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Department of Management and Production Engineering
MSc in Engineering and Management

Lean Management Principles Applied in The Aerospace Industry

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Table of Contents

Introduction

Keeping up the pace with intense competition, weaker customer demand, facing the economic uncertainty trend and the ongoing trade war between the U.S. and China, many businesses are likely to face more challenging time than most.

Given the following outlook of the industry by Deloitte;
"The defense sector soared in 2019 as defense budgets increased. But production-related issues, cancelations and fewer orders slowed growth in the commercial aerospace sector and the global aerospace and defense industry overall."

Since the high pressure and slow growth in the aerospace & defense industry, the redesign of their strategies, organization and operating business model is becoming a necessity for the current market leaders.

The key challenge is to realize the threat, focus on the opportunities which can be exploited to better redesign the business, adopt innovative improvement actions, implement waste reduction, and assuring high customer satisfaction.

Lean management is the tool that has proven its reliability, consistency and resiliency when dealing with lean transformation. The approach to lean management is learning by doing, in a continuous improvement contest.

The lean transformation is the process of introducing organizational changes to maximize the value proposed to the customer.
It is possible to apply lean management in any production process, activity and business.
The three pillars of lean management are:

1. Continuous improvement
2. Eliminating any waste
3. Generate more value (from the point of view of your customer)

Lean management encourages shared responsibility, incentives leadership and does not centralize the work control.

1. Lean management history

Talking about lean management the first name you that comes in mind is Toyota, even though it's interesting to say that the first person who implemented the system was Henry Ford. However, Henry Ford's system had some limitations, since it was very specific and lacked variety.

It was after the WWII, in 1930s Toyota invented the TPS (Toyota Production System) -inspired from Henry Ford's flow of production-, but the new system was designed to give more focus on the production process as a whole. The goal was to reduce costs and improve the workflow, which is interpreted as achieve operational excellence and economies of scale.

Lean management was continuously revived, whenever industry needs have changed.
The evolution can be summarized as follows:

1. Early developments (Frederick W. Taylor Originator of Scientific Management)
2. Henry Ford era with the first (comprehensive manufacturing strategy)
3. TPS (Toyota Production System)
4. WCM (World Class Manufacturing)
5. Lean Manufacturing

2. What is lean management

Lean management is continuously improving the working process, people and purposes. It's the decentralization of working process, which encourages leadership and shared responsibility, instead of trying to centralize the control of the working process. Lean management cannot be created in an instant, instead, it needs to evolve gradually.

Lean management basic five activities are illustrated in figure 1:

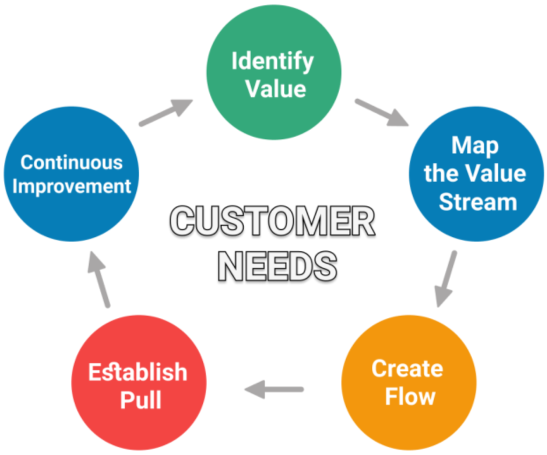


Figure 1, Lean management Basic five activities

1. Identify the value:

The value added should be from the customer's point of view, in more detail the value lies in the solution you are trying to provide for your customer, from here willingness to pay arise.
If other activities -that do not bring value to the final product are part of the process- exists, those type of activities are called waste.

2. Map the value stream:

The mapping the whole value of any company is an important activity. All people with effective actions should be involved in the process, then the waste is identified (the non-value adding activities).
Mapping the value stream should make it easier to measure, evaluate, report and then improve the process.

3. Create flow:

The flow should be streamlined by breaking the production process into smaller batches and visualizing the flow.
After that the next step is to identify bottlenecks and production problems, to resolve them.

4. To establish a pull system:

A well-established pull system can guarantee, optimize capacity and deliver the product or service when needed.

5. Continuous improvement:

The last step and the most important one because the system is not static, and if any problem occurs every employee should be involved in the process improvement to guarantee a sane production system.

Some benefits of implementing lean management on the overall organization:

1. Leads to cost reduction achievements
2. Can increase the production output and the process quality
3. Helps to better utilization of resources
4. Improves various important metrics like productivity and efficiency

3. Thesis objective

The lean management practices are widespread across many industries, especially in the aerospace industry thanks to its effectiveness, positive impact and core values, those practice are necessary to assure efficient company performance. It is also considered a very efficient managerial tool to eliminate waste and to improve different working aspects.

The aim is to apply the philosophy of lean management in various business segments; production, design, and efficiency management.

The thesis will illustrate in a practical way the adoption of ACE (Achieving Competitive Excellence) operating system, which establishes on a solid base the change of some strategic decisions, along with many improvements in the current manufacturing process.

The implementation of a new production cell based on Achieving Competitive Excellence Operating System (ACE OS) -where the most undesirable effect is the waste generated in the process, which must be eliminated-, the methodology is considered the turning point to achieve operational excellence.

Once the cell is implemented then monitoring, improving the efficiency, improve the utilization of resources (UOR) and productivity metrics is based on the lean methodology that becomes a priority.

Then finally formulating a business plan, given all the challenges and possibilities of improving the process with the aim of generating more value added.

4. Thesis structure

The thesis is structured in three main pillars:
1. A new production cell according to ACE (Achieving Competitive Excellence) principles.
2. Efficiency management, by following a structured process of calculating the efficiency by following lean management principles and activities.
3. Business plan to introduce the average tool life concept on a specific machine, -due to the importance of the part numbers manufactured on this machine-, and the strategic decision to outsource the warehouse tool management.

Chapter 1: Industrial context of the aerospace and defense industry

1. Defining the aerospace and defense manufacturing industry

Given the current outlook of the aerospace and defense industry already introduced in the previous section, applying the Porter's five forces analysis model is helpful because it assesses how is the industry structured in order to formulate a correct corporate strategy based on the industry weaknesses and strengths. The main goal of the analysis is to be a guide to formulate the right strategy to achieve competitive advantage.

The model mainly is focalized on the threat of new entrants, the threat of substitutes, the buyers and suppliers bargaining power and finally the rivalry in the current situation. The model is applied on the aerospace and defense industry below.

1. Threat of new entrants: Low

The reason behind the low threat of new entrants is that the A&D (aerospace and defense industry) is characterized by high capital requirements, high cost of initial investments, high R&D expenditures and the presence of economies of scale.

All the intense capital requirements make it difficult for small companies to enter the competition, and even if they can secure the funds needed, the high-risk environment imposes severe barriers to entry on the small companies.

2. Threat of substitutes: Low

The reason behind the low threat of new substitutes is that the market is dominated by OEM's (original equipment manufacturers) because the reputation and safety is a main concern in the aerospace industry and the fleet owner companies have to follow all the standards and regulations imposed by the government.

In addition, they need to buy products that obtained certain certifications, to be considered valid and eligible to fly.

3. Bargaining power of buyers: Medium

The reason behind the medium bargaining power of buyers, is the high manufacturer market concentration ratio, which leaves the buyer with limited choice when comes choosing the suppliers.

Also, due to quality reasons the main manufacturers are always preferred over other suppliers.

4. Bargaining power of suppliers: Medium

The reason behind the medium bargaining power of suppliers is that there are few manufacturers, it gives the suppliers more bargaining power, and the raw material has become a commodity, so suppliers try to establish a long-term contract to have a more stable business.

5. Rivalry in the industry: Moderate

The reason behind the moderate rivalry in the industry is that the large manufacturers compete with each other, to secure long-term supply contracts.

Based on Porter's 5 forces analysis, it's clear that in this phase of the industry, operational excellence becomes the key success factor and from here emerges the need of having a lean management system, which can correctly implement a continuous improvement methodology which leads to the achievement of competitive excellence.

2. Illustrating ACE (Achieving Competitive Excellence) principles

The thesis is focused on a real case study performed in a company in Turin operating in the aerospace industry, from the market analysis it turned out that the main key success factor in aerospace industry is operational excellence. This is the starting point to introduce the company Op-Sys (operating system), in order to be aligned and formulate the future strategy on solid bases.

An ACE (Achieving Competitive Excellence) operating system represents the method in which every employee in the company work every day, by using simple instruments and tools to improve quality and optimize the value flow for the benefit of the customer.
Figure 2 represents the key elements of the ACE (Achieving Competitive Excellence) operating system which are culture, competence and instruments.

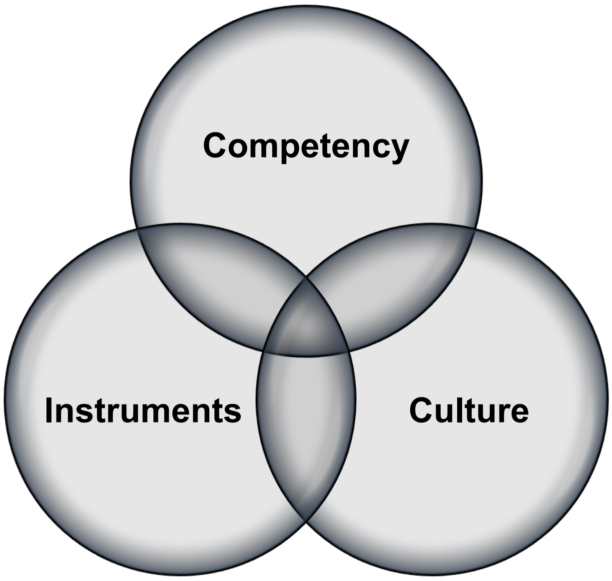


Figure 2, Key elements of ACE operating system.

Culture is the shared set of rules, values and languages beside the enabling infrastructures that characterizes the organization. ACE's (Achieving Competitive Excellence) competencies are mainly achieved only if every employee understands and uses the operating system and tools.

The ACE (Achieving Competitive Excellence) framework is client-centered, data-oriented, process-driven and is focused on the achievement of results. An ACE (Achieving Competitive Excellence) tools are a set of methods and strategies that empowers to actualize principal changes in the process and in the products.

The tools are considered the hardware that integrates and completes the human component of the culture. Competence is the set of skills that allows to effectively utilize the culture and tools of the ACE (Achieving Competitive Excellence) operating system.

Competence is acquired by the learning, application and share of the ACE (Achieving Competitive Excellence) informational knowledge system. The ACE (Achieving Competitive Excellence) certification program provides a framework to deal with the advancement of personal and individual abilities.

