on this branch of the graph, the root cause identified consists in a strategy based on minimum stock value as reorder point.

The second one reason engaged the info flow between the two warehouses in which components are stored. As explained in the previous part of the work, logistic operators within the SP1 often need to consult the stock of the SP2 and the only way to do this is by sending an info request to another logistic operator. This procedure is without a doubt non-value-added very time absorbing.

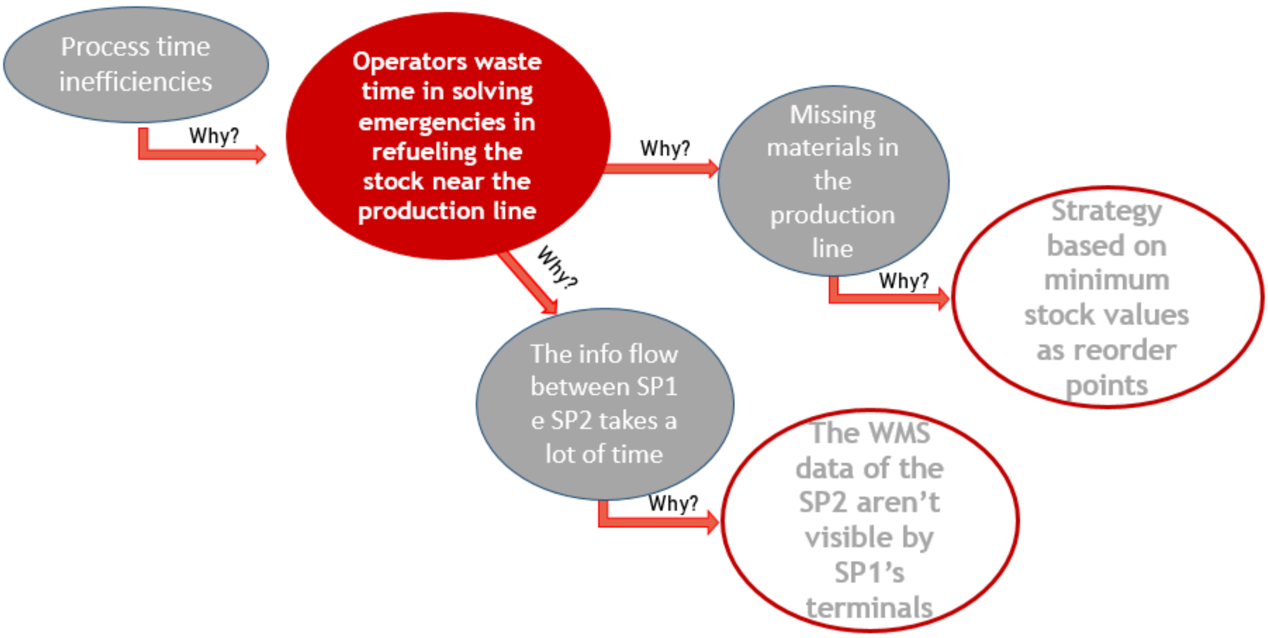


Figure 13 - "Management" Cause

The cause behind this phenomenon is simply related to the fact that the fixed location of the SP1's WMS does not allow the user to view the stock of the SP2.

The next issue investigated is the first linked to the machine framework. On the first level of the Five-Whys explosion, three direct causes were defined:

1. Some picking rows have to be deleted: in the kitting of PPLD the picking list used is not adequate, as already explained in the problem breakdown section. The root cause of this branch is that the logistic department falls in creating the mentioned picking lists.
2. Long picking path of each mission. In turn, it is caused by two other reasons, the first one regards the random logic with which components are stored during the loading process; the second one is about picking rows that compose the picking list. They are not ordered basing on the location of the single code, but randomly.
3. Codes have to be scanned to carry out the picking in the WMS. This action could be value-adding if exploited to check the achievement in picking the correct SKU and not to find the location (AS-IS situation). This happens because picking lists are paper made and because they are generated in the office, they have no info related to the locations.

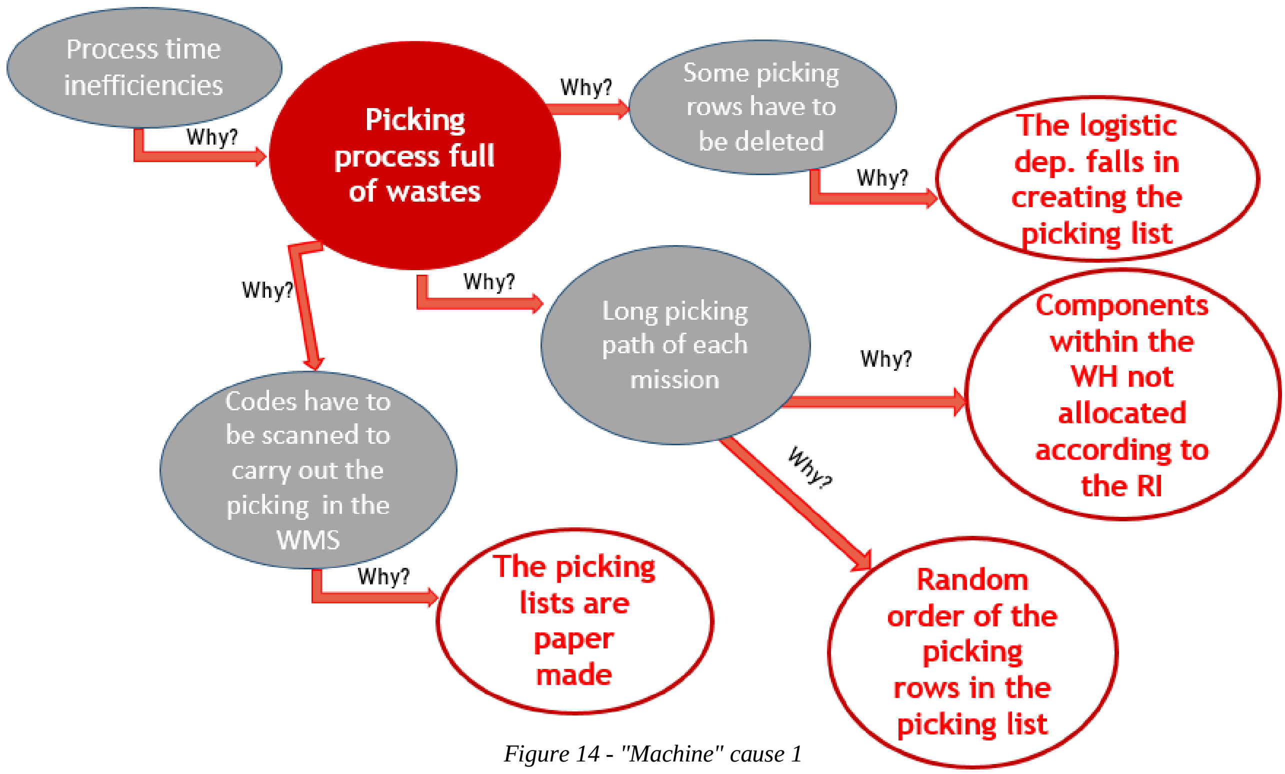


Figure 14 - "Machine" cause 1

The last cause investigated belongs to the “machine” framework. It consists in the impossibility to directly load product in the warehouse. The main reason that implies this situation is the absence of the upload on the WMS of the stock downloaded from the administration software. It is necessary in order to make the WMS able to accept the loading request by the operators. In the last phase of this analysis, two root-causes can be identified. The first one is the missing communication between the WMS and the administration software (phenomena already faced up) the second is the too high workload assigned to a single with-collar of the Planning&Logistic department.

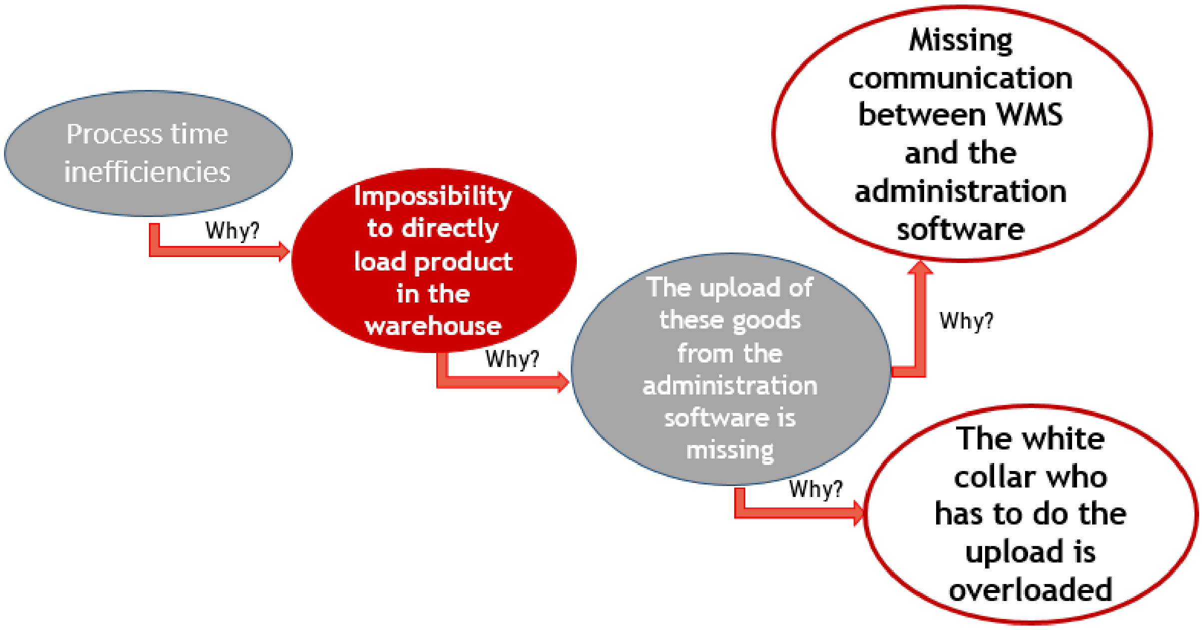


Figure 15 - "Machine" cause 2

DEVELOPING COUNTERMEASURES

The fourth step of the A3 model is the development of countermeasures. In this phase of the project, specific countermeasures have to be defined starting from the root-cause previously identified. Developing them, it is necessary to never forget the link with the inefficiencies. Indeed each corrective action proposed has to reduce the impact of an existing issue or to eliminate it totally.

Therefore, for each countermeasure proposed will be reported the root-cause from which it takes origins, the inefficiency solved and the monetary saving obtained.

COUNTERMEASURE 1: NEW PDAs

The first countermeasure implies a hardware change; indeed, PDA means Personal Digital Assistant. In particular, logistic operators generally use two kinds of hardware in order two interface with the WMS. The first one are fixed locations in which the WMS software is installed on a normal computer. The second one instead are the radiofrequency terminals (PDAs) that are mobile tools able to scan barcode and directly modify WMS data sending info through radiofrequency.

Figure 16 – Radiofrequency terminal

There are different companies all over the world that supply this kind of product. The actual devices are produced by this firm and the feedback of the operators is negative. For this reason, the idea is to close the partnership and to opt for Zebra's products which are the most diffused.