3. <u>Sharing ACE (Achieving Competitive Excellence)</u>

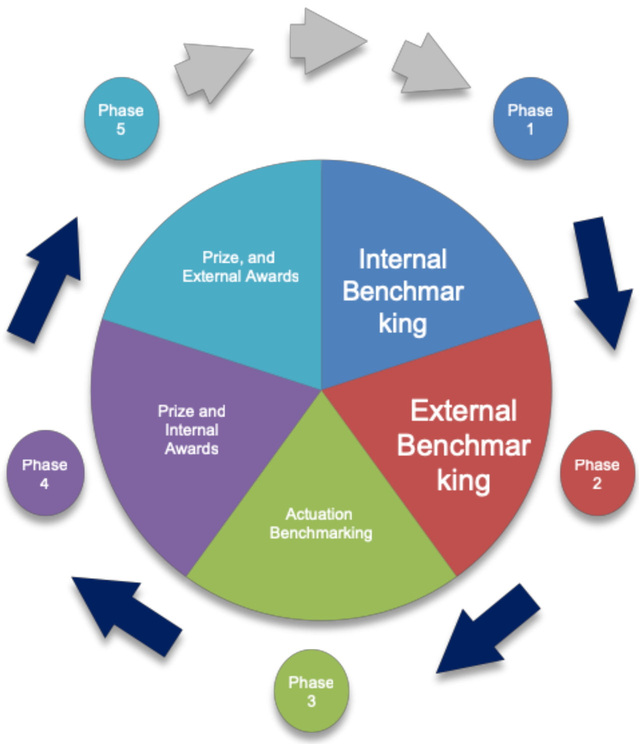


Figure 3, Phases of sharing ACE

In figure 3, the framework of sharing the system within the company is organized in five main phases. The ACE (Achieving Competitive Excellence) operating system encourages stimulation by the successes and the usage of the best practices implemented by individuals across the organization.

The first, second and third phase is benchmarking, with internal and external partners to understand how others have resolved the problems. The third and fourth phase is the prize, internal and external award, when an effective solution is found to solve any problem, it is important that the success is shared, so that others gets the incentive and makes congratulations for whoever person that solved the problem.

4. <u>ACE Instruments (Achieving Competitive Excellence)</u>

Figure 4, Tools of ACE system

The breakdown of ACE (Achieving Competitive Excellence) tools is composed by two main categories:

1. Process improvement and waste elimination: it includes 5s, VSM (Value Stream Mapping), standard work and TPM (Total Production Maintenance)
2. Problem Solving DIVE (Define, Investigeate, Verify and Ensure) Process: it includes MFA (Market Feedback Analysis), QCPC (Quality Clinic Process Chart), and mistake proofing

Taking figure 4 as a reference, the most important concepts are explained in detail:

- 5s: is the set of japanese words that describes the organization process in a workplace, the english equivalent words are:

  1. Seiri (Sort): is the process of removing the items that are not needed
  2. Seiton (Straighten, Set): is the process of organizing to insure higher efficiency and better working flow
  3. Seiso (Shine, Sweep): is the process of housekeeping to make the working area clean, and hence much easier to detect potential problems
  4. Seiketsu (Standardize): is the implementation of color lables, and define the standard work, to make the flow more streamlined
  5. Shitsuke (Sustain): is the development of the set of behaviours to sustain all the organized method of working over the long term

- TPM (Total Productive maintenance): it's the system, that improves and maintain the integrity, quality and safety of the produced parts by keeping all equipment in the best working conditions to avoid any delay or breakdown of the production system.

  TPM (Total Productive maintenance) involves the line operators by extending their role from just using the machine to perform cleaning and other important maintenance functions. The involvement of the line operators to maintain the machines is an effective way to increase the productivity and efficiency, because it makes it easier to diagnose the machine if there is an abnormality. The concept is associated to other methods used like 5s, and SW (Standard Work).

- SW (Standard Work): The fundamental premise of standard work is to facilitate the flow of people, material, and information in order to deliver to the customer what they want in the amount they want it, the moment they want it. Manufacturing Standard Work is the system of developing a baseline standard of how to perform a process, then analyzing the standard to develop the best-known method for performing the work.

  Once the best-known method is known or identified, the standard work is re-written and used to minimize variation in the work. In any efficient continuous improvement system, the process of applying manufacturing standard work is cyclical.

The standard applies until a better standard is found.

- MFA (Market Feedback Analysis): Is the collection of customer feedback in order to analyze the quantitative data, regarding their whole experience from placing the order to the recipient of the final products, in terms of product quality, service, delivery and responsiveness, which means the overall customer satisfaction from the organization.

  This process is done by a customer survey, and the customer should fill in the survey. Once done the scores can be reported by a monthly basis, it's also often used as a KPI (Key Performance Indicator).

- EH&S (Environmental, Health & Security): the implementation of EH&S program, is mainly for preventing serious injuries, illness and harmful workplace incidents.

5. <u>Defining lean management</u>

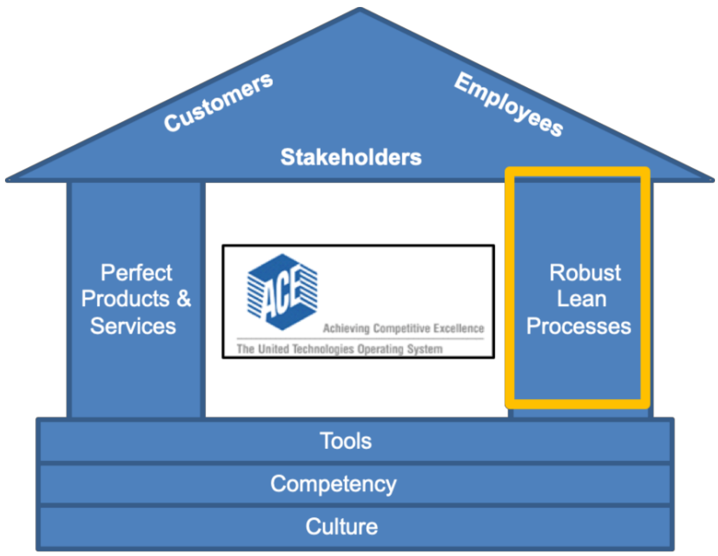


Figure 5, Importance of Lean in ACE Operational system

Lean management is a business strategy to profitably grow market share focused on creating and improving flow, the main idea is based on delivering the customer requirements that they expect, with perfection.

Lean management business strategy is based on ACE (Achieving Competitive Excellence) methodology. In figure 5 the tools, competency and culture are the main foundational elements of the strategy, lean process is the first main pillar to sustain the strategy, perfection is the second pillar.

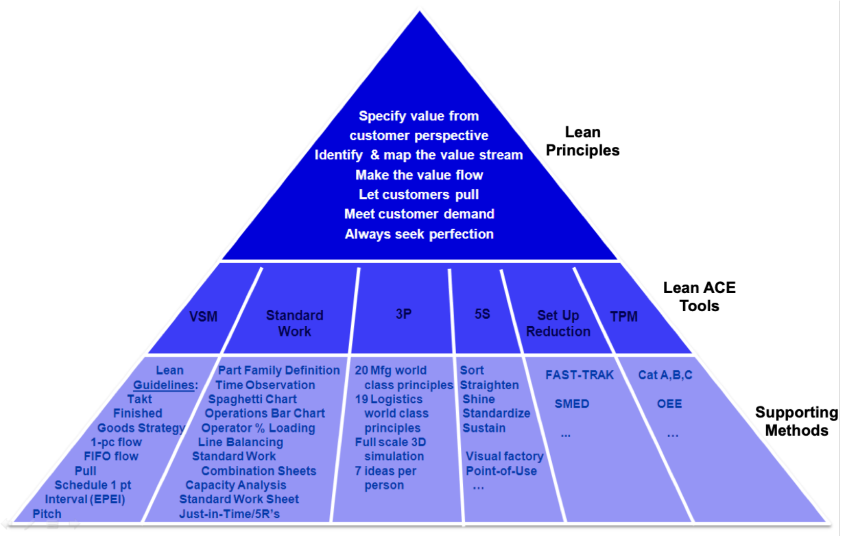


Figure 6, Lean principles, ACE tools and supporting methods

As illustrated in figure 6, in the topline of the pyramid lean principles are associated with understanding the customer needs, the appropriate tools used which are the ACE (Achieving Competitive Excellence) tools, with the support of some supporting elements and methods.

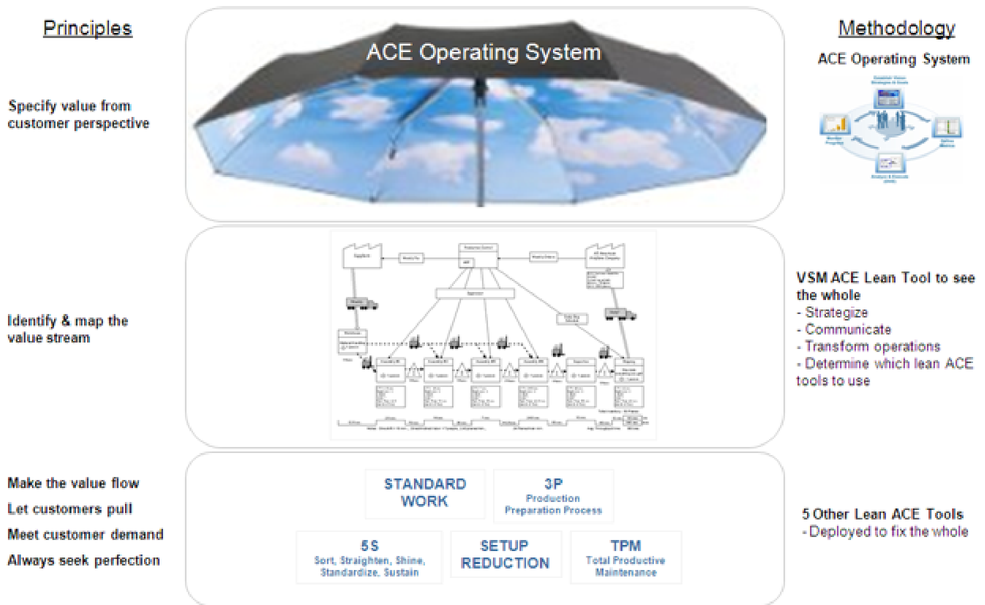


Figure 7, Principles and methodology of ACE

As illustrated in figure 7, VSM (Value Stream Mapping) is considered the link between the operating system and the tools, because it is the lean management instrument that allows to map the whole process starting from suppling to the end users (customers), where it is challenging to understand and identify the non-value adding processes.

The correct implementation of the lean management business strategy and the commitment to use the appropriate ACE (Achieving Competitive Excellence) tools and supporting methods, especially in the machining department can lead to the reduction of the manufacturing costs, improvement of the final product quality and increasing the utilization of resources.

6. Cell design introduction

After having introduced the operating system of the company and the lean management business strategy, this section is dedicated to design a new production cell following the same ACE (Achieving Competitive Excellence) methodology.

Cell design is a methodology applied to design and adapt physical processes to guarantee the best-known work method implementation. Cell design is the physical design and layout of a process area to optimize flow and reduce waste.

MSW (Manufacturing Standard Work) and cell design are foundational elements to understand the current processes, the opportunities, developing and operating in a lean future state.
This ensures that the product is delivered in the best possible time, at the lowest possible cost, and with the least turn-backs.

Everyone should have a well-defined responsibility and role. For example the operator should follow the standard work and also should know what the customer needs are, the cell leader (the supervisor) should have a quick visibility for what regards the areas of opportunity within the cell for example (capacity, demand and violation of standards, the general manager, should also have a quick visibility but for what regards the opportunities of improvement between the cell and the whole site.

Following the MSW (Manufacturing Standard Work) methodology for cell design ensures the following:

- Work areas (cells) are defined into part families in order to make the flow streamlined and not facing any obstacles
- Processes are measured in order to understand in the reality the situation today (what the baseline is)
- Processes are analyzed to identify how the baseline performance compared with the customer needs is situated
- Processes are optimized and a new layout that facilitates the streamline is defined
- Processes are standardized and the best processing methods are followed

7. Phases of cell design

After defining what is cell design, in this section the discussion is focalized on the phases needed to design a cell.

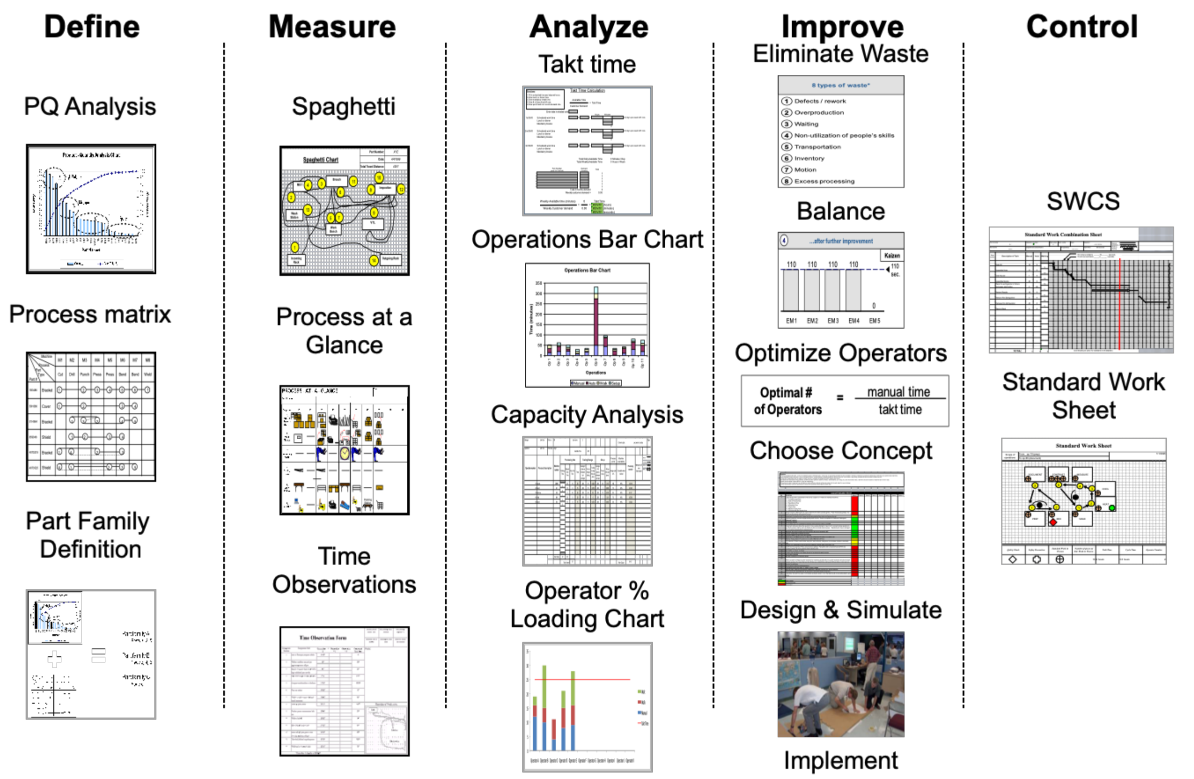


Figure 8, Generalization of all the steps and sub-steps to design a cell

In figure 8, a visual overview of the cell design steps and tools that are used in MSW (Manufacturing Standard Work) and cell design is provided. Each element is crucial to ensure the best possible outcome and the cell ability to create a reliable streamlined flow to the customer and achieve the best possible design.

The first phase is the define stage; and it is composed by PQ (Product & Quantity) analysis, process matrix and part family definition. At the end of the define stage it is possible to know how many part families and which part families are present.

The second phase is the measure stage; and it is composed by spaghetti chart, process at a glance and time observation. At the end of the measure stage it is possible to know the baseline of the current performance.
The third phase is the analyze stage; and it is composed by takt time analysis, operation bar chart implementation, the capacity analysis and the operator load chart. At the end of the analyze stage the imbalances that are occurring and where the bottlenecks are occurring to the customer standard are easily identified.

The fourth phase is the improve stage; and it is composed by waste elimination, line balancing, optimizing the operator, design & stimulate and implement. At the end of the improve stage a clear roadmap on what can be improved to create a stable flow and to design or modify the cell is available.

The fifth and the last phase is the control stage; and it is composed by the SWCS (Standard Work Combination Sheet). At the end of the control stage, each operator will be provided the documents they need to understand their task to ensure flow is occurring in our cell design.

The task now is becoming clearer, following the steps illustrated above, one by one it is possible to design the cell for the machining department.

7.1. Define phase

- PQ (Price & Quantity) analysis

PQ (Price & Quantity) analysis is important to understand and analyze the relationship between products and quantities (production output). The main idea is evaluating the mix of products being produced.

Procedure to apply PQ (Price & Quantity) analysis:

1. Three to six months data on product and parts for all the output is needed to perform the calculations
2. Use the data to calculate the total production output required for each part number, after that they should be listed in a descending order on P-Q analysis

Note that:

- The running total is the sum of this part plus all previous rows of demand quantities.
- Total quantity % is the running total divided by the total quantity.
- % total part number is the number divided by the total number of part numbers (example 1/21 = 5%)

3. Converting the list into a chart, where the quantity is on the vertical axis and part numbers are on the horizontal axis.
4. Use a graph to plot the running total, and the % of total part numbers on the previous same chart.

Part Number	Part Name	Demand Quantity	Running Total	% Total Quantity	Cumulative % Total Quantity	% Total Part Numbers
15xxxx	SHAFT GLOBAL	684	684	23,2%	23,2%	5%
15xxxx	SHAFT GLOBAL	432	1116	14,7%	37,9%	10%
15xxxx	SHAFT GLOBAL	336	1452	11,4%	49,3%	14%
15xxxx	SHAFT GLOBAL	314	1766	10,7%	60,0%	19%
15xxxx	SHAFT GLOBAL	180	1946	6,1%	66,1%	24%
15xxxx	SHAFT	180	2126	6,1%	72,2%	29%
16xxxx	SHAFT	180	2306	6,1%	78,3%	33%
15xxxx	SHAFT	96	2402	3,3%	81,6%	38%
15xxxx	SHAFT 1-2-3	90	2492	3,1%	84,6%	43%
15xxxx	SHAFT	80	2572	2,7%	87,4%	48%
15xxxx	SHAFT NR4	74	2646	2,5%	89,9%	52%
16xxxx	SHAFT	50	2696	1,7%	91,6%	57%
16xxxx	SUPPORT BUSH	50	2746	1,7%	93,3%	62%
16xxxx	SUPPORT BUSH	40	2786	1,4%	94,6%	67%
16xxxx	SUPPORT BUSH	40	2826	1,4%	96,0%	71%
16xxxx	SUPPORT BUSH	40	2866	1,4%	97,4%	76%
15xxxx	SUPPORT BUSH	24	2890	0,8%	98,2%	81%
15xxxx	SUPPORT BUSH	20	2910	0,7%	98,8%	86%
15xxxx	SUPPORT BUSH	12	2922	0,4%	99,3%	90%
15xxxx	SUPPORT BUSH	12	2934	0,4%	99,7%	95%
15xxxx	SUPPORT BUSH	10	2944	0,3%	100,0%	100%
Total Quanitiy =		2944	Number of P/N's =			21

Figure 9, P&Q analysis calculation for the machining cell

In figure 9, the calculations (for example the cumulative % total quantity and % total part number) for the part numbers of the machining new cell is illustrated and the total quantity is calculated.

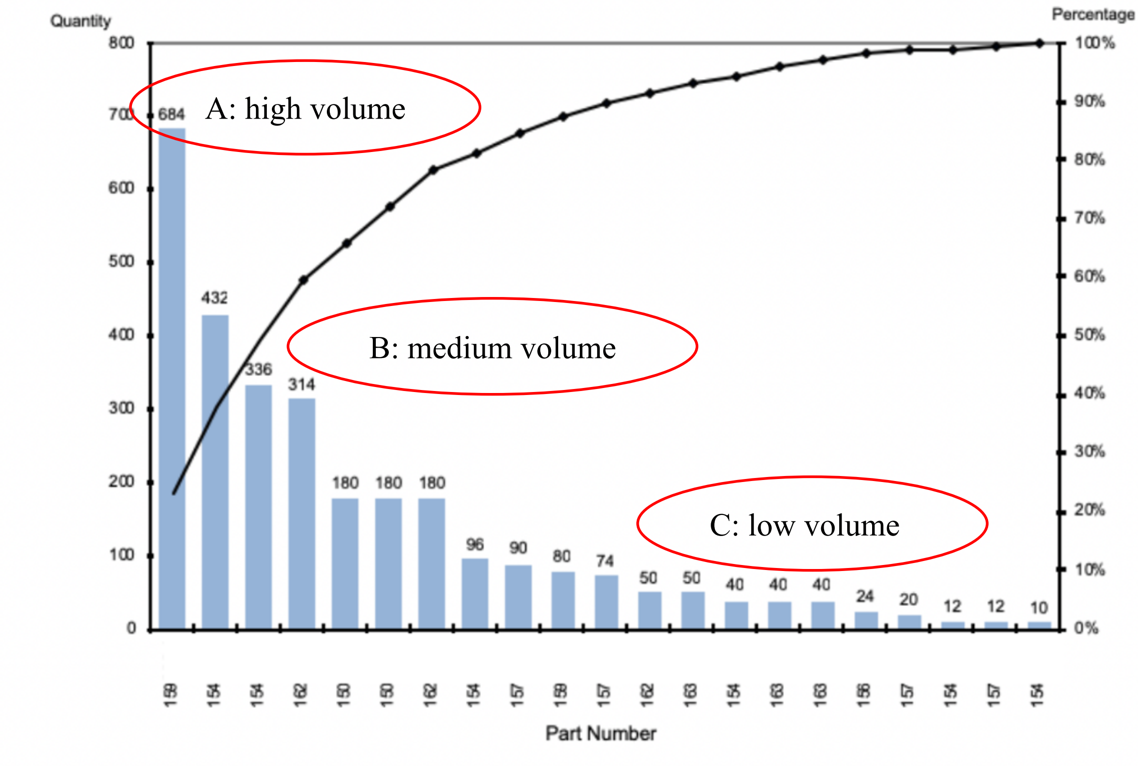


Figure 10, P&Q analysis chart

Figure 10 is simply a comparison between quantity (represented by the blue bar) and different part number percentage. The first axis represents the quantity, the second axis represents the part number and the third axis represents the percentage. There are 3 main part number categories, the first one A is characterized by highest volume, B by medium volume and C with low volume.

- <u>Process matrix</u>

Process matrix has the aim of establishing the various types of machines, tools and equipment needed to process each part number and define the path the process takes.