Going into detail, the new PDAs have to be able to scan each type of alphanumeric code of a maximum of twenty digits. Furthermore, a minimum 4 inches touchscreen is suggested and the keyboard must have large buttons to be used also with work gloves (it could seem a not significant detail but it represents a source of errors and discomfort). In figure 16, an example of an adequate terminal. Comparing this product with actual ones, a relevant difference emerged: on each Datalogic's device is installed the WMS software, the new Zebra's, instead simulate it through a virtual machine. This implies two benefits: higher performance because the PDA's RAM is always available and lower cost of maintenance (if a device is replaced it will not be necessary to contact the WMS' supplier for a new software installation).

COUNTERMEASURE 2: PRE-LOADING GENERATION

The second countermeasure modeled regards pre-loadings. As explained previously, they are Excel files generated by a P&A employee in the office. These files are then shared in an online folder and uploaded in the WMS by the logistic operator. Nowadays this time-saving procedure is carried out only for the loading of customs engines and for the loading of components arrived from Japan (CKD and not Local).

There are two possible solutions useful to extend the use of pre-loading to any process that needs it:

- OCR technology (Optical Character Recognition) would make the logistic operator able to create, from the delivery note, the necessary Excel file. The implementation of this countermeasure would change the work of the logistic operators, enlarging the number of their ordinary tasks.
- Implementation of a new WMS able to extrapolate this excel file from the delivery notes without the work of the logistic operator. To implement this feature is necessary to create an interface between the WMS and the ERP. In this situation, an intermediary would be bypassed both respect to the AS-IS scenario and the scenario in which the other solution has been chosen. Indeed nobody would have to elaborate the delivery notes or any other info managed by the administration software to obtain the pre-loading.

The driver, that can guide the choice of which solution adopt, is the cost of the second option. This kind of software interface could result very costly. In one of the following countermeasures, it will be more precisely described.

COUNTERMEASURE 3: SHARED REGISTRIES

The third corrective action proposed consists in a collaboration project with the suppliers. The hypothetical agreement aims to adapt Yanmar's registries with the suppliers' ones. The positive effect would be the elimination of the misunderstanding related to the revisions. Indeed, the Japanese company does not consider this concept distinguishing always revised SKU in a completely different one (inefficiency explained in the dedicated section)

COUNTERMEASURE 4: ONLINE STOCK VISIBILITY

Besides, the fourth countermeasure is linked to the implementation of a new Warehouse Management System. Going into detail, each computer (fixed location, one in any warehouse) must have online access also to the stock of the other warehouses within the company perimeter.

In this way, the info flow lead time would significantly decrease. Indeed the word of mouth necessary to align the different logistic operators can be eliminated.

Coming back to the inefficiency that will benefit from this feature, the info request sent by the SP1 workers could be substituted by a simple check on his terminal.

A further positive effect that can pour out on the logistic processes regards the MRP. Indeed the white-collar of the Planning&Logistic department (FF) periodically does checks of the real stock. In the AS-IS situation, FF has to call on the phone one of the SP1 logistic operators and ask for a research in the WMS. Implementing this countermeasure, also this info flow will be shortened.

COUNTERMEASURE 5: REQUIREMENT BASED LOGIC

Is useful to remind that Surplus 2 replenishes Surplus 1 through a reorder point logic. Indeed, more than one time per day, LM extrapolates from the WMS the SKUs with the stock under the reorder point, he crosses them with the entire list of components managed by the SP2 and he infers the products to be required. As already described, the AS-IS situation implies saturated storage capacity and emergencies. Indeed, due to the variability of the production mix, could occur that goods brought in SP1 are not necessary to the production for months or that, tomorrow, an SKU, the whom stock is over the reorder point, will be consumed much more than the available quantity.

For this reason, the fifth countermeasure proposed regards the adoption of a different replenishment logic. The stock of the SP1 could be replenished with a requirement base logic in order to guarantee the necessary stock for refuel the production line in the following day.

It is necessary to underline that this countermeasure is out of the borders of the project requested by the company. Nevertheless, from a lean philosophy point of view, it should improve the logistic performance of the firm reducing wastes. For this reason, it is already proposed to the top management and deep-dive analysis will be carried out in future.

COUNTERMEASURE 6: NEW PP/LD PICKING LIST GENERATION

The picking list of PowerPack and Local Dress engines is created in the Planning and Logistic department within the office. It is hastily generated considering the entire bill of materials.

However, as reported in the correspondent inefficiency, some SKU should not be included for different reasons.

Regarding a possible solution, the in-charge white-collar should change his procedure excluding the picking rows related to components not to be picked from the list. In practical terms, she should cross the output of the old process generation with the list of SKU stored in the SP2 and with a list of codes which when picked from the SP1's WMS are managed with ground locations.

COUNTERMEASURE 7: OPTIMUM PICKING PATH GENERATOR

In the third inefficiency proposed, “Not optimum picking path”, was highlighted, through a Spaghetti Chart as the logistic operator, who manages the PPLD kits, travels useless distances. The countermeasure that can solve this issue consists in a new WMS able to transform a picking list into a picking mission whose stages’ order optimize the path to be followed. In Figure17, the path necessary to fulfill the same picking mission proposed in the problem breakdown is shown.

Figure 17 - Optimized picking path

Only taking a quick look, could be noticed the significant reduction of the distance travelled. To precisely estimate the possible saving in terms of time and money, a performance analysis was carried out. The period used as a sample starts on July 20 and ends on July 24. In particular, 89 picking missions were monitored. In order to explain the structure of the data collected, the first day records are reported. In the second column is shown the entire list of engines managed through kitting. Often, two or four identical motors are aggregated in the same picking mission. In this way, components necessary for the assembly of more than one engine are picked in the same mission.

The third column indicates the picking time for each mission, moving to the right the motor quantity and the unitary picking time (Picking time/motor quantity) are shown. The sixth column is a percentage compute as Variable Time on Unitary Time. The variable

Picking date	Motor model	PickingTime (min)	Motor quantity	Unitary PT (min)	Variable % on PT	Variable PT	Distance travelled (AS-IS)	Distance travelled (TO-BE)
20/07/2020	4TNV98-NSAP	/	0	/	54%	/	/	/
	4TNV98CT-NYI2	45	2	22,5	57%	12,825	284,5	96,5
	4TNV98T-ZGGEP	75	4	18,75	55%	10,3125	213,3	79,9
	4TNV98-IGEP	/	0	/	56%	/	/	/
	4TNV88-DSAP	/	0	/	60%	/	/	/
	4TNV88-GGEP	55	2	27,5	63%	17,325	329,9	146,9
	4TNV88-BDYE2T	96	4	24	62%	14,88	288,3	127,6
	4TNV88-BDYE2	36	1	36	61%	21,96	406,0	178,1
	4TNV88C-DYI2	15	1	15	59%	8,85	190,0	67,4
	4TNV88-BIGEP	/	0	/	58%	/	/	/
	4TNV88-BDYE	35	1	35	64%	22,4	378,5	112,2
	4TNV88-DSC	55	2	27,5	64%	17,6	332,6	131,7
	4NTV86CT-DYI2	/	0	/	54%	/	/	/
	3TNV88-BDYE	/	0	/	57%	/	/	/
	3TNV88-BDYE2	30	1	30	63%	18,9	358,1	102,8
	3TNV88C-DYI2	/	0	/	58%	/	/	/
	3TNV88-GGEP	26	1	26	59%	15,34	324,5	126,4
Tot motors	3TNV88C-DYI2	/	0	/	61%	/	/	/
23	3TNV88-DSAP	70	4	17,5	56%	9,8	194,9	72,4

Table 8 - Performance analysis day 1 part 1

time in this case was considered as the time dedicated to the handling of the forklift. It was measured for each motor during the first day and an average for each model was computed. The last two columns regarding the distance travelled in the AS-IS and in the TO-BE situation (approach of figure 17: serpentine path).

Motor model	Avoidable Path (m)	Avoidable Path (%)	Avoidable time loss per motor (min)	Avoidable time loss (%)	Avoidable time loss (min)
4TNV98-NSAP	/	/	/	/	0,0
4TNV98CT-NYI2	188,0	66%	8,47	38%	16,9
4TNV98T-ZGGEP	133,4	63%	6,45	34%	25,8
4TNV98-IGEP	/	/	/	/	0,0
4TNV88-DSAP	/	/	/	/	0,0
4TNV88-GGEP	183,0	55%	9,6	35%	19,2
4TNV88-BDYE2T	160,8	56%	8,3	35%	33,2
4TNV88-BDYE2	228,0	56%	12,3	34%	12,3
4TNV88C-DYI2	122,6	65%	5,7	38%	5,7
4TNV88-BIGEP	/	/	/	/	0,0
4TNV88-BDYE	266,3	70%	15,8	45%	15,8
4TNV88-DSC	200,8	60%	10,6	39%	21,3
4NTV86CT-DYI2	/	/	/	/	0,0
3TNV88-BDYE	/	/	/	/	0,0
3TNV88-BDYE2	255,4	71%	13,5	45%	13,5
3TNV88C-DYI2	/	/	/	/	0,0
3TNV88-GGEP	198,1	61%	9,4	36%	9,4
3TNV88C-DYI2	/	/	/	/	0,0
3TNV88-DSAP	122,4	63%	6,2	35%	24,6

Table 9 - Performance analysis day 1 part 2

The second part of the performance analysis consists in a time quantification of the possible saving. The avoidable path is the difference between the AS-IS and the TO-BE distance travelled, then it has been brought in percentage terms.

The value obtained was used to compute the Avoidable Time per motor ("Avoidable Path %" * "Unitary picking time").

In the end, this value was brought in percentage terms and the "Avoidable Time per-mission" was computed. After this analysis was inferred that 816 minutes per week can be saved. In this way, for the first time, the real inefficiency was quantified. It was possible only through a comparison between the AS-IS and TO-BE situation.

Bringing this loss in monetary terms, the total annual waste amount to 13.856 €/year (816 minutes/week * 48 weeks/year * 20/60 €/hour). It is the heaviest waste of money that the implementation of a new WMS can eliminate.

Trying to extend this performance analysis to the other picking processes, can be assumed that the picking of Series L component in the Surplus 1 can be positive affected by the picking path optimizer with the same percentage of saving. In table 10, the computation of the annual loss linked to the mentioned process is shown.

Daily SKU picked	Unitary time	Daily LT	Avoidable path	Daily loss	Annual loss
90	2,5 min	225 min	38%	85,5 min	6.840 €

Table 10 - SP1 Series L components picking

For what concerns the other picking process, the same effects cannot be hypothesized. Indeed:

- Neander and YDG components are picked always from the two same lanes
- Series L components in SP2 are picked only in entire pallets so the operator always comes back to the warehouse centre to put down the single SKU

So the total loss implied by the non-optimum picking path amounts to 20.696€/year (13.856 €/year + 6.840 €/year).

COUNTERMEASURE 8: ROTATION INDEX BASED WAREHOUSE

The actual allocation of goods within the different warehouses, as explained in inefficiency 9, does not follow any logic. The only measures adopted by the logistic operators are relying on their expertise. Observing the rotation of some SKUs, they tend to allocate these near the starting point of the missions or at least they avoid putting them on the higher shelf floors. This countermeasure aims to digitize and standardize the workers' know-how, translating it into a software feature.

To achieve it, during the loading process of each component or finish product, the radiofrequency terminals will suggest an area in which stock the item. Naturally, the WMS, to prompt this macro-location, will use the rotation index of the code as a driver.

In this way, in theory, both the path travelled during the loading process and the one of the picking process will be lower. With the aim to demonstrate it, different analysis were carried out.