Process Matrix highlights the parts that should be processed together in the production cell and which parts should be re-processed in order to match or at least have a similar flow compared with the flow of the other parts.

Procedure to apply the process matrix:

1. Listing part numbers and part type vertically, then using the primary part loads (80% of the volumes) from the P-Q analysis
2. The star part is inserted first, then the other part numbers based on the descending order of load

Star Part definition: is the part with the largest schedule that goes through the most processes in its part family. The star part is taken, it's the highest volume identified for the part family in the PQ Analysis.

3. Listing machines, equipment and the process name horizontally
4. Showing the sequence of operations for each part number using a number that is inside a circle
5. The dash line represents reversal
6. Identify the key re-processing sequences to eliminate any reversals

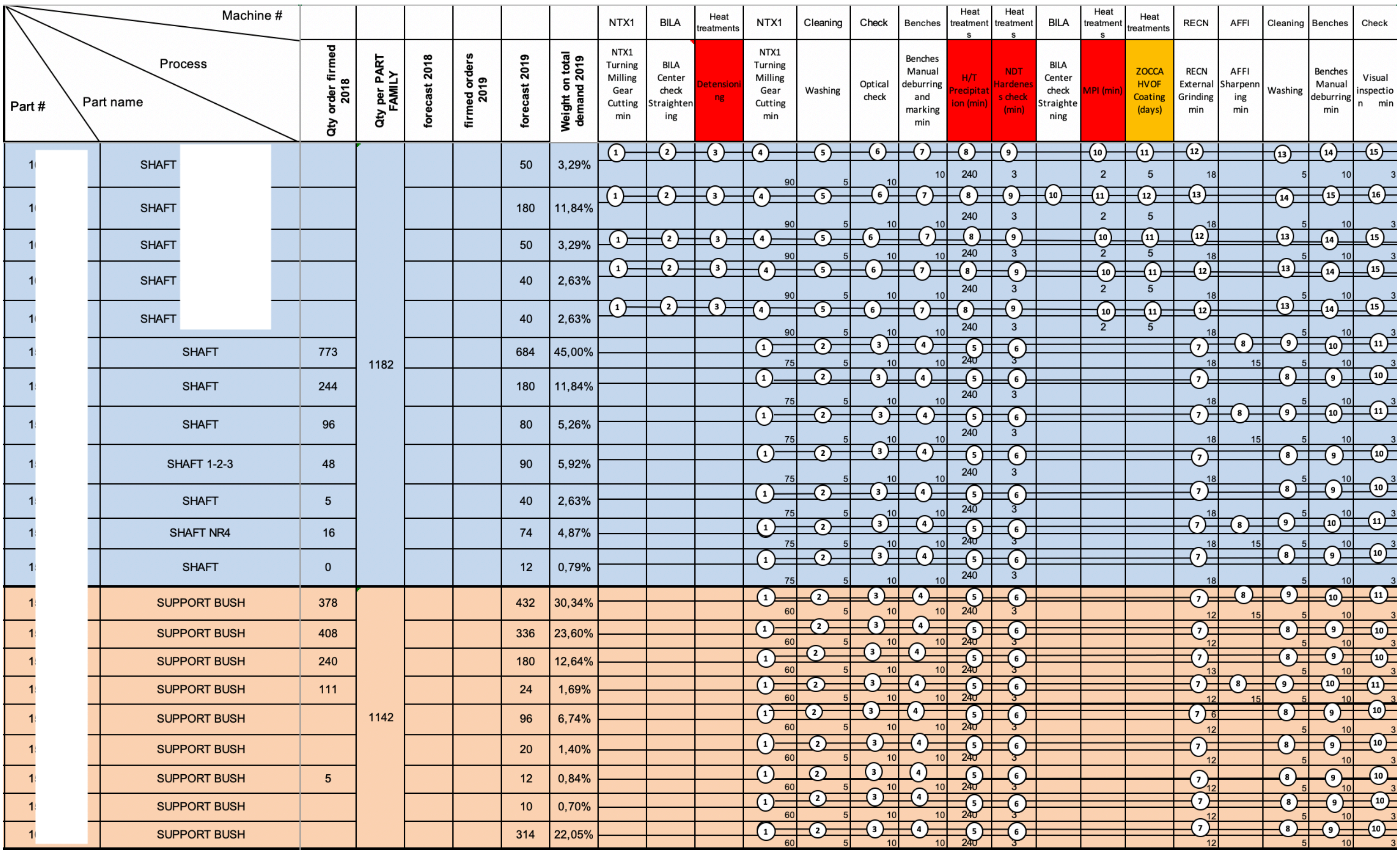


Figure 11, Process matrix of the new machining cell

In figure 11, the process matrix is defined first by the part number, then by the part name and finally by the process the part number will follow.

To apply the processes matrix the usage of different work centers and machines is needed, then process is listed in order starting from the process name till the machine name. The different operations are given numbers then connected using lines, to better understand the flow of parts in the whole design area.

- <u>Part family definition</u>

It is the technique of collecting parts which are similar either because of design attitude or manufacturing processes. The parts within the family are different but their similarities are close enough to put them under the same part family.

Before starting with defining the part families, the previous analysis should be revised, when doing that the focus is on the families in the previous process matrix to understand which parts have similar process steps.

Once reviewed, we can start to define part families, keeping in mind the following:

1. The parts which is decided to group them into one cell should have the same or similar process flow
2. Considering various types of materials
3. Considering the ability to utilize the same tools across the family parts
4. Considering the geometry and size of the parts
5. Considering the machine size and type which is analyzed

In the previous process matrix, the categories are divided into shafts and support bush, because shafts have a similar working process and type of material (aluminum), also the same concept applies for the supporting bushes.

The part family definition is defined in table 1, by family A and B:

P/N	Name	Program	Family
16*****	SHAFT GLOBAL	G	A
16*****	SHAFT GLOBAL	G	A
16*****	SHAFT GLOBAL	G	A
16*****	SHAFT GLOBAL	G	A
16*****	SHAFT GLOBAL	G	A
15*****	SHAFT	E	A
15*****	SHAFT	D	A
15*****	SHAFT		A
15*****	SHAFT 1-2-3		A
15*****	SHAFT	F	A
15*****	SHAFT NR4		A
15*****	SHAFT	F	A
15*****	SUPPORT BUSH	D	B
15*****	SUPPORT BUSH	D	B
15*****	SUPPORT BUSH		B
15*****	SUPPORT BUSH		B
15*****	SUPPORT BUSH	F	B
15*****	SUPPORT BUSH		B
15*****	SUPPORT BUSH	F	B
15*****	SUPPORT BUSH		B

Table 1, Part family definition

7.2. Measure phase

- Spaghetti chart

Transportation, motion and waiting times are the waste that exists in every process or operation. Spaghetti chart goal is to illustrate the flow of product graphically through the factory, in the same time also to identify value and non-value-added activities, in order to detect waste.

Procedure to draw the spaghetti chart:

1. Walking the process starting with the star part and documenting the process steps and workstations in the map:
    a. Using a copy of the most recent company layout
    b. Using the factory layout or scale grid sheet to draw to scale
    c. Making a sketch as you go to each point throughout the shop
    d. Number the significant process steps, actions and components. They are used as component tasks and break points in the standard work combination sheet for example.
2. Measure the travel distance between each station, preferably in meters
3. In the end, the count the number of pieces activity of work in process and inventory at each location is performed

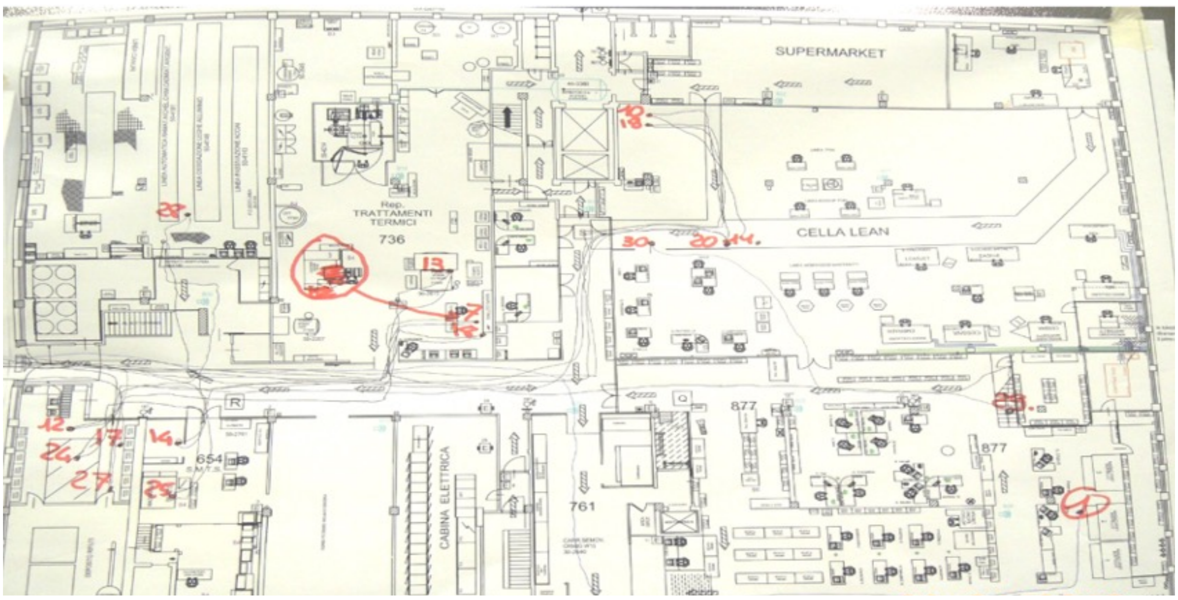


Figure 12, Spaghetti chart implementation in the first plant

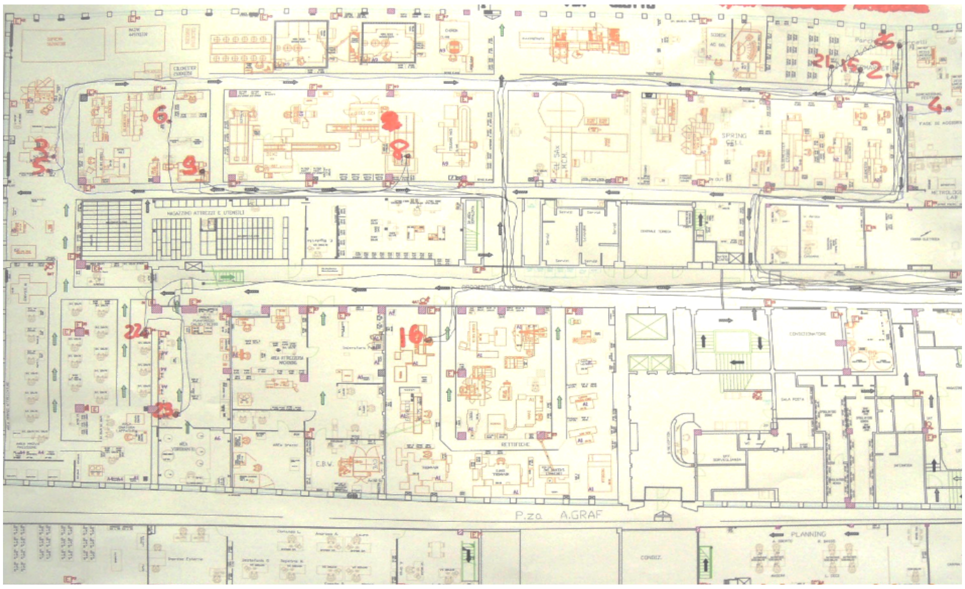


Figure 13, Spaghetti chart implementation in the second plant

In both figures 12 and 13, in red is highlighted the number of part number in inventories at each location.
The distance was measured, and it is 2800 meters.

- <u>Process at a glance:</u>

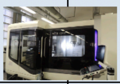
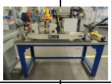
The process at glance aims to illustrate the processes and therefore, the different operation components within the processes for given parts. It can easily identify waste and areas for improvement.

Procedure to define the process at a glance:

The procedure begins by listing the operation numbers across the top, then illustrate in each column the following items as they belong to that process by;

1. Documenting what and how the process looks like
2. Identify a suitable working method
3. Perform the measurement activity
4. List the different cutting tools used
5. Identify the fixtures needed
6. Illustrating the machine and other equipment needed

Process At a Glance
Part Number: 15xxxx
Date: 12/5/18

Sequence Operation	Tornitura/ Fresatura/ Dentatura		Straightening		Deburring/ Marking		Brushing	
	Common	Specific for P/N	Common	Specific for P/N	Common	Specific for P/N	Common	Specific for P/N
1. Machine	NTX 1 Tornio Fresa 		pressa e supporto con due punte 	alberi Global	manipolo, penna vibrante e banco lavoro 			
2. Work Method	Load part turn + mill Unload	Mancano cicli: 154047 / 157767 /154110 /162011			prelievo parte, sbavatura, scritturazione e deposito in cassetta	159896-1 non richiesta scritturazione da disegni (verificare se scritturazione è richiesta per gli altri P/N)		
3. Material/ Documents	Disegni su PC BAR	GREEK ASCOLOY AMS 5616 diametro 38,1 PH 13-8 AMS 5629 diam 47,625 mm 40 CDV 12 VA AFMOR 35 mm	Shaft and support bush		Shaft and support bush		Shaft and support bush	
4. Tooling	Attrezzi per montaggio/staffaggio pinza scaffale per attrezzatura (inserti) Utensili per lavorazione meccanica				lima rotativa 0,2 diametro dichi bentex			
5. Fixture	Pinze mandrino 38,1 HAINBUCK DENTATA Pinza contromandrino 14 Hainbuck liscia Pinza mandrino 47,6 Pinza mandrino 35 Guida barre in base al diam (set-up) Scarico pezzi lavorati progetto metal to metal				Attrezzo bloccaggio pezzo			
6. Measuring instruments	Micrometro centesimale (rango 0-25 mm) Calibo centesimale scanalati per boccole							
7. Other	Rastrelliera row Material Raccolta pezzi finiti PC Banco operatore				Lampada con tente 5X			

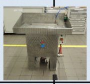
Sequence Operation	Washing		Optical check		Grinding		Visual inspection		Taglio codolo	
	Common	Specific for P/N	Common	Specific for P/N	Common	Specific for P/N	Common	Specific for P/N	Common	Specific for P/N
1. Machine	Vasca lavaggio 		TBD macchina di misura otica o alternativa		RECN (Catania's machine) 		banco sbavatura?		Macchina di taglio 	
2. Work Method	Prelievo parte, lavaggio, asciugatua e deposito in cassetta		Prelievo parte, Misuazione, Verifica conformità, stampa report e deposito in cassetta			159896-1: 3 diametri 3 grooves 154984: 1 diametro1 spallamento 154992: rasamenti 150245: 2 diametri 2 gooves 150251:1 diametro 1 spallamento	Controllo visivo e della documentazione		Taglio codolo	
3. Material/ Documents	Shaft and support bush		shaft and support bush misura		Mole norton A80 KV5 40/30 mm+ una da 1,20 mm		shaft and support bush		Shaft and support bush	
4. Tooling	Pennello Pistola aria compressa Stracci		Punte e contropunte							
5. Fixture										
6. Measuring instruments					Piano di riscontro Calibro centesimale Micrometo 0,25mm (micrometro digitale collegato al PC) Altimetro				Calibro	
7. Other	Liquido per lavaggio (tipo e quantità)		Stampante pe report con opitcal measurement machine se necessario cassetta		PC Banco operatore				Cassetta	

Figure 14, Process at a glance applied to the new machining cell

In figure 14, the process at a glance is applied on the new machining cell, by identifying the sequence, the different operations and the methodology to better understand if there is any waste to eliminate.

- <u>Time observation</u>

Time observation is used to observe and record the task and the time need of the operator’s actual work. It is mainly used to establish a standard method for the work.

Process of compiling the time observation sheet:

1. Sketching the component numbers and breaking points from the spaghetti chart.
2. A ticking clock is used to track the time and record it in the sheet.

3. After time recording is complete, the component task time is subtracted from the previous time and record it in the sheet.
4. The lowest repeatable observed time can be considered as the task time.
5. Document any abnormal activities that happen.

Component Number	Component Task	Observation # 1	Observation # 2	Observation # 3	Component Task Time
1	Lavorazione machina	45'			A
		0			
2	Misurazione intefase con pezzo in macchina	5'			M
		50			
3	Fine programma lavorazione	5			
		55			

Figure 15, Time observation sheet filled in with lowest observed task time for the new machining cell

In figure15, the time observation is performed various times then the result and lowest repeatable observed time was as reported in the table, it's then considered as the task time.

Some notes that was carefully considered when doing the time observation process:

Time observation is a crucial step in starting of an improvement activity, it is the tool used to document the reality.

Documenting reality (by observation) is critical because existing written documents maybe have some inaccurate or obsolete information and the real shop floor conditions are always different than the theoretical approach used to define the processes.

Time observation is performed with an experienced line operator help. Ensuring the line operators are aware of the activity is preferred. A video can be used, to clarify or repeat the procedure of a step that is not very clear. Stopwatch is the fastest method to take multiple measures, they are recommended (how many measures depends on the process time).

The process and work sequence should be fully understood prior to record the timing; the shortest observed repeatable time is considered the correct time. The watch should run continuously, and the watch is only stopped if operator work is interrupted.

7.3. Analyze phase

- Takt time

Takt time is a very important concept because takt time is the rate at which the company should produce parts in order to meet the customer demand. The purpose of takt time is to identify the maximum time available to produce a part in order to meet the customer demand.

To calculate the takt time we should have two main inputs: customer demand and time availability

The formula to calculate takt time is

$$Takt\ Time = \frac{Total\ Available\ Time}{Customer\ Demand}$$

The concept of takt time should not be confused with:

Lead time: is the time horizon difference between order recipient and the client getting their final product
Cycle time: is the time spent to process the customer order from all aspects
Takt time: the maximum time, to comply with orders to meet customer demand goals.

The customer takt is the value stream rhythm, the takt time is based on the average customer demand. This is the heart rate driving the production system. The takt time concept entails working at a constant peace.

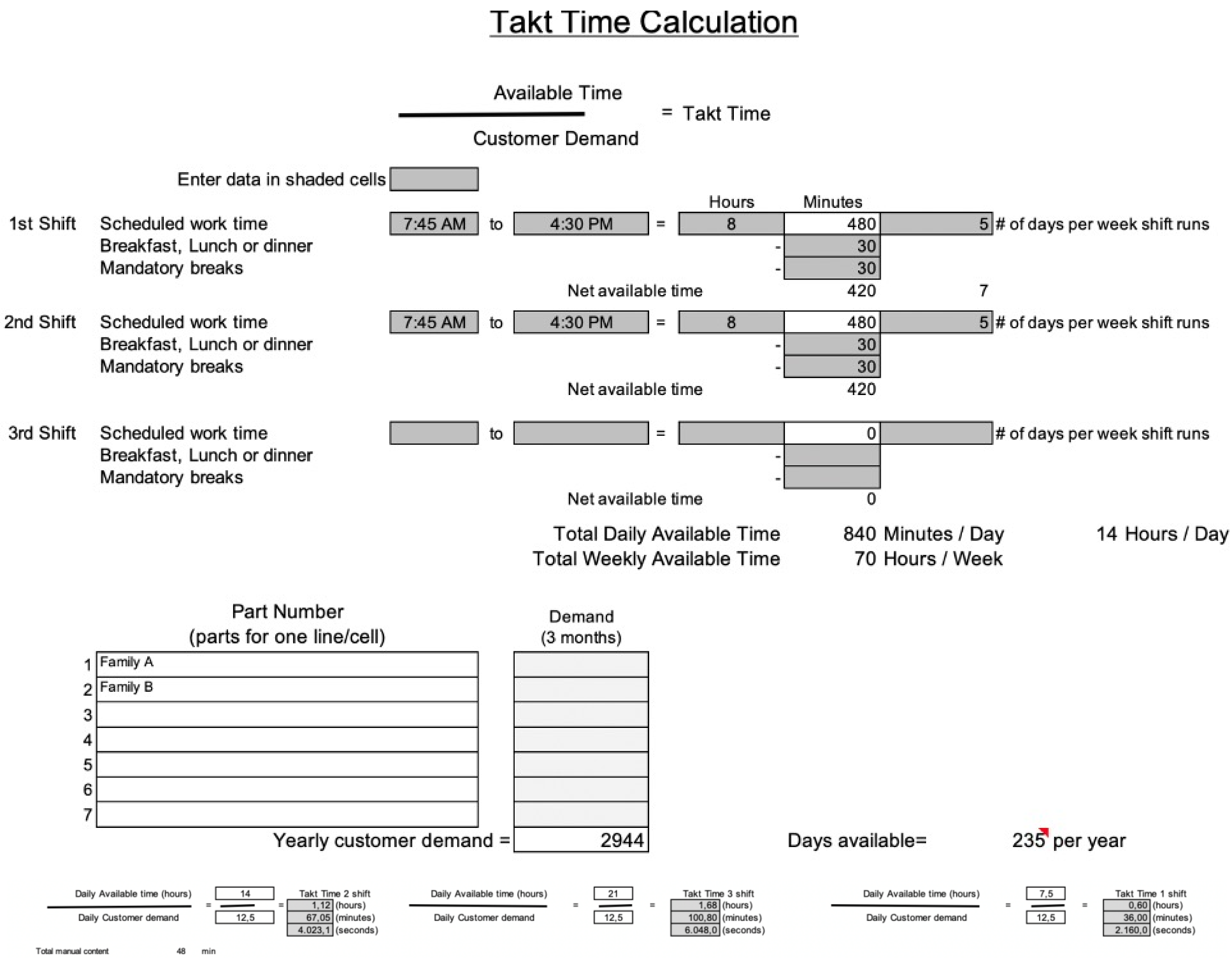


Figure 16, Takt time calculation procedure sheet

The sheet in figure 16 should is filled; the schedule time, elapsed hours, lunch or dinner time, mandatory break time, number of days the shift runs, and lastly entering the part number and demand rate.