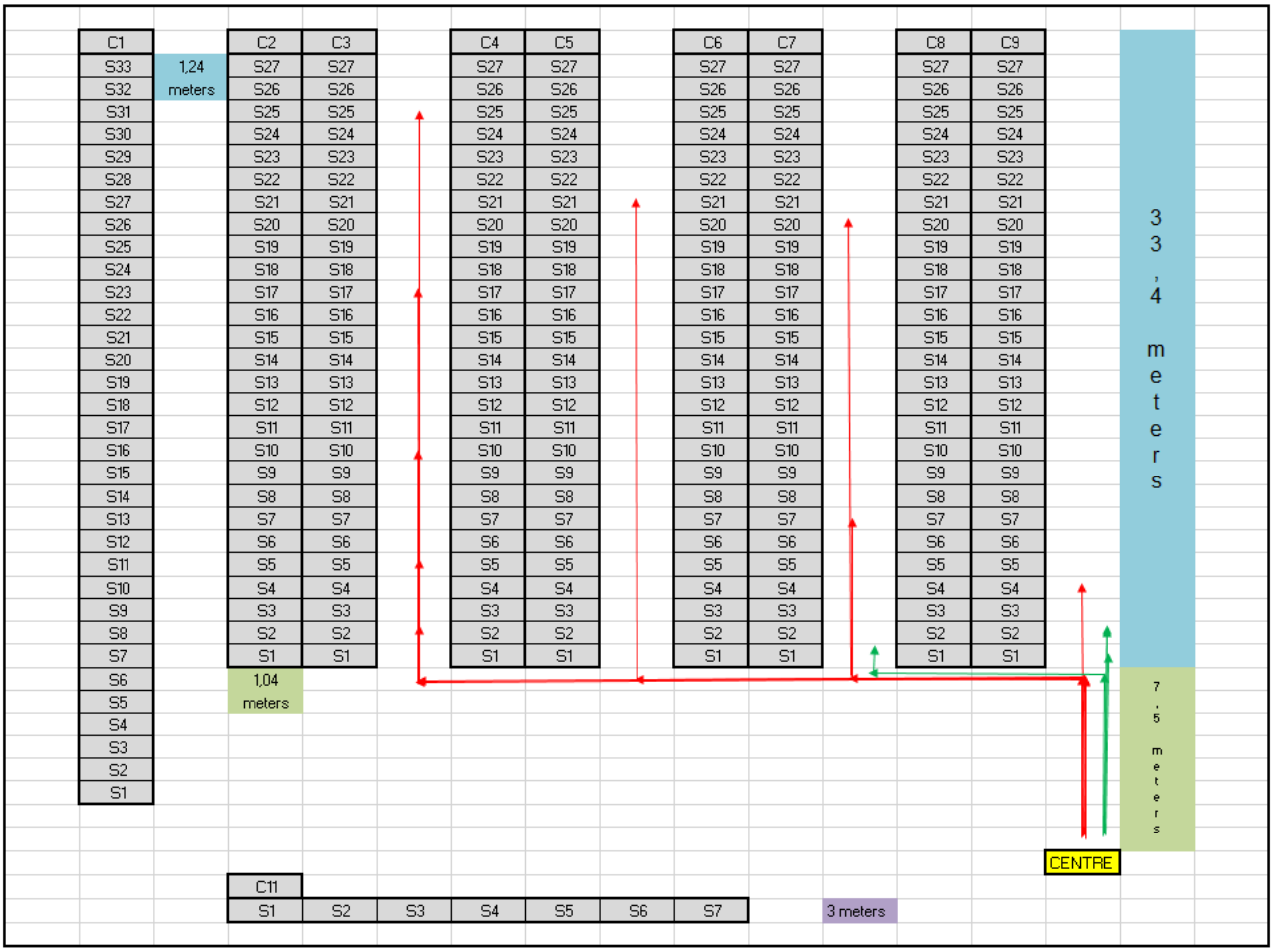


Figure 18 - Spaghetti chart on a sample loading mission

Starting with a classic Spaghetti chart done on a loading sample mission, can be understood the magnitude of the desired change. In this loading mission, the nine SKUs considered are the ones with the highest rotation index. They were stored coming back to the centre (yellow cell) whenever every single pallet is stored. The red lines, already proposed in inefficiency 9, corresponds to the hypothetical path required to fulfill the

Location	Distance (m)	CODE	RI	Location RI	Distance RI (m)	Saving (m)	Saving %	RI%	Weighted Saving (%)	Total Saving (%)
1_1_1	20,8	114110-45130	0,56534	7_3_1	18,84	1,96	9,423%	0,238%	0,022%	38,526%
1_1_2	20,8	119028-44510	0,05585	3_18_1	31,32	-10,52	-50,577%	0,024%	-0,012%	
1_2_1	19,56	26216-080182-YC	0,21435	6_10_2	22,8	-3,24	-16,564%	0,090%	-0,015%	
1_2_2	19,56	114310-22200	0,33138	7_5_1	21,32	-1,76	-8,998%	0,140%	-0,013%	
1_3_1	18,32	129602-49010	0,08829	5_14_2	27,76	-9,44	-51,528%	0,037%	-0,019%	
1_3_2	18,32	114354-59020-YC	4,74468	5_1_1	11,64	6,68	36,463%	2,001%	0,730%	
1_4_1	17,08	11421C-11100	0,24702	3_11_1	22,64	-5,56	-32,553%	0,104%	-0,034%	
1_4_2	17,08	714349-51610	0,87234	4_6_2	16,44	0,64	3,747%	0,368%	0,014%	
1_5_1	15,84	129988-77920	0,00002	9_26_2	50,94	-35,1	-221,591%	0,000%	0,000%	
1_5_2	15,84	183387-61201-YI	0,05912	1_19_1	30,72	-14,88	-93,939%	0,025%	-0,023%	
1_6_1	14,6	114210-01210	0,56462	8_3_1	18,84	-4,24	-29,041%	0,238%	-0,069%	
1_6_2	14,6	26106-100302-YC	0,93131	8_1_1	16,36	-1,76	-12,055%	0,393%	-0,047%	
1_7_1	15,84	714139-53200	0,27098	1_12_2	22,04	-6,2	-39,141%	0,114%	-0,045%	
1_7_2	15,84	119515-42830	0,02978	2_16_1	34,44	-18,6	-117,424%	0,013%	-0,015%	
1_8_1	17,08	114252-66053	0,09127	4_15_2	27,6	-10,52	-61,593%	0,038%	-0,024%	

Table 11 - Simulation 01 RI based WH

mission in the AS-IS situation (it has to be doubled considering forward and backward distances). The green ones instead represent the path necessary in the TO-BE situation in which codes are allocated in the WH basing on their rotation index. To have data related to the latter, a request to the IT department was done.

Suddenly a deep-dive analysis was carried out (table x). It is based on eight simple steps:

1. 500 SKUs were randomly chosen by the database and allocated to the first two floors of the SP2.
2. For each location of the warehouse, the distance from the loading mission centre was computed
3. SKUs with high RI were located in the nearer locations and vice versa
4. The AS-IS (Distance) and TO-BE (Distance RI) paths were compared and the delta distance (Saving) computed both in meters and in percentage terms
5. The single weight of the RI on the sum of all the RI was computed (RI%)
6. The Weighted Saving was computed as multiplying the RI% by the Saving %
7. The overall sum of the weighted saving consists in the Total Saving in percentage terms
8. Iteration of this procedure until this percentage stabilized itself

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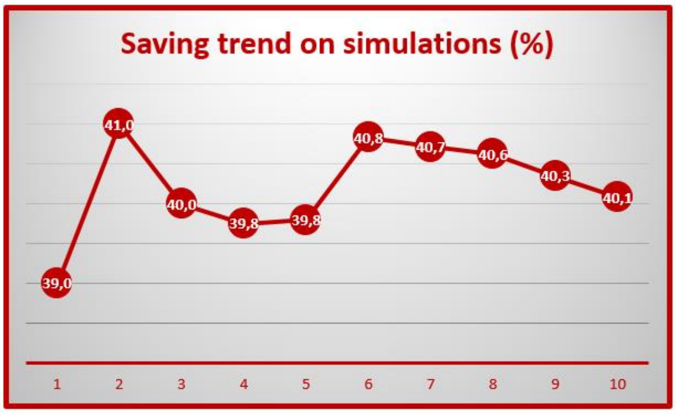


Figure 19 - Average saving trend on simulation (%)

As shown in the graph the simulation based on the allocation of 500 SKU was carried out ten times. The percentage ten times reported is the average updated after each simulation. After some initial fluctuations, the value started to stabilize around 40%. As driver value will be used 40,01%.

After this analysis was done the assumption that, considering all the 6 floors of the warehouse the same percentage savings can be obtained. The relevant fact that the necessity of bringing SKU in high altitude implies higher variable time was not neglected. Indeed, in more than 15 missions in all the processes that take advantage of this countermeasure, the percentage of variable time (distance-dependent) were measured. In particular, was referred that on average the 59% of the time required for a mission directly depends on the distance travelled. The other two processes mentioned are the loading of Series L component in the SP1 and the picking of them in the SP2. Indeed, as in the main process analysed, they are characterized by the centre location of the respective warehouse as a fixed stop whenever a single SKU is loaded or picked.

So proceeding the real inefficiency (comparison between AS-IS and TO-BE situation) can be computed:

Process	Warehouse	Units/day	Time/unit (min)	Daily saving (min)	Annual saving (€)
Series L component loading	SP1	10	3,5	8,3	662,5
Series L component loading	SP2	25	3,5	20,7	1656,1
Series L component picking	SP1	4	3,5	3,3	265,0
				Total annual saving (€)	2583,6

Table 12- Random allocated of goods in the warehouses

COUNTERMEASURE 9: DIGITAL PICKING LIST

Each kind of picking list should be digital and no more paper made.

Also in the development of this countermeasure, more than one strategy can be pursued.

During the definition of the interfaces, has to be defined according to the WMS' supplier the informative process that guides the info flow from the administration systems.

To create a picking list, whichever is the process considered, some information related to the SKUs required has to be elaborated by the WMS. Starting from this info, the new system has to create the picking list and to deliver it within the radio-frequency terminals used by the operators.

The first option is the cheapest and easiest to be implemented: the picking list, which in the AS-Is situation are generated by different white collars belonging to the Planning and Logistic department, instead of being printed, will be sent in a shared fold ("Postman") to the warehouses' computers in the form of an Excel file. The new WMS has to be able to extrapolate info from the latter and exploit them.

The second scenario, instead, implies a complex computer interface. The issue linked to it is not related to who will supply the chosen product, but to the rigid rules imposed by the existing Japan administration software: YGLS. Further analysis has to be done to verify the concrete feasibility of the download of the info required to generate the different lists. In other terms, the existence of a solid channel, that links WMS to orders and delivery notes (internally and externally), is not so obvious.

COUNTERMEASURE 10: WMS INTERFACE WITH ACG AND YGLS

Before starting to explain this countermeasure, it is useful to define the concept of computer interface, a term already mentioned above.

Indeed, in the development of this project, as "interface" is intended the logical component that allows two or more electronic systems to communicate and interact. Interfacing, therefore, means connecting, following a standard format that allows the exchange of data, two or more heterogeneous devices to allow them to exchange information.