The daily available time is 14 hours, the daily customer demand is calculated by dividing the total customer demand over the days available per year, so 2944/235 = 12.5 is the customer demand, which is round to 13. Then the takt time formula is applied to calculate what the takt time is.

The process is repeated 3 times for 1,2 and 3 shifts and of course the takt time changes every time.

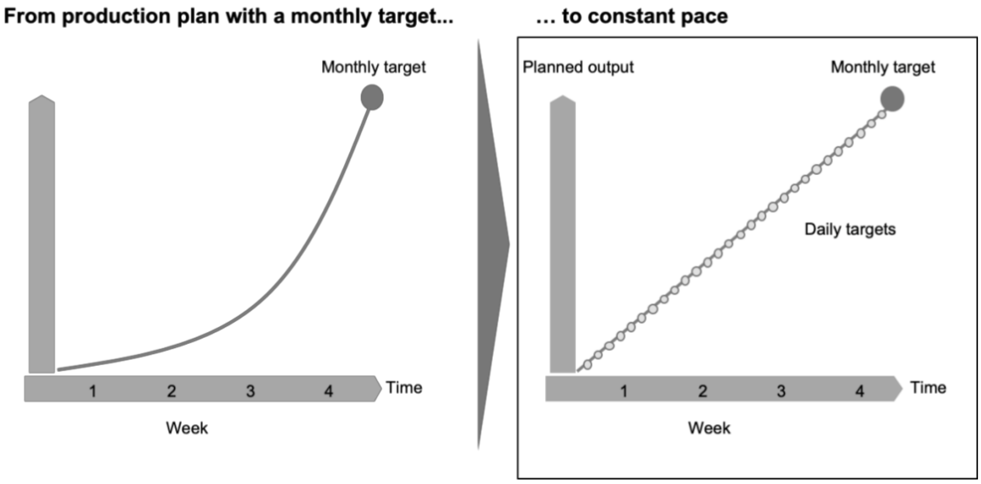


Figure 17, Process stability moving to takt time approach

As illustrated in figure 17, the implementation of takt time methodology, should move the production form a monthly target with a non-stable path, to a daily target with a stable path.

Once the takt time is defined, it should not be changed for at least 4 months.

- <u>Operations bar chart</u>

The operation bar chart identifies the real capacity of the operations and the can lead to the placement of a standard work to the process to maintain smooth part flow. It is the process of plotting the manual, automatic, walking, and set-up time for each operation as it concerns to the flow of the material.

Operation	Manual internal	Automatic (machine time)	Manual external	Takt time (1 shift)	Takt time (2 shift)	Takt time (3 shift)
Turning/Milling/ Dentatura	1	50	5	36,00	67,05	100,80
Brushing/Washing			5	36,00	67,05	100,80
Deburring/Marking			20	36,00	67,05	100,80
Optical check		7	6	36,00	67,05	100,80
Grinding	1	18	1	36,00	67,05	100,80
Grinding AFFI			9	36,00	67,05	100,80
Washing			3	36,00	67,05	100,80
Deburring			8	36,00	67,05	100,80
Visual Inspection			5	36,00	67,05	100,80

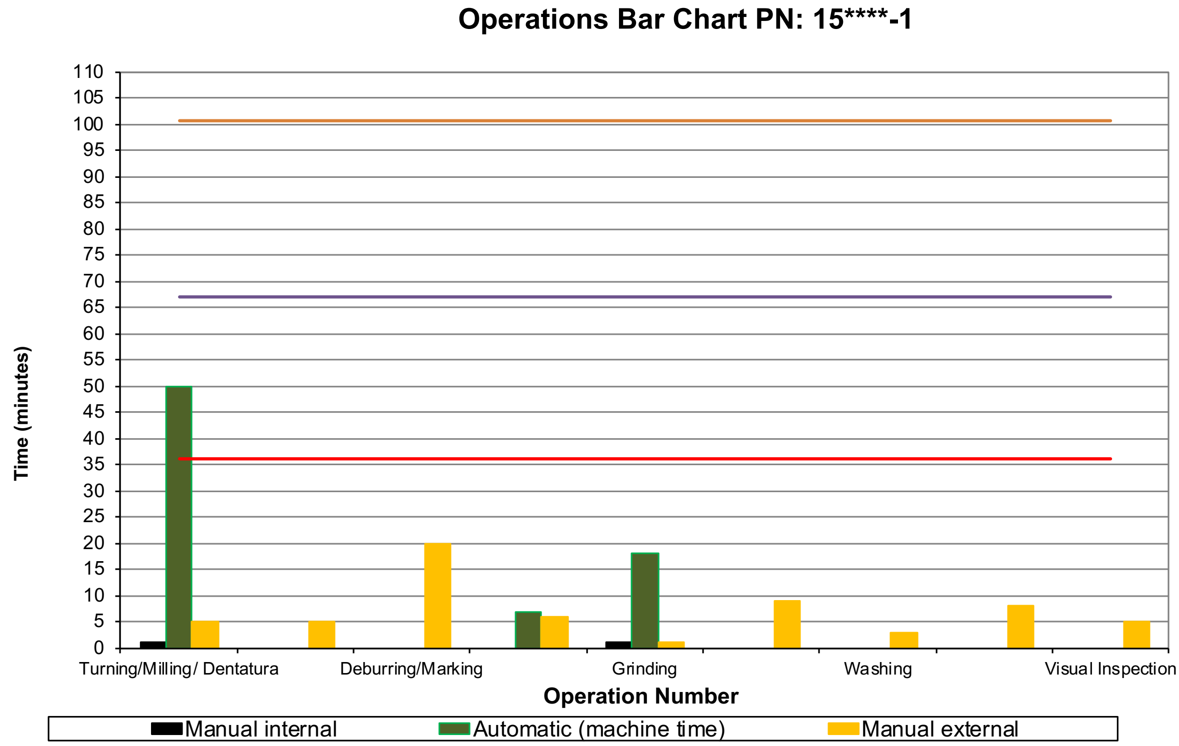


Figure 18, Bar chart for the new machining cell

In figure 18, first the measurement is identified from the time observation phase, the takt time is reported in the sheet (the three straight lines in the graph), and finally the bar chart is plotted.

Carefully observing the operations bar chart for the star part number, it is noticed that for 1 shift takt time the turning/milling machining operation takes more time than the takt, unfortunately it cannot be changed because the activity is a machining activity, so the CNC program runs in 50 minutes, and cannot be reduced.

- <u>Capacity analysis</u>

The capacity analysis is crucial to understand the real situation; the goal is to meet the takt time, so this analysis assesses the ability of the resources (people, machines and equipment) to meet the target (finishing the operations before reaching the takt time).
Capacity analysis identifies any type of constrain the process may face, where the areas of excess capacity exists and the potential areas where improvement can be implemented.

It also shows what the maximum process capacity is for each machine and determines the number of machines ideally required to perform the process.

PRODUCTION CAPACITY GRINDING MACHINE								
	PN	Descrizione	Materiale	TEMPO MACCHINA in minuti	VOLUMI 2019			
A	1*****	Albero	***	18	50	900		
A	1*****	Albero	***	18	180	3240		
A	1*****	Albero	***	18	50	900		
A	1*****	Albero	***	18	40	720		
A	1*****	Albero	***	18	40	720		
A	1*****	ALBERI SCANALATI	***	18	684	12312		
A	1*****	ALBERI SCANALATI	***	18	80	1440		
A	1*****	ALBERI SCANALATI	***	12	40	480		
A	1*****	ALBERI SCANALATI	***	12	90	1080		
A	1*****	ALBERI SCANALATI	***	18	74	1332		
A	1*****	ALBERI SCANALATI	***	18	12	216		
A	1*****	ALBERI SCANALATI	***	18	180	3240		
B	1*****	BOCCOLE DI SOSTEGNO	***	12	336	4032		
B	1*****	BOCCOLE DI SOSTEGNO	***	12	432	5184		
B	1*****	BOCCOLE DI SOSTEGNO	***	13	180	2340		
B	1*****	BOCCOLE DI SOSTEGNO	***	12	24	288		
B	1*****	BOCCOLE DI SOSTEGNO	***	6	12	72		
B	1*****	BOCCOLE DI SOSTEGNO	***	12	96	1152		
B	1*****	BOCCOLE DI SOSTEGNO	***	12	20	240		
B	1*****	BOCCOLE DI SOSTEGNO	***	12	10	120		
B	1*****	BOCCOLE DI SOSTEGNO	***	12	314	3768		
			Sum	307	2894	43776	729,6	ore
			AWCT=	15				
		AVAILABLE WORKING TIME	235	7	1645			
			Uptime 98%	730	0,98	744		
			Planned load	1645	0,95	1.563		
			MACHINES REQUIRED	**744**	**1.563**	**0,48**		

Figure 19, Grinding machine capacity analysis

In figure 19, the capacity analysis for the grinding machine is analyzed. The analysis starts with the part number, description, material, then the machining time and volume. The volume row (7^{th} row) is the multiplication of volumes and time, dividing by 60 the sum, the total time needed is calculated.

AWCT, is the weighted average cycle time, it is calculated as the sum of volumes multiplied by machining time then divided by the sum of volumes. Note that the calculation should take into consideration the uptime at 98%, and the planned load at 95% as convention. Then finally the number of machines required is calculated.

			PRODUCTION CAPACITY MORI SEIKI					
	PN	Descrizione	Materiale	TEMPO MACCHINA in minuti	VOLUMI 2019			
A	1*****	Albero	***	90	50	4500		
A	1*****	Albero	***	90	180	16200		
A	1*****	Albero	***	90	50	4500		
A	1*****	Albero	***	90	40	3600		
A	1*****	Albero	***	90	40	3600		
A	1*****	ALBERI SCANALATI	***	60	684	41040		
A	1*****	ALBERI SCANALATI	***	60	80	4800		
A	1*****	ALBERI SCANALATI	***	60	40	2400		
A	1*****	ALBERI SCANALATI	***	60	90	5400		
A	1*****	ALBERI SCANALATI	***	60	74	4440		
A	1*****	ALBERI SCANALATI	***	60	12	720		
A	1*****	ALBERI SCANALATI	***	60	180	10800		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	336	20160		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	432	25920		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	180	10800		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	24	1440		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	12	720		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	96	5760		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	20	1200		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	10	600		
B	1*****	BOCCOLE DI SOSTEGNO	***	60	314	18840		
			Sum	1410	2894	187440	3124	ore
			AWCT=	65				
		AVAILABLE WORKING TIME	235	14	3290			
			Uptime 98%	3124	0,98	3188		
			Planned load	3290	0,95	3.126		
			MACHINES REQUIRED	**3188**	**3.126**	**1,02**		

Figure 20, Turning machine capacity analysis

The same concept also is applied to the second turning machine, and in figure 20 the calculations are illustrated.

- <u>Operator loading chart</u>

It is the graphical tool that helps creating continuous flow in a multi-stage operation phase by distributing elements of the operator's work in relation to takt time. The operator loading chart is used to compare operator’s actual task cycle time to the process takt time.

The procedure is simple, by plotting each operator physical time to do the activity (standard work combination sheet totals for manual, walking and waiting time) and compare the numbers with the takt time.