It is necessary to specify that the two interfaces proposed as countermeasures are very different. Indeed, in order to connect the WMS with the administration software that manages generator YDG and Neander outboard marine engines (ACG) consists in a common activity carried out by the technical provider of the WMS. In informative terms, this interface is called connector; with this computer link, all data required by the WMS will become available solving the inefficiency described in the dedicated section. The implementation of this interface results not so cumbersome, because ACG is a diffused software and WMS providers are used to propose a product fully compatible with it.

For what concerns YGLS instead, it is a Japanese information system developed and brought worldwide by Yanmar Japan in all the company's branches. For this reason, the firm that will be chosen as supplier will have the burdensome assignment of interface the WMS with a software not known and difficult to be managed. Indeed Yanmar Italy, during the development of old projects (not all fulfilled nowadays) had troubles in creating a connection with YGLS useful to obtain data required. Coming back to the specific necessities of the actual project, customers' orders, delivery notes, data related to the day-by-day manufactured engines and the other info the whom missing implies inefficiencies will become available to the WMS through the creation of small interfaces targeted and not thanks to a total connector.

COUNTERMEASURE 11: TASK REDISTRIBUTION

The Planning and Logistic department is composed of seven workers within the office. The entire set of tasks typical of this division is not equally distributed among these white collars. Indeed, the different job duties are allocated to them on the base neglecting the workload. Until now is preferred to attribute one kind of job to a single person. A possible solution consists in estimate the total amount of hours required to carry out each activity and split them equally among the different team members. Using the hours of work as driver, the variability of time required to carry out a specific job would be absorbed. Moreover, each white-collar will develop a large know increasing his expertise.

Going into detail, all the processes related to the management of the customs warehouse should be taught to the entire division to lighten the actual overload that affects PG. The coaching period that the other workers have to do would be very concise because the procedures, even if often required a lot of time to be fulfilled, are simple to be metabolized. Furthermore, in the P&L department, whenever a new task is introduced, a detailed tutorial is generated. For this reason, the learning period should be even briefer.

COUNTERMEASURE 12: SMART MATCHING

In the “Double IM7” inefficiency explanation, the entity of the issue, that countermeasure 12 has to solve, was precisely described. The solution proposed entirely relies on a technical feature of the WMS that is willing to be bought.

Indeed, if engines belonging to different customs documents have to be loaded in the same moment, the new WMS has to be able to attribute the scanning of a barcode to the correct document, whatever the order in which the scans are made.

In order to carry out this smart matching, in addition to the feature just described, the WMS has to be able both to obtain, from a pre-loading, info regarding the document already mentioned (IM7) and to manage them.

COUNTERMEASURE 13: UPDATE POST INVENTORY

The missing alignment between the real stock in the warehouse and WMS’ data is an issue implied by different causes. Countermeasure 13 cannot solve this inefficiency in absolute terms over time. However, updating all the values of stock within the WMS after the inventory, a precise moment of total alignment will exist. Moreover, the inventory procedure will be easier and faster allowing operators to carry out it even two times a year instead of one (AS-IS situation).

Besides, considering that, with the implementation of the new WMS, the total number of errors committed within the warehouses should decrease, the monitoring efficiency of WH’s stock and, consequently, the real alignment between data and reality will deeply be furthered.

COUNTERMEASURE 14: PURCHASING A NEW WMS

The fourteenth and last countermeasure assumes a symbolical meaning.

Indeed, the focus adopted in the definition of the large part of the countermeasures involves the purchasing of a new WMS. In particular, several solutions proposed consist in a technical feature of the tool, in a new way to use it or in a new interface. Going into detail, the phenomenon of system failure described in the last inefficiency can be easily avoided by purchasing a new product that is not obsolescent as the old one.

PARETO ANALYSIS

As anticipated previously, inefficiency 3 and 9 were monetarily quantified only after the definition of the respective countermeasures. Indeed, even if, thanks to preliminary analysis was referred that objectively time was wasted, only with the comparison with the TO-BE situation more precise info was obtained. For this reason, carrying out a Pareto analysis is now possible.

Inefficiency	Annual loss (€)	Cumulated (€)	Cumulated (%)	Class
Non-optimum picking path	20696	20696	42%	A
Paper picking list	9060	29756	61%	A
WMS/YGLS not aligned	6000	35756	73%	A
WMS/ACG not aligned	3900	39656	81%	B
Manual typing of codes	3080	42736	88%	B
Random allocation of goods in the warehouse	2584	45320	93%	B
WMS SP1/WMS SP2 not aligned	1200	46520	95%	C
Blue boxes	727	47247	97%	C
Authorized revisions	633	47880	98%	C
Picking rows deleting	573	48453	99%	C
Double IM7	218	48671	100%	C
WMS breakdown	80	48751	100%	C

Table 13 - Pareto Analysis on inefficiencies

This analysis aims to identify on which inefficiency to intervene before. In this kind of project, the prioritization phase is more than fundamental. Indeed, 72% of the money wasted in all the logistic processes taken into consideration is linked to only three issues. This means that by solving them with an adequate choice of corrective actions and countermeasures, the final result will be near the achievement of the “nice to have target”, which was set as the resolution of the 80% of the monetary waste. However, what just described could result not so easy to be brought into practice.

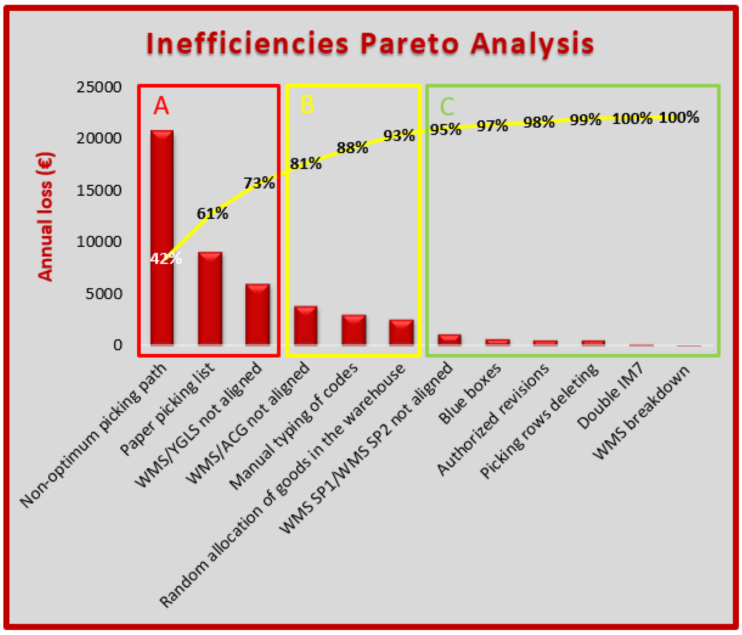


Figure 20 - Pareto Analysis on inefficiencies

In particular, following the A3 model, countermeasures are developed starting from the root-causes identified, for this reason, the one-to-one ratio between inefficiency and countermeasure is not assured. Indeed, could occur that more than one corrective action will be necessary to solve one waste or vice versa. Therefore, the final prioritization has to be carried out on the saving implied by every single countermeasure. This analysis will be done in the next chapter.

In the end, deep-dive analysis were done. In table 14, the monetary losses implied by the twelve inefficiencies previously identified were split on all the logistic processes analysed. In this way, was evinced which are the processes more negatively affected with the final aim of prioritizing the implementation of countermeasures.

In particular, the processes just mentioned are the picking of Series L component in SP1, the picking of PowerPack and LocalDress in SP2 and the loading of engines within the finish product warehouse.

			INEFFICIENCIES (€/year)												
Process	Object	Warehouse	1	2	3	4	5	6	7	8	9	10	11	12	Total
Loading	Series L	SP2	2195								1656			8	3859
	Series L	SP1									663			8	671
	PP/LD	SP2												8	8
	Neander/YDG	SP2	885	727		633								8	2253
	Engines	FP						4350	3450					8	7808
Picking	Series L	SP2								1200				8	1208
	Series L	SP1			6840		2267				265			8	9380
	PP/LD	SP2			13856		3247					573		8	17684
	Neander/YDG	SP2					3547							8	3555
	Engines	FP						450	450				218	8	1126
Partial Sums (€/year)			3080	729	20696	633	9060	4800	3900	1200	2584	573	218	80	47552

Table 14 - Inefficiencies on processes (€/year)

In this table the QC process is missing, it amounts to a further loss of 1200€ linked to inefficiency 6, as explained in the dedicated section.

ROOTCAUSES vs COUNTERMEASURE vs INEFFICIENCIES

#	Rootcause	Countermeasure	Inefficiency solved	Saving (€)
1	Radio-frequency terminals are obsolescent	NEW PDAs	MANUAL TYPING OF CODES	€ 3.080,00
2	The suppliers goods attachment and they registries don't fit Yanmar software	PRE-LOADING GENERATION		
		SHARED REGISTRIES	AUTHORIZED REVISIONS	€ 633,00
3	The WMS data of the SP2 aren't visible by SP1's terminals	ONLINE STOCK VISIBILITY	BLUE BOXES	€ 727,00
			WMS SP1/WMS SP2 NOT ALIGNED	€ 1.200,00
4	Strategy based on minimum stock values as reorder points	REQUIREMENT BASED LOGIC		
5	The logistic department falls in creating the picking list	NEW PPLD PICKING LIST GENERATION	PICKING ROWS DELETING	€ 573,00
6	Random order of the picking rows in the picking list	OPTIMUM PICKING PATH GENERATOR	NOT OPTIMUM PICKING PATH	€ 20.696,00
7	Components within the WH not allocated according to the RI	ROTATION INDEX BASED WAREHOUSE	RANDOM ALLOCATION OF GOODS IN THE WAREHOUSES	€ 2.583,60
8	The picking lists are paper made	DIGITAL PICKING LIST	PAPER PICKING LIST	€ 9.060,00
9	Missing communication between WMS and the administration software	WMS INTERFACE WITH ACG AND YGLS	WMS/ACG NOT ALIGNED	€ 7.800,00
			WMS/YGLS NOT ALIGNED	
10	The white collar who has to do the upload is overloaded	TASK REDISTRIBUTION	WMS/ACG NOT ALIGNED	€ 2.100,00
			WMS/YGLS NOT ALIGNED	
11	Old WMS feature Loading units based	/	/	/
12	The actual WMS fails in distinguish code linked to different documents	SMART MATCHING	DOUBLE IM7	€ 218,00
13	The WMS data are not coherent with the real stock	UPDATE POST INVENTORY	/	/
14	WMS software is obsolescent	PURCHASING A NEW WMS	WMS BREAKDOWN	€ 80,00

Table 15 - Savings implied by countermeasures

As anticipated in the incipit of this section, it is useful to link the countermeasures defined with the root-causes previously identified. Moreover, through linking inefficiencies, it is possible to aggregate also the monetary losses. In this way, the economic savings implied by each countermeasure can be quantified.

This procedure highlights the correctness of the logical flow followed in the entire project development. Indeed, starting from the identified inefficiencies, their origin was investigated by identifying root causes. The latter are annihilated through the implementation of countermeasures, which should "close the circle" and solve the initial inefficiencies.

Even if, from a theoretical point of view, the entire process works, it necessary to underline that the final check would ensure the validity by the monitoring of the results obtained. However this is not now possible due to the time horizon in which the master thesis writing takes place.

Observing Table 15, could be notice that more than one countermeasure solves the same inefficiencies and vice versa. For this reason, not always, can be computed how the savings implied are split on the correspondent countermeasures (for example for inefficiency "Manual typing of codes").

COUNTERMEASURE	Saving	Cum (€)	Cum (%)	Class
OPTIMUM PICKING PATH GENERATOR	€ 20.696,00	€ 20.696	42%	A
DIGITAL PICKING LIST	€ 9.060,00	€ 29.756	61%	A
WMS INTERFACE WITH ACG AND YGLS	€ 7.800,00	€ 37.556	77%	A
ROTATION INDEX BASED WAREHOUSE	€ 2.583,60	€ 40.140	82%	B
TASK REDISTRIBUTION	€ 2.100,00	€ 42.240	87%	B
NEW PDAs	€ 1.540,00	€ 43.780	90%	B
PRE-LOADING GENERATION	€ 1.540,00	€ 45.320	93%	B
ONLINE STOCK VISIBILITY	€ 1.327,00	€ 46.647	96%	C
SHARED REGISTRIES	€ 633,00	€ 47.280	97%	C
REQUIREMENT BASED LOGIC	€ 600,00	€ 47.880	98%	C
NEW PPLD PICKING LIST GENERATION	€ 573,00	€ 48.453	99%	C
SMART MATCHING	€ 218,00	€ 48.671	100%	C
PURCHASING A NEW WMS	€ 80,00	€ 48.751	100%	C

Table 16 - ABC analysis on countermeasures

Finally, it is possible to prioritize countermeasures implementing an ABC analysis on the savings implied.

From table 16, can be evinced that the most impacting countermeasures are three:

- Optimum picking path generator
- Digital picking list
- WMS interface with ACG and YGLS

LEAD TIME ANALYSIS

A parallel analysis can be carried out to understand how logistic issues spotted out stretch the lead time of each process.

From a general point of view, the lead time is a parameter that characterizes a logistics network at different levels. It is also called "response time" because refers to the time interval necessary for a company to satisfy a request. In this analysis, the requests to be satisfied are for the large part internal (nine on ten processes) except for the picking of engines.

The first step of this analysis is a computation of the single lead time of each process.

Because of the number of SKUs managed by each activity is very variable, it was decided to consider an average value computed basing on one working day (8 hours).

The second step of the analysis consists in the comparison, for each process, between the lead times with the time wastes identified by the previous inferences. Subtracting the second one to the first one, the new lead time is evinced. In order to obtain the wasted

			INEFFICIENCIES (minutes/day)												
Process	Object	Warehouse	1	2	3	4	5	6	7	8	9	10	11	12	Total
Loading	Series L	SP2	27,4								20,7			0,1	48,2
	Series L	SP1									8,3			0,1	8,4
	PP/LD	SP2												0,1	0,1
	Neander/YDG	SP2	11,1	9,1		7,9								0,1	28,2
	Engines	FP						43,5	49,5					0,1	93,1
Picking	Series L	SP2								15,0				0,1	15,1
	Series L	SP1			173,2		25,9				3,3			0,1	202,5
	PP/LD	SP2			85,5		36,9					7,2		0,1	129,7
	Neander/YDG	SP2					39,9							0,1	40,0
	Engines	FP						4,5	4,5				2,7	0,1	11,8
Partial Sums (minutes)			38,5	9,1	258,7	7,9	102,8	48,0	54,0	15,0	32,3	7,2	2,7	1,0	577,2

Table 17 - Inefficiencies on processes (minutes/days)

times, was built a parallel table to the previous one. In particular, losses are no more reported in monetary terms but in minutes. In this way, the total loss for each process can be evinced and used to proceed with the analysis. Finally, the saved lead time is brought in percentage terms to make possible a further comparison among the different processes identifying those that will be the ones who would obtain the most significant benefits in the scenario in which all inefficiencies are remedied. As result, the highest lead time variations of the ten processes analysed can be spot

(Picking of Series L components in SP2). The value-added of this analysis consists in simulate a TO-BE scenario in which all the possible performance improvements are implemented.

Process	Object	Warehouse	Old Lead Time	Time wasted	New Lead Time	Saving %
Loading	Series L	SP2	131,3	48,2	83,0	37%
	Series L	SP1	52,5	8,4	44,1	16%
	PP/LD	SP2	15,0	0,1	14,9	1%
	Neander/YDG	SP2	74,0	28,2	45,8	38%
	Engines	FP	216,0	93,1	122,9	43%
Picking	Series L	SP2	29,0	15,1	13,9	52%
	Series L	SP1	337,5	114,8	222,7	34%
	PP/LD	SP2	702,0	217,4	484,6	31%
	Neander/YDG	SP2	224,7	40,0	184,7	18%
	Engines	FP	206,6	11,8	194,7	6%

Table 18 - Saved Lead time

Process	Object	Warehouse	Units/day	Time required (mins/units)	Handling Time(mins)	Pre-handling time (mins)	Post-handling time (mins)	Lead time
Loading	Series L	SP2	25	3,5	87,5	33,1	10,6	131,3
	Series L	SP1	10	3,5	35,0	11,9	5,6	52,5
	PP/LD	SP2	5	2	10,0	2,6	2,4	15,0
	Neander/YDG	SP2	3	5	15,0	51,3	7,7	74,0
	Engines	FP	19	2	38,0	131,7	46,3	216,0
Picking	Series L	SP2	4	3,5	14,0	15,1	0,0	29,0
	Series L	SP1	90	2,5	225,0	32,6	79,9	337,5
	PP/LD	SP2	18	26	468,0	78,4	155,6	702,0
	Neander/YDG	SP2	20	8	160,0	40,8	23,9	224,7
	Engines	FP	69	2	137,7	37,9	31,0	206,6

Table 19 - Old Lead Time

The column named "Old lead time" refers to the time required to fulfill each process in the AS-IS situation. In order to compute them, were used quantifications obtained through Gemba Walks, measurements and operators' interviews.

The total Lead Time has been considered composed of three parts:

1. Pre-Handling time: time required to make the process ready to be physically fulfilled. For example, time spent in generating a paper list
2. Handling time: composed in turn by a variable part (directly linked to the distance travelled) and a fixed one, it corresponds to the time spent in physically moving the goods.
3. Post handling time: time spent in carrying out activities after the fulfillment of the process. For example, movements of PP/LD kits from SP1 to SP2.

IMPLEMENTING COUNTERMEASURES

This step of the A3 model was not included in the project boundaries, which should end with the definition of the specifications and features of the Warehouse Management system to be purchased. However, from the first analysis and investigations, the approach used went beyond the threshold preliminarily fixed even if without stop considering them as the main goal.

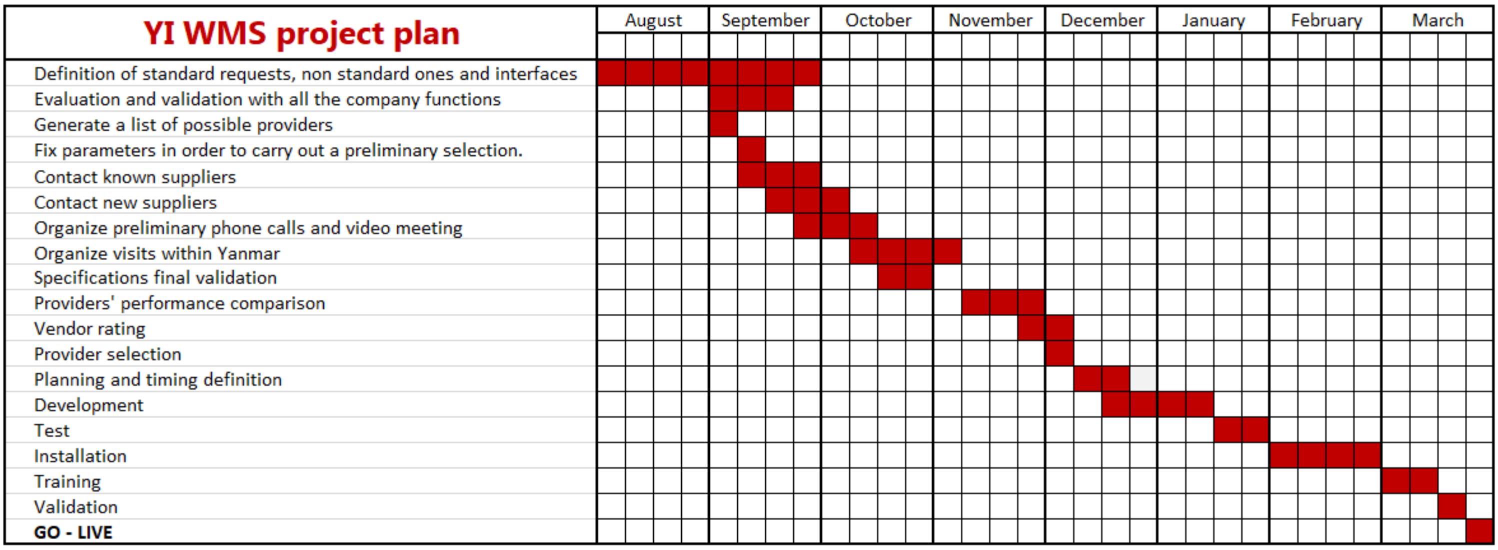


Figure 21 - WMS project plan

In this specific case, the effort required to carry out the previous steps was concentrated in less time than estimated. For this reason, in the final period of experience, the implementing phase took place.

The countermeasures prioritization ended with the decision to concentrate efforts on the implementation of the new WMS. Indeed, even if the focus adopted was always larger, the heaviest inefficiencies would be solved through specific WMS features.

The approach adopted in this A3's step was twofold. Indeed two activities were carried on parallel. The first consists in the final definition of the specifications of the WMS.

Until this moment, were found and discussed different features to further the processes, to solve issues and to optimize the activities. In the implementation phase, indeed, detailed and technical specifications have to be defined in other to:

1. Understand the level of complexity of the actual tool's environment (interfaces, links, dialogue with other info systems…)

2. Consolidate the requests
3. Send them to the provider

The parallel activity instead consisted in the analysis of what the information system market offers. This process is mainly based on the following steps:

1. Generate a list of possible providers.
2. Fix parameters in order to carry out a preliminary selection.
3. Contact the providers chosen.
4. Organize visits within Yanmar in order to make them able to formulate a proposal
5. Set up a comparison between the importance attributed by Yanmar to each request and how each supplier satisfies them.
6. Carry out a complete Vendor Rating and choose the more adequate software provider.

Unfortunately, it was not possible to complete this procedure before the end of the project period. However, all the data collected and the analyses carried out up to the current day have been reported in the document.

WMS SPECIFICATIONS

Defining the WMS specifications, a simple distinction was done. Indeed, they were split into standard requests, non-standard ones and interfaces. Going into detail, eighteen standard requests were identified and reported in table 17.

STANDARD REQUESTS	
1.	Management of 20 digit alphanumeric codes
2.	Creating codes
3.	LU management
4.	Management of finished product serial numbers
5.	Search by code / station
6.	SKU and LU displacement
7.	Assigning codes to LU
8.	LU assignment to station
9.	Adding / removing quantity codes in Lu
10.	Barcode and QR code reading
11.	Print code / LU label
12.	Layout faithful cell representation
13.	Color usage (cell status)
14.	Total number of cells + number of occupied cells
15.	Reading Excel file for preload / pre-delivery notes
16.	Picking list creation
17.	Reports with codes appearing whose stock is under 1.6 times the minimum stock
18.	Match between preload and what was scanned (customs)

Table 20 - Standard requests

These specifications were classified as standard because was assumed that each WMS provider has to include them by default in their software.