In figure 21, the operator loading chart illustrates the comparison between the takt time for 1,2 and 3 shifts with the manual, walking and waiting time, all summed together. In this case there is only one-line operator, and this is the reason why there is only one bar (which represents the line operator time).

FUTURE STATE

	A	B	C	D	E	F	G	H	I	J	K
Manual											
Walk	45										
Wait											
Takt Time 2 shift	67,05	67,05	67,05	67,05	67,05	67,05	67,05	67,05	67,05	67,05	67,05
Takt Time 1 shift	100,80	100,8	100,8	100,8	100,8	100,8	100,8	100,8	100,8	100,8	100,8
Takt Time 3 shift	36,00	36	36	36	36	36	36	36	36	36	36

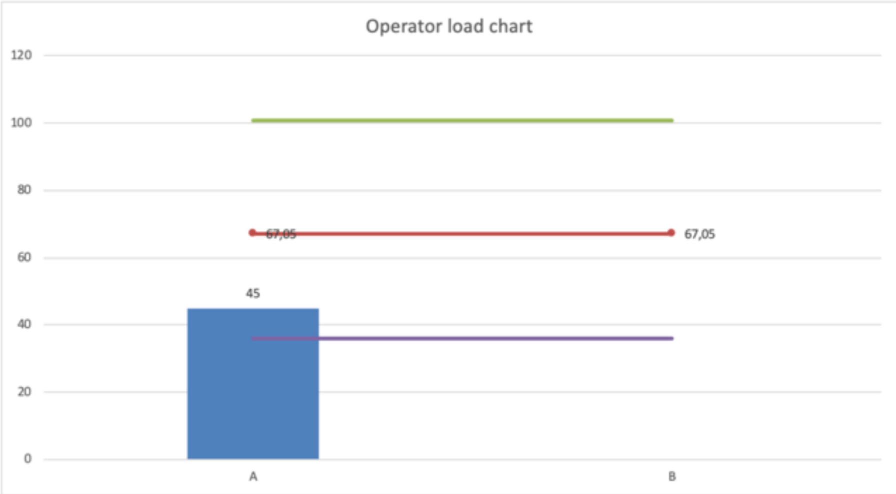


Figure 21, The operator loading chart for the first operator

7.4. Improve phase

- Waste elimination

After analyzing the cell, the analysis should be focused to improve the workflow and eliminate all type of waste.

Optimizing the cell is the process of considering the existing process as a baseline, then applying the lean methodology to identify and remove any waste and to make the cell a top performer for what regards the process improvement.
The optimization of a cell is done by following some simple rules:

1. Having identified the non-value adding activities and waste, those activities should be removed
2. Line balancing the line operators process and eliminate the need for waiting and inventory accumulation
3. By only having the right number of operators
4. Defining the new cell layout
5. Finally implementing the new cell

The following section is focused on defining some basic concept in order to perform a correct analysis of the processes:

Value-adding activities represents only a small proportion of the process. Overproduction is considered the waste core source.

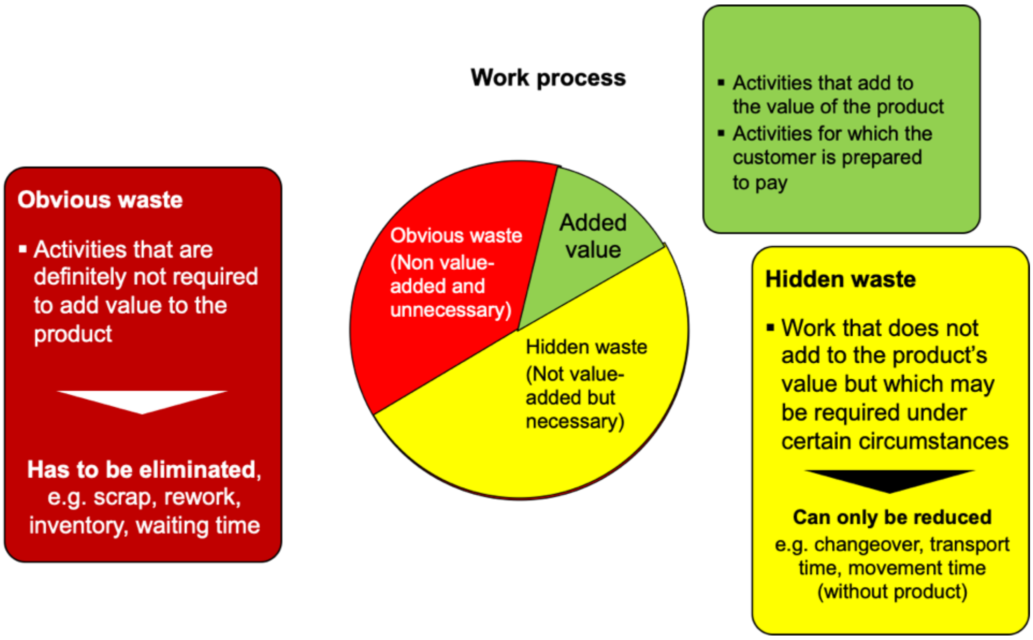


Figure 22, Overall value of any working process

As illustrated in figure 22, there are 3 areas of value to the process:

1. Value added: are the set of activities that the customer is willing to pay for.
2. Incidental (non-value added but necessary): incidental is referring to processes like inspection and paperwork, that is required by regulatory agencies, the customer is not willing to pay for that kind of activity, but it is necessary and, in some cases, mandatory.
3. Pure waste: all kind of activities that do not add value to the product

Now, the identification of non-value adding activities is important to eliminate or reduce them.

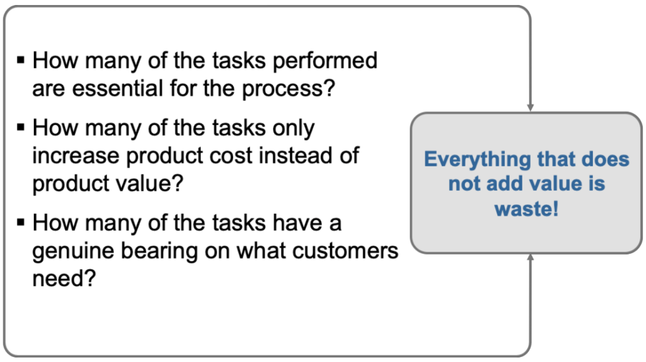


Figure 23, Questions to identify non-value adding activities

Figure 23 illustrates the types of questions, the cell leader can analyze then answer, in order to define the non-value adding activities.

Different than traditional thinking, lean methodology takes into account the throughput time (figure 24).

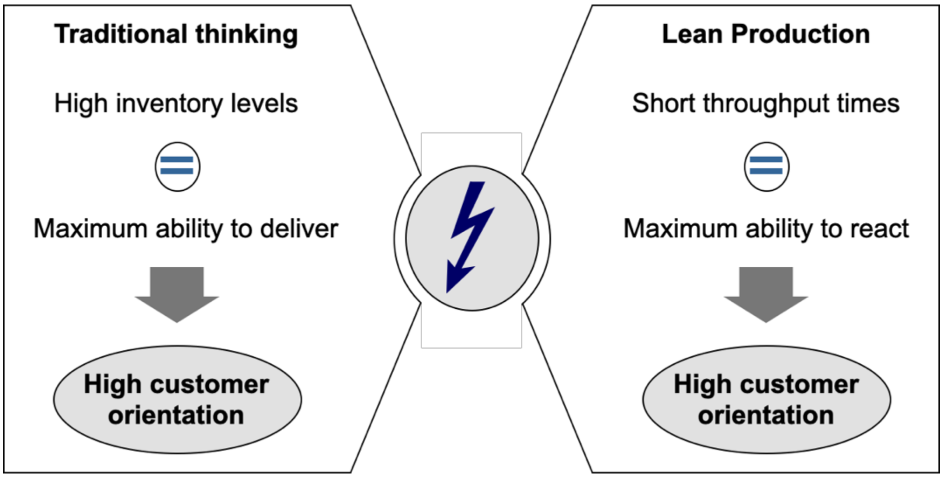


Figure 24, Traditional thinking vs lean thinking

A very interesting question arises, why would the focus be on throughput times and not looking at an efficiency calculation and person productivity?

By focusing on efficiency or productivity of the line operator, the system is stressed. If the focus is on efficiency or productivity the system will not run as a team and high inventory levels is created.
Instead, if the focus is on the inventory level also called WIP (Work in Process), then it is easier to eliminate waste.

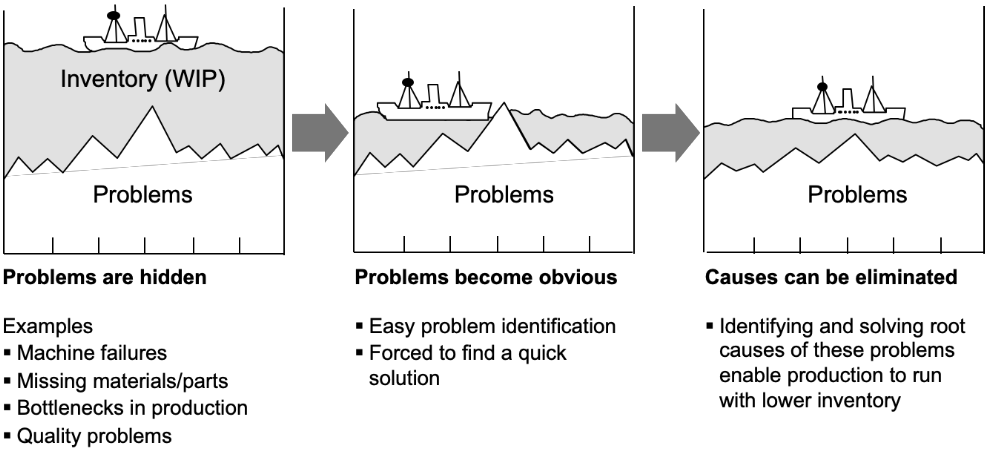


Figure 25, Effect of reducing inventory on the overall system

In figure 25, the main idea is that only effective method of reducing waste is to eliminate the obviously the inventory, because at first the problems are hidden, then when the WIP (Work in Progress) is decreased the problems are seen better, and the diagnosis is quite fast. The root cause analysis is performed to understand the problem causing waste, and finally exploit the opportunities and resolve the problem. Hence, the system should be operating by the one-piece flow methodology.

The main goal of one-piece flow is to reduce the lead time, by reducing the WIP (Work in Progress) in order to move to an agile system.

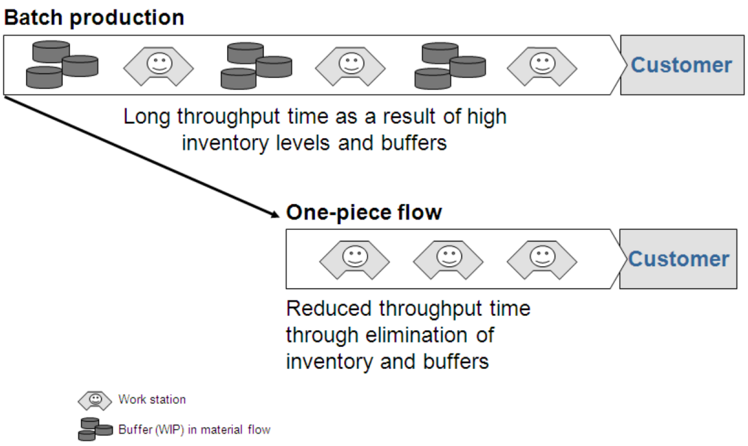


Figure 26, Comparison between batch production and one-piece flow

In figure 26, the main difference between batch production and one-piece flow is the elimination of buffers in the one-piece flow production system, which reduces the throughput time.