In order to make it easier to consult this list, results useful to specify that:

- As code is intended any serial number which univocally identifies the single SKU
- LU is the acronym of Loading Unit, it is a digital container to which SKU’s code can have to be allocated (it can contain one or more product)
- Location is the physical cell to which LUs can be associated (as seen in inefficiency 3, they are characterized by lane, shelf and ground)

Standard request 17 could seem too much specific to be classified as standard, however is a simple communication tool that underlines SKUs with a stock quantity lower than a fixed value.

Also request 18 could be considered to be non-standard, but the possibility to manage a customs warehouse is commonly provided as a basic WMS' feature.

Suddenly were defined fourteen non-standard requests, they are related to features not yet available by the actual WMS or not easily offered by WMS suppliers. The possibility that some of them have to be realized by zero through customization has to be considered.

NON-STANDARD REQUESTS	
1.	Radio-frequency terminals able to read any barcode
2.	Digital picking list management
3.	Optimized picking path
4.	Loading area suggestion
5.	Delivery notes transformation in pre-loading
6.	Codes in "Processing phase" or "In transit"
7.	Loading and picking history with quantities for each code
8.	Automatic LU creation
9.	Not rigid but intelligent code search (browser)
10.	Distribution of serial numbers for IM7 (customs)
11.	Use of colors to identify product type and low RI SKUs
12.	Inventory management
13.	Creation of digital picking list directly visible on WMS
14.	Stock visibility (access to WMS) in SP1, SP2, QC, FP, P&L
15.	Inclusion of the Lamp Guide system in the WMS

Table 21 - Non-standard requests

Some useful explanations:

- "Processing phase" would describe the status of goods under mechanical processing
- "In transit" would describe the status of goods which are moving from one warehouse to another
- Intelligent search means having the possibility to insert code wrong by one or

more digits and still be able to see the serial number requested

- non-std request n°10 is the countermeasure 12: “Smart matching”
- The department and the warehouses mentioned in non-std request n°14 would have online access to the WMS to consult the stock when necessary
- The Lamp Guide System, explained in the incipit of the Problem Breakdown section, will be mapped by the WMS

Part of the features within this list represents some countermeasures proposed in the dedicated section. For this reason, implementing them means to solve issues identified and save time/money.

In the future steps, for each non-standard request will be necessary to carry out a Cost-Benefit Analysis and decide, one by one, if the implementation effort in monetary terms is justified by the positive effect generated. This benefit consists in the saving obtained through the resolution or the partial resolution of one of the inefficiencies previously analysed.

The third step of the specifications definition process is related to interfaces.

In the explanation of countermeasure 10, the concept of interface was before described from a general point of view and then traduced in more specific terms considering the

	INTERFACES		
1.	Packing information system → direct loading on WMS / loading through file Excel		
2.	Codes regisitry: ACG/YGLS as master (ACG/YGLS → WMS) + free creation of code in WMS without return in ACG/YGLS		
3.	Stock Update from ACG/YGLS to WMS (for purchased product)		
4.	Picking list created in ACG/YGLS and uploaded in the WMS' radio-frequency terminals 5.1 AS IS 5.2 AS IS	 YDG: automatic print from ACG PP/LD: manual print from YGLS → Excel file → WMS	 TO BE: ACG → WMS → Palmari TO BE: File XL → WMS → radio-frequency terminals
5.	Interface with ACG/YGLS in order to access to the SKUs in Free Pass		
6.	Interfaces for loading process 6.1 Comp. CKD 6.2 Comp. LOCAL 6.3 FP from YJ 6.4 FP Series L 6.5 FP PP/LD 6.6 FP YDG/Neander	 AS IS: Excel file sent by YJ → WMS AS IS: / AS IS: YGLS → Excel file → WMS AS IS: Packing → CSV file → WMS AS IS: Packing → CSV file → WMS AS IS: download ACG → Excel file → WMS	 TO BE: ACG/YGLS → WMS → radio-frequency terminals TO BE: YGLS → WMS → radio-frequency terminals TO BE: YGLS → WMS (replicate) TO BE: YGLS → WMS (replicate) TO BE: ACG → WMS (automation)
7.	Interface with mechanical processing and QC		
8.	Interface with YGLS / ACG to access the rotation indexes		
9.	Interface with YGLS/ACG in order to unload the Lamp Guide WMS post production of each FP		

Table 22 - Interfaces

existing differences between YGLS and ACG (the two management software). In the current phase, however, a detailed description of all the info that through interfaces has to reach the WMS is necessary.

Some useful explanations:

- in the AS-IS situation, to make the Finished product WMS able to accept the serial numbers of the new engines assembled by the production plant, a CSV file is necessary. This file is created by the packing system and sent through a shared fold. In the TO-BE situation, this existing interface has to be set up with the same logic. Besides, if it will be possible the info flow can be furthered through a direct interface between the WMS and the Packing System bypassing the CSV file creation.

- The new WMS through an interface with YGLS and ACG has to receive all serial numbers and codes manage by the company. In this way the managerial software will push info within the WMS, but, at the same time, the WMS has to be able to create codes that will never compare in ACG/YGLS.

- Interface n°3 will be modeled to automate the stock download from the managerial server and the upload in the WMS as explained in the developing countermeasure section.

- FP means Free Pass. Not all goods managed by Yanmar Italy's warehouses, have to pass the quality control check. Indeed, based on the component's type and on the supplier who provides it, each SKU will have to undergo QC tests or not. For example, components sent by Yanmar Japan are always in FP. All this info, required by the WMS to guide the logistic operators, belongs to managerial software, so a specific interface is necessary.

- The sixth interface has the aim to further the loading process linking the one carried out in the managerial software and the one done in the WMS. For each process that uses a file as data driver, it will be necessary to either replicate the procedure, i.e. to make the new WMS able to perform it, or to automate it, bypassing the creation of the file. The final choice will be taken with the selected supplier, who will be able to technically evaluate the feasibility of creating the interface.

- The requirement of the mechanical processing department must be visible from the WMS, which with a frequency yet to be defined must create picking missions and propose them on the radio frequency terminals of the SP2.

- In order to implement countermeasure n°8: "Rotation index based warehouse", the new WMS must have access to the rotation indexes of each SKU managed by the warehouses. This information is contained in YGLS and ACG. For this reason, it will be necessary to have a dedicated interface capable of providing the WMS with constantly updated rotation indexes.

- In the scenario in which the part of the establishment not yet mapped by the WMS falls within the scope of the new product, it would be necessary to facilitate the process of unloading the Lamp Guide from the system. In this way, the operators who take care of restocking the production line will not be loaded with a new job. To implement this improvement, it would be necessary to create an interface capable of allowing administrative software to be able to automatically download the WMS when an engine is built (the components will be downloaded within the bill of materials of the engine in question)

WMS' PROVIDER SELECTION

The activities, carried out in parallel with the specifications' definition, have the aim to pursue the selection of the supplier of the WMS. This process, as described before, was structured on six steps:

1. Generate a list of possible providers.

   In order to identify the companies which can be validate candidates, three strategies were adopted. The first one consists in look within the company inquiring if the software firms already collaborating with Yanmar Italy provide also WMS. The second one, instead, engages the experience of white collars within the Planning&Logistic department. Through it, known and valuable companies can be proposed. In the third case, an info collection has to be fulfilled, to do it, the searching on the web was the main tool exploited.

2. Fix parameters in order to carry out a preliminary selection.

   The list of companies, built from the three sources of information just described, has been thinned out considering three single parameters as a driver:

   - the solidity of the software- provider company
   - the possibility to connect the provided software with ACG and YGLS
   - the nature of the finished product: it must be a group of one or more packages to be purchased, installed and parametrized and not something that has to be built from zero

   The third parameter proposed is implied by the necessity to implement the WMS in a restrained time horizon. Indeed, building an ad hoc product, naturally, requires more working days spent in software development. This kind of solution results useful whenever the client society managed logistic processes characterized by very particular mechanisms and procedures (Not as in Yanmar's reality).

3. Contact the providers chosen.

   The third step involves the organization of phone calls or video meetings in which preliminary information about the procedures, the logics and the info/material flows are provided to potential suppliers. In this first contact, the software companies briefly describe themselves and the main characteristics of the product offered.

4. Organize visits within Yanmar in order to make them able to formulate a proposal. In these visits WMS providers can see in first person how Yanmar's processes work, concretizing the explanations previously done. Moreover, also demos of the product are proposed to the Planning&Logistic employees.
5. Set up a comparison between the importance attributed by Yanmar to each request and how each supplier satisfies them.

Each provider who passed the previous selection was judged, with a value from

VENDOR RATING Technical Specification			PROVIDER	PROVIDER	PROVIDER	PROVIDER	PROVIDER	Value attributed	Weight
STD REQUESTS	1	Management of 20 digit alphanumeric codes	5	5	5	5	5	5	2,451%
	2	Creating codes	5	5	5	5	5	5	2,451%
	3	LU management	5	5	5	5	5	5	2,451%
	4	Management of finished product serial numbers	5	5	5	5	5	5	2,451%
	5	Search by code / station	5	5	5	5	5	5	2,451%
	6	SKU and LU displacement	4	5	4	4	5	5	2,451%
	7	Assigning codes to LU	5	5	5	5	5	5	2,451%
	8	LU assignment to station	5	5	5	5	5	5	2,451%
	9	Adding / removing quantity codes in Lu	5	5	5	5	5	5	2,451%
	10	Barcode and QR code reading	4	5	5	5	5	5	2,451%
	11	Print code / LU label	5	5	5	5	5	5	2,451%
	12	Layout faithful cell representation	1	5	4	4	5	5	2,451%
	13	Color usage (cell status)	1	4	4	4	5	5	2,451%
	14	Total number of cells + number of occupied cells	5	5	5	5	5	5	2,451%
	15	Reading Excel file for preload / pre-delivery notes	5	5	5	5	5	5	2,451%
	16	Picking list creation	5	5	5	5	5	5	2,451%
	17	Reports with codes appearing whose stock is under 1.6 times the	4	5	5	4	5	5	2,451%
	18	Match between preload and what was scanned (customs)	1	5	5	1	5	4	1,961%
NON STD REQUEST	19	Radio-frequency terminals able to read any barcode	3	5	5	4	5	5	2,451%
	20	Digital picking list management	5	5	5	5	5	4	1,961%
	21	Optimized picking path	5	5	5	5	5	4	1,961%
	22	Loading area suggestion	4	5	5	5	5	4	1,961%
	23	Delivery notes transformation in pre-loading	4	5	4	4	5	4	1,961%
	24	Codes in "Processing phase" or "In transit"	5	4	5	1	4	3	1,471%
	25	Loading and picking history with quantities for each code	5	5	5	5	5	4	1,961%
	26	Automatic LU creation	5	5	5	5	5	2	0,980%
	27	Not rigid but intelligent code search (browser)	4	5	4	4	5	2	0,980%
	28	Distribution of serial numbers for IM7 (customs)	1	5	5	1	5	1	0,490%
	29	Use of colors to identify product type and low RI SKUs	1	4	4	4	5	1	0,490%
	30	Inventory management	4	5	5	5	5	4	1,961%
	31	Stock visibility (access to WMS) in SP1, SP2, QC, FP, P&L	3	5	5	5	5	4	1,961%
	32	Inclusion of the Lamp Guide system in the WMS	5	4	4	4	4	1	0,490%
INTERFACES	33	Packing information system	4	4	5	4	5	5	2,451%
	34	Codes regisitry	5	5	5	5	5	5	2,451%
	35	Stock Update from ACG/YGLS to WMS (for purchased product)	4	5	4	5	5	4	1,961%
	36	Picking list created in ACG/YGLS → WMS' radio-frequency terminals	4	5	4	4	5	4	1,961%
	36.1	YDG generators	5	5	5	5	5	4	1,961%
	36.1	PowerPack/LocalDressed	3	4	3	3	4	4	1,961%
	37	Free Pass SKUs	3	5	4	4	5	4	1,961%
	38	Interfaces for loading process	4	5	4	4	5	5	2,451%
	38.1	Comp. CKD	4	5	4	4	5	5	2,451%
	38.2	Comp. LOCAL	5	5	5	5	5	5	2,451%
	38.3	FP from YJ	4	5	4	4	5	5	2,451%
	38.4	FP Series L	4	4	5	4	5	5	2,451%
	38.5	PowerPack/LocalDressed	3	4	3	3	4	5	2,451%
	38.6	FP YDG/Neander	5	5	5	5	5	5	2,451%
	39	Interface with mechanical processing	5	5	4	4	5	3	1,471%
	40	Interface with YGLS / ACG to access the rotation indexes	4	5	5	5	4	3	1,471%
	41	Interface with YGLS/ACG in order to unload the Lamp Guide WMS	5	4	4	4	4	1	0,490%
			4,16	4,84	4,66	4,42	4,91		

Table 23 - Specifications comparison

one to five, based on how his product satisfies each technical specification. These features, divided into standard requests, non-standard requests and interfaces, are the ones defined in the specifications definition phase. The last two columns, instead, are referred to how much importance Yanmar attributes to them, both with a value from one to five and in percentage terms (weight of the single importance). In the last row, the final evaluation is reported, it is computed as the sum of the value of each provider multiplied by the percentage importance attribute by the company. In this way, the highest value of this row corresponds to the software provider who better satisfies the proposed specifications.

6. Carry out a complete Vendor Rating and choose the more adequate software provider.

	VENDOR RATING	PROVIDER 1	PROVIDER 2	PROVIDER 3	PROVIDER 4	PROVIDER 5	Weight
1	Mobile hardware performance	3	4	4	4	5	10%
2	Software performance	4,16	4,84	4,66	4,42	4,91	30%
3	Mobile hardware cost (€)	16725	17540	17474	16578	16640	4%
4	Sofware license cost (€)	22000	25000	39850	15632	39460	8%
5	Software annual cost (€)	4000	3400	7173	2501	5472	2%
6	Time required (days)	17	6	40	30	49	13%
7	Implementation cost (€)	7650	3840	26900	33000	30160	8%
8	Years on the market	15	30	40	2	40	5%
9	N° installations	30	500	750	15	1000	4%
10	N° employees	2	22	50	10	150	3%
11	References	2	1	5	4	5	9%
12	Modularity (future add-ons)	3	5	5	3	5	4%
		2,91	3,58	3,09	2,80	3,30	

Table 24 - Vendor rating

In this final step, a classic vendor rating was implemented. To each parameter proposed was attributed a percentage weight. All these values were sized in accordance with the Planning&Logistic department consulting also the Administration office.

Rows 1, 11 and 12 are fulfilled with a judgment expressed with a value from 1 to 5, based on how the corresponding voice is satisfied by the software offered.

In particular, as “Reference” is intended the feedback released by companies that already have implemented the software considered.

“Modularity”, instead, is linked to the possibility to add further software packages post-WMS implementation. For example, provider 2 offers an add-on able to trace finish products and components expeditions. This feature depends on the nature of the product offered, some WMS was born able to be integrated with several other software, other ones have not this possibility.

All the other rows do not require explanations, but the computations of the final value which identifies every single provider (from 1 to 5) is not clear only observing the table. Indeed from row 2 to 10, were not proposed value within the already used range, but precise information obtained by providers during the visits or from the price quotations received.

As can be seen some cells are empty, this affects the truthfulness of the overall value obtained. However, the missing information is, nowadays, not yet provided by the software companies contacted.

THE HUMAN FACTOR

The implementation of the entire project involves the change, both from a hardware and software point of view, of an asset used by several workers within the company.

Any project similar to this one, also, implies procedural changes that, in turn, create a delicate situation to be managed. Indeed, to pursue the pre-set objectives, the implementation of the new product will not be enough, but also the logistic operators who use it will have to adapt themselves. For this reason, it is useful to propose a general examination of the difficulties that can characterize change within a generic logistics department. These issues can be summarized in six main pillars:

- Fear of the unknown: in the workplace, it is usual for each operator to be intimidated by the lack of information regarding the change that will be made
- Link to the old. The new is risky and difficult: operators have to get back into the “game” and change the schemes they have relied on. However, it is important to objectively recognize the shortcomings of the system and the benefits that a change would bring.
- Lack of skills: "What if I'm not capable?" This is a doubt which can afflict workers’ mind. Each change is preceded by doubts and insecurities about personal strengths and abilities. Changing the company's methods means changing the mentality of those who work there. Training courses, updating events, forming key users are the most useful tools
- Edit routine. Changing a tool means changing timing and methods, workflows, personnel management, data collection and reading. Each of these sub-change implies further difficulties
- Effect group: could occur that operators perceive the change as imposed on them without able to be part of it, so the first reaction is to reject it.

Starting from this background a qualitative analysis on logistic operators was done.

In particular, interviews with the eight warehouse workers were carried out. It was asked how they perceive their workload and the entity of the typical activities that they have to fulfill every day. Subsequently, through the help of the company tutor, who is the head of the Planning and Logistics department, a qualitative judgment of their workload was expressed. To carry out this step, also the Gemba Walk previously done result very useful.

In the third phase of the analysis, the reduction of the lead time previously computed was allocated on the eight operators considering that more than one workers fulfill more than one process based on the current company needs. For this reason, was possible only to obtain a qualitative description of the imminent workload reduction.

In the end, always through interviews, the openness to change of each person was defined. All steps described are reported in table 20.

Operator	Workload perception	AS-IS Workload	Workload reduction	Opennes to change
DZ	High	Low	Midium	Medium
AL	Medium	High	High	High
BD	Medium	Medium	Medium	Medium
LM	High	High	High	High
MH	High	Medium	Low	Low
MS	Medium	Medium	Low	Low
AA	Low	High	Medium	Medium
GC	Low	High	Medium	Medium

Table 25 - The human factor

The importance of the results obtained and the judgments expressed consists in deciding how to manage the change in progress. The company tutor will have additional information to his experience within the company to follow with greater attention the operators less open to change and, by broadening the focus of the analysis, exploit the procedural change in progress to redistribute departmental activities in a balanced way.

Indeed, during the implementation process of any change, managers must be focused on empowering their employees to take the necessary steps to achieve the goals of the initiative. They should also do their best to anticipate roadblocks and prevent, remove, or mitigate them once identified. Repeated communication of the organization's vision is critical throughout the implementation process to remind team members why change is being pursued.

Finally, the last consideration has to be done: once the change initiative has been completed, managers must prevent a reversion to the prior state or status quo. This is particularly important for organizational change related to processes, workflows, and strategies (as for this kind of project).

Without an adequate plan, employees may backslide into the "old way" of doing things, particularly during the transitory period. By embedding changes within the company's culture and practices, it becomes more difficult for backsliding to occur. New organizational structures, controls, and reward systems should all be considered as tools to help change consolidation. Among them, standardization is the most useful one; indeed, standardizing a process means defining its operating methods making the improvement achieved effectively acquired and exploiting it as new baseline for future changes.

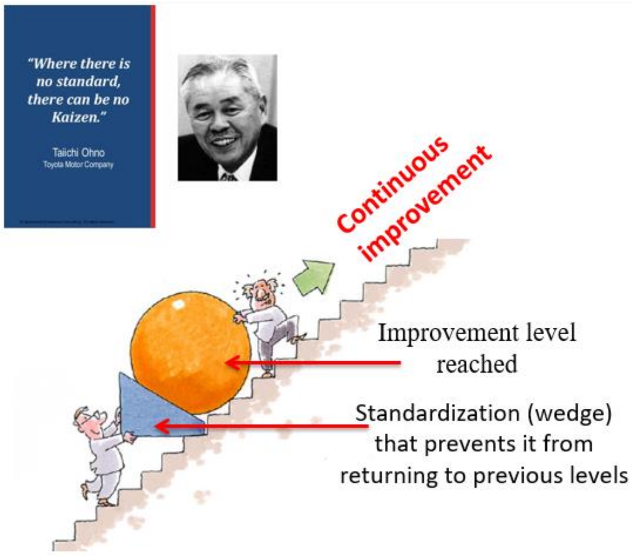


Figura 22 - Standardization Wedge

Concluding the section dedicated to the "human factor", it is useful to consider it as a driver in the selecting process of the product to be purchased. Indeed, the change in the technology adopted cannot be unilateral but, precisely, must be bilateral. Specifically, not only the organization, as a group of people, has to change itself to optimize the final result, but also the choice of the most suitable alternative for the people who will have to use the new WMS must be at best performed.

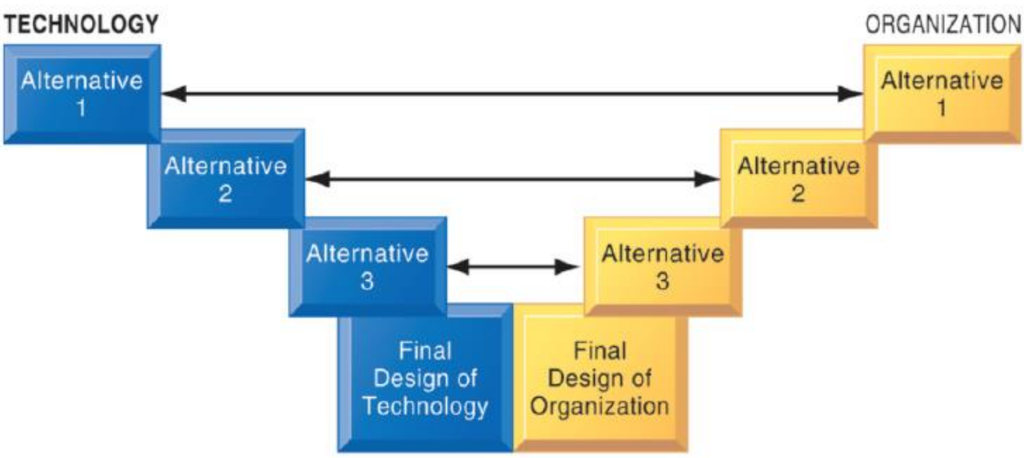


Figure 203 - Technology and Organization adaptation

MY EXPERIENCE

The best way to conclude the writing of this master thesis is to describe the experience lived in first person.

The project started on July 6, the day when I was thrown into a completely new working environment. The first impression, confirmed in the following months, was more than positive, both in terms of welcome towards me and seriousness demonstrated by the entire company staff.

During the project, I had the opportunity to meet and know the majority of the Yanmar's workers: each of them have never been reluctant to explain the procedural peculiarities typical of the processes they carry out. In terms of professional growth, this experience was outstanding, I learned what it means living the office-life every day, collaborating and aligning on the work personally done.

Moreover, I noticed how immersing completely in the world of logistics is exciting and at the same time extremely complicated.

For what concerns technical the developed skills , today, I can claim to have a good knowledge of the main logistics regularly carried out in a manufacturing company.

I sincerely acknowledge Engineer Alberto Villa, head of Planning&Logistic department as well as company tutor of this industrial management laboratory 2. He always believed in my potential, he followed me constantly throughout the project and, supporting me with his experience and his know-how, he supervised every analysis made, information obtained or decision taken in order to achieve the best result. I moreover express further thanks to Yanmar Italy's president, Engineer Carlo Cavallero, active presence in the project development: day after day he enriched the whole experience by maintaining the focus always on the big picture and providing his terrific expertise. Fundamental was the help of also all other Yanmar's employees and operators who always demonstrated themselves available to dedicate their time when necessary.

The final thanks are dedicated to Bassel Kassem, academic tutor of the laboratory, he not only offered me the opportunity to live this experience, but he provided essential support

for the development of the project. Moreover, I noticed how the IMLAB seminars proved to be very useful when implemented in daily working life. More than once, I exploited “relationship management” tips from Prof. Marangon and the presentation techniques of Prof. Baiguini. For all these reasons, I am truly grateful to the entire Industrial Management Lab team under the supervision of Prof. Portioli for the opportunity offered and their efforts.

LIST OF FIGURES AND TABLES

FIGURES

TABLES

REFERENCES

BIBLIOGRHPHY

1) G. RICHARDS, “Warehouse Management: A Complete Guide to Improving Efficiency and Minimizing Costs in the Modern Warehouse”, Kogan Page Publishers, 2017
2) J. P. WOMACK, D. T. JONES, “Lean Thinking: Banish Waste and Create Wealth in Your Corporation”, *Journal of the Operational Research Society* 48(11), 1997
3) J. FLINCHBAUGH, “A3 Problem Solving: Applying Lean Thinking”, Lean Learning Center, 2012

WEBOGRAPHY

1) https://www.yanmar.com/global
2) https://searcherp.techtarget.com
3) https://discovery.rsm.nl Article by Jan Dul: “Human factors in business: creating people-centric systems”
4) https://www.inboundlogistics.com

A3 No. and Name	Team members (name & role)
	1. Simone Ratti

Stakeholders (name & role)	Department
1. Carlo Cavallero	President
2. Alberto Villa	Head of Planning & SupplyChain
3. Leonardo Marino	WH operator
4. Aristide	Wh operator

YANMAR

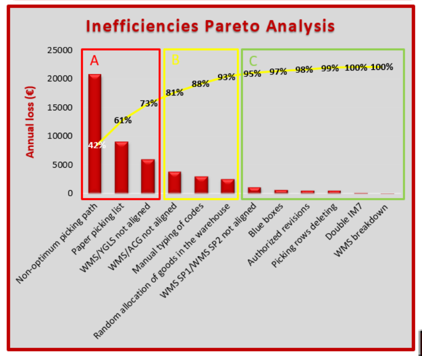
1. Clarify the problem / Problem Backgroud / Current situation

Timelosses, process time inefficiencies. Absence of real time information. Inefficent digital information flow (IT) characterized by the missing connection among the software of the different departments.

Future benefits of an agile IT information flow:

- Financial aspect. Reduction of human error which imply costly corrective action.
  Avoided losses optimizing the support to the production
- Managerial aspect. Reducing time dedicated to avoidable and non-value-added tasks both within:
  1) the wharehouse
  2) the Planning and Logistic Department
  3) Manufacturing site

2. Breakdown the problem



Inefficiency	Annual loss (€)	Cumulated (€)	Cumulated (%)	Class
Non-optimum picking path	20696	20696	42%	A
Paper picking list	9060	29756	61%	A
WMS/YGLS not aligned	6000	35756	73%	A
WMS/ACG not aligned	3900	39656	81%	B
Manual typing of codes	3080	42736	88%	B
Random allocation of goods in the warehouse	2584	45320	93%	B
WMS SP1/WMS SP2 not aligned	1200	46520	95%	C
Blue boxes	727	47247	97%	C
Authorized revisions	633	47880	98%	C
Picking rows deleting	573	48453	99%	C
Double IM7	218	48671	100%	C
WMS breakdown	80	48751	100%	C

			INEFFICIENCIES (€/year)												
Process	Object	Warehouse	1	2	3	4	5	6	7	8	9	10	11	12	Total
Loading	Series L	SP2	2195								1656			8	3859
	Series L	SP1									663			8	671
	PP/LD	SP2												8	8
	Neander/YDG	SP2	885	727		633								8	2253
	Engines	FP						4350	3450					8	7808
Picking	Series L	SP2								1200				8	1208
	Series L	SP1			6840		2267				265			8	9380
	PP/LD	SP2			13856		3247					573		8	17684
	Neander/YDG	SP2					3547							8	3555
	Engines	FP						450	450				218	8	1126
Partial Sums (€/year)			3080	729	20696	633	9060	4800	3900	1200	2584	573	218	80	47552

1) The picking time for assembly kits of power pack motors is very high

In fact he missions related to this kind of picking are not optimized, as we can see in the spaghetti chart

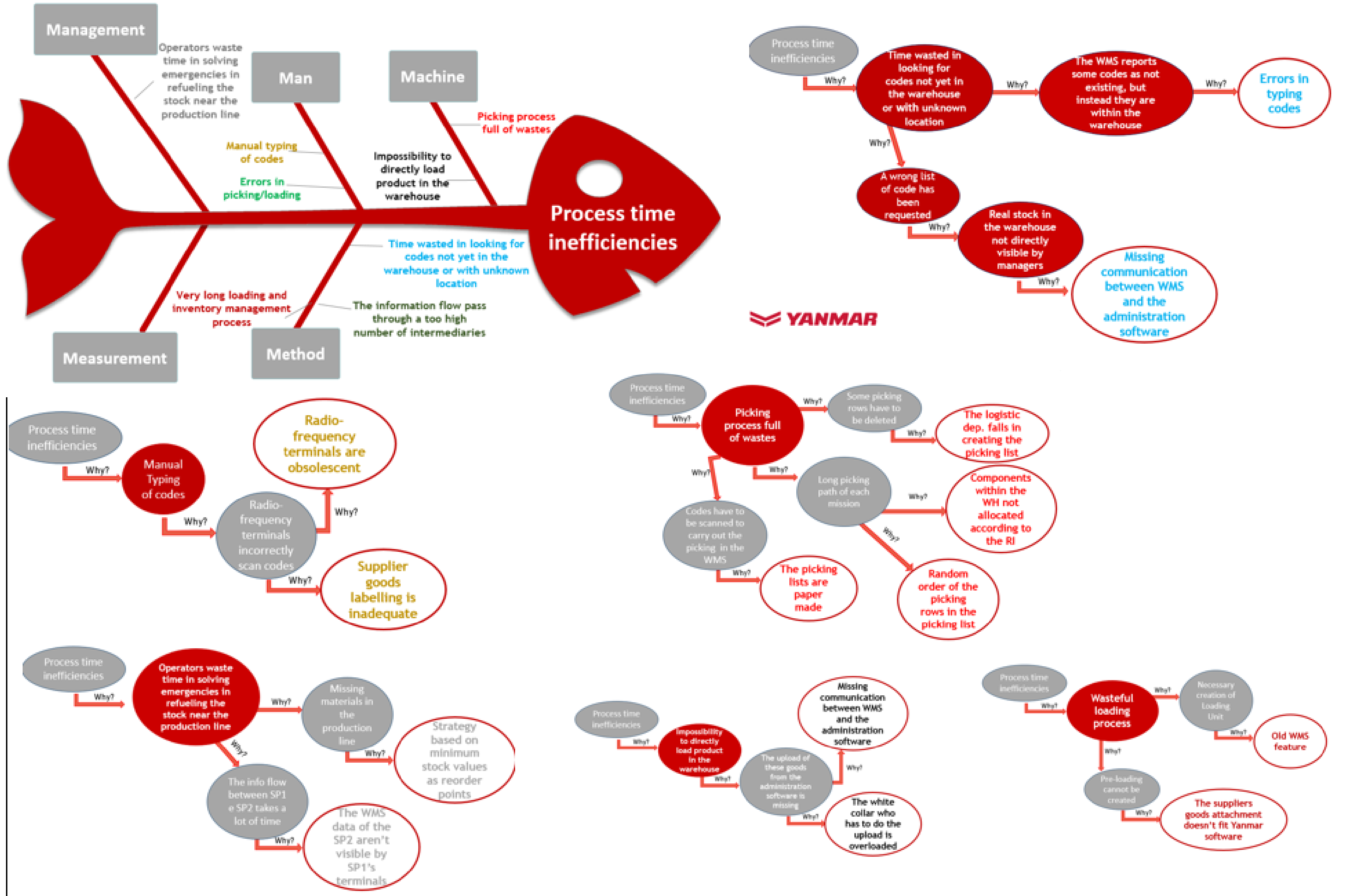
3. Set the Target

Focusing on reducing time/monetary inefficiencies:

> Must have:
1) Elimination of the heaviest inefficiencies with a reduction of the 40 % of the monetary losses

> Nice to have:
Elimination of the majority of the inefficiencies with a reduction of the 80% of time losses

4. Analyse the Root Cause



5. Develop Countermeasures

#	Rootcause	Countermeasure	Inefficiency solved	Saving (€)
1	Radio-frequency terminals are obsolescent	NEW PDAs	MANUAL TYPING OF CODES	€ 3.080,00
2	The suppliers goods attachment and they registries don't fit Yanmar software	PRE-LOADING GENERATION SHARED REGISTRIES	AUTHORIZED REVISIONS	€ 633,00
3	The WMS data of the SP2 aren't visible by SP1's terminals	ONLINE STOCK VISIBILITY	BLUE BOXES	€ 727,00
4	Strategy based on minimum stock values as reorder points	REQUIREMENT BASED LOGIC	WMS SP1/WMS SP2 NOT ALIGNED	€ 1.200,00
5	The logistic department falls in creating the picking list	NEW PPLD PICKING LIST GENERATION	PICKING ROWS DELETING	€ 573,00
6	Random order of the picking rows in the picking list	OPTIMUM PICKING PATH GENERATOR	NOT OPTIMUM PICKING PATH	€ 20.696,00
7	Components within the WH not allocated according to the RI	ROTATION INDEX BASED WAREHOUSE	RANDOM ALLOCATION OF GOODS IN THE WAREHOUSES	€ 2.583,60
8	The picking lists are paper made	DIGITAL PICKING LIST	PAPER PICKING LIST	€ 9.060,00
9	Missing communication between WMS and the administration software	WMS INTERFACE WITH ACG AND YGLS	WMS/ACG NOT ALIGNED WMS/YGLS NOT ALIGNED	€ 7.800,00
10	The white collar who has to do the upload is overloaded	TASK REDISTRIBUTION	WMS/ACG NOT ALIGNED WMS/YGLS NOT ALIGNED	€ 2.100,00
11	Old WMS feature Loading units based	/	/	/
12	The actual WMS fails in distinguish code linked to different documents	SMART MATCHING	DOUBLE IM7	€ 218,00
13	The WMS data are not coherent with the real stock	UPDATE POST INVENTORY	/	/
14	WMS software is obsolescent	PURCHASING A NEW WMS	WMS BREAKDOWN	€ 80,00