One-piece flow production can be achieved through the coupling of pre-assembly and final assembly processes with no buffers which leads to the JIT (Just in Time) production system:

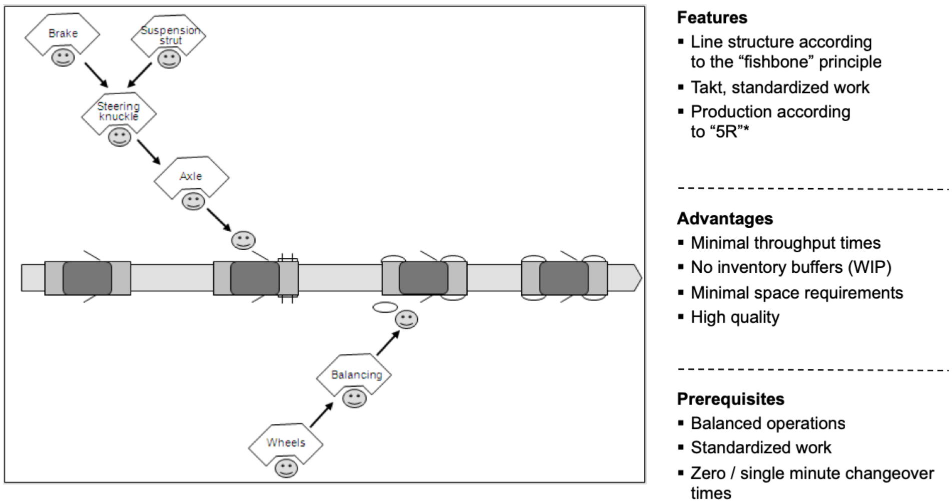


Figure 27, Fishbone one-piece flow production line

Figure 27 is an example of a fishbone one-piece flow production line.
A short throughput time is obtained by reducing all elements in the process that do not add value.

The 8 most famous types of waste that should be reduced or eliminated are:

1. Defects/Rework
2. Overproduction
3. Waiting
4. Non-Utilization of people’s skill
5. Transportation
6. Motion
7. Excess Processing

Finally, following all the above methodology, in figure 28, the following optimization to the star part, was implemented.

PN150245-1 – Star Part

OP 70/80: Dentatura
1) Specific washing to remove grease in building B (T)
2) Operator not authorized for approval (piece goes to dimensional testing ½ times + waiting time) (W + T+ N)
3) Cleaning not planned (E)

OP 85: Washing
4) Excessive waiting time before cleaning (1/2 weeks) (T)
5) Unpacking / packing raw material (N +E)
6) Operator washes cassettes

OP 90: Milling
7) Operator goes to dimensional inspection although there is a DIMA (T + N)
8) Lack of spare parts in case of failure (W + O + N + D)

OP 110: Tuning
7) Operator goes to dimensional inspection although there is a DIMA (T + N)
8) Lack of spare parts in case of failure (W + O + N + D)

OP 115: Deburing
9) Long waiting time of boxes with components (Also 12 days) (W)
10) Excessive quantity of boxes on shelves
11) Priority is not managed (W)

OP 120: Bonifica Heat treatment
12) Tying pieces too long before entering the oven

OP 125: Hardness Control
13) Scraps for non confonity of hardness (d)

OP 130: Grinding
14) Setup: Spindle change and alignment ti-tip (W)
15) Scraps: 5% (D)
16) Calibrated but obsolete measuring instruments

OP 134:
NONE

OP 135: Deburing
17) Same of OP 115

OP 140: Shot peening
18) Dust in the ground

OP 150:
None

OP 160: Final check
19) Scraps (D)

General wastes:
20) Pieces pass always from the supermarket
21) Waiting time of pieces in entrance of heating treatment

Figure 28, Optimization of the cell applied with the star part number

- Line balancing

Line balancing is a manufacturing strategy that involves the balancing of the operator and machining time to match the production rate to the takt time.

Figure 29, Line balancing applied to the new machining cell

In figure 30, the procedure for line balancing is applied, which is moving the work from the more stressed operator to the least stressed operator, and as it is clear in the after-heat treatment phase, the time the last operator needed is reduced while increasing the work of finishing operator. The milling and turning time could not be reduced or balanced, because we need to wait till the machine finishes the work (production cycle time).

- <u>Optimize operators:</u>

This phase is crucial in cell design, because in this phase the optimal number of operators is identified in a process or production area or cell. The procedure to identify the optimal number is not always easily achievable because some operations can be split, and others cannot split. To calculate the optimal number of operators needed there are only two factors that are considered: Takt Time and Manual Time.

$$\text{Optimal Number of Operators} = \frac{Manual\ Time}{Takt\ Time}$$

$$Manual\ Time = Total\ Time - Auto\ Time$$

Note that the optimal number of operators should be calculated three times, because three shifts are considered.

In this case, the total manual content is 48 minutes, and the takt time are:

1. For the first shift: Takt Time = 36 minutes
2. For the second shift: Takt Time = 67.05 minutes
3. For the third shift: Takt Time = 100.8 minutes

Now, the optimal number of operators can be calculated for each shift:

Number of operators needed for the first shift: 48/36 = 1.33
Number of operators needed for the second shift: 48/67.05 = 0.7158
Number of operators needed for the third shift: 48/100.8 = 0.4761

The conclusion is that only one operator per shift is needed.

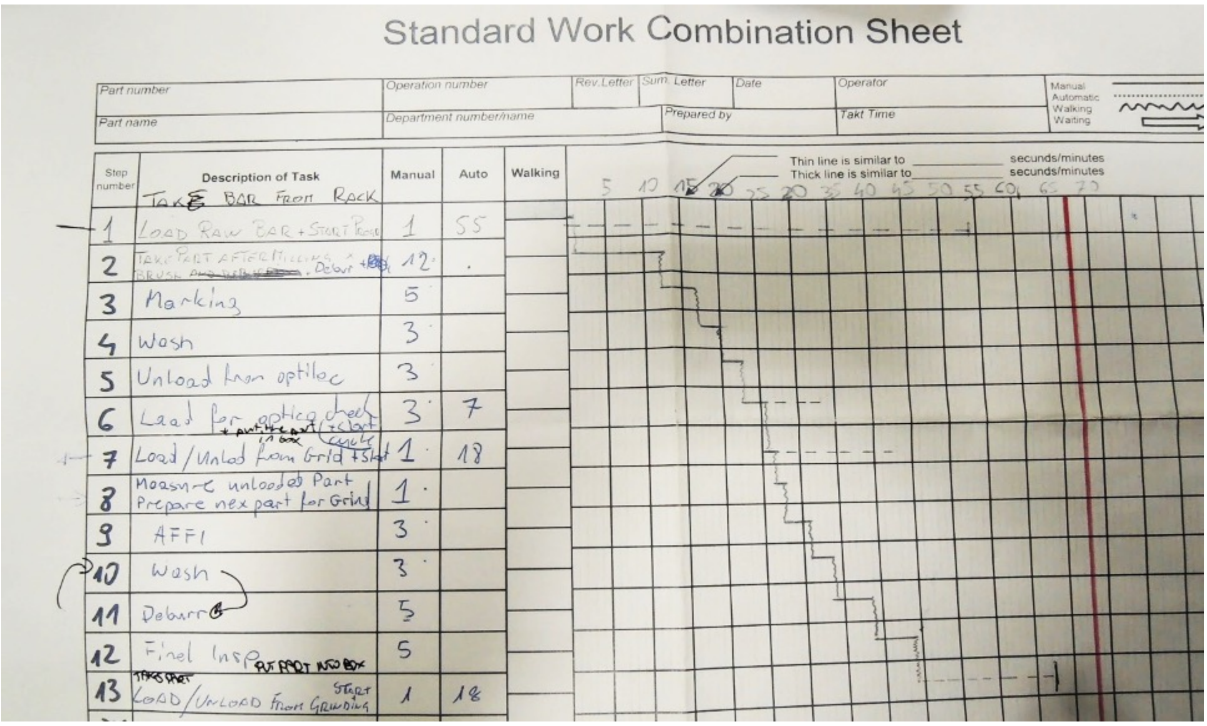
7.5. Control phase

- SWCS (Standard Work Combination Sheet):

After having done all the steps above, the SWCS (Standard Work Combination Sheet) shows the work sequence of the operator, not the machine process as it defines only the manual work which the operator needs to perform.

SWCS for a given cell is positioned at the most advantageous location where the cell supervisor can observe the operator working through the working activity cycle and can easily identify the wasteful motion. The supervisor should highlight the collection of changes in reduced motion waste in the SWCS only after a period of time (from three to four months).

The standard work developed for the manufacturing cell, is illustrated in figure 31, where the red line represents the takt time, the step number and the description of the task, the manual and automatic work time, and finally, the process did not exceed the takt time which can illustrate that the cell was designed properly.



Standard Work Combination Sheet

Step number	Description of Task	Manual	Auto	Walking
	TAKE BAR FROM RACK			
1	LOAD RAW BAR + START PROG	1	55	
2	TAKE PART AFTER MILLING + BRUSH ~~AND DEBURR~~. Deburr + [illegible]	12	.	
3	Marking	5		
4	Wash	3		
5	Unload from optilec	3		
6	Load for optical check + put the part in box (+start cycle)	3	7	
7	Load / Unload from Grid + Start	1	18	
8	Measure unloaded Part Prepare nex part for Grind	1		
9	AFFI	3		
10	Wash	3		
11	Deburr	5		
12	Final Insp PUT PART INTO BOX	5		
13	TAKES PART LOAD/UNLOAD FROM GRINDING START	1	18	

Figure 30, Final standard work combination sheet for the machining cell

Chapter 2: Efficiency management

1. Manufacturing costs

Manufacturing costs of a part number could be broken down into two main costs:

1. Direct Cost: is the cost which the company pays to transform raw material into a final product. (value added concept)
   "Also said in other words the cost easy attributable to an object"

   Examples: labor cost and material cost
2. Indirect Cost: is the cost which cannot be assigned to a particular activity

   Examples: indirect labor, indirect material and indirect overhead

In this case the machining department considers the direct and indirect cost by a unit of measure, called hours.
The manufacturing engineering department assigns a given number of hours for each part number which is a standard, and the machining department performance is measured in terms of hours. This leads to an important concept, actual hours and earned hours.

The earned hours are the standard time defined by the manufacturing engineering department in which the completion machining a given part number is achieved.

	Std Value	Unit
Labor	0,000	HR
SET-UP	1,000	HR
AGBackflush	0,000	HR
Machine	2,500	HR
Rework	0,000	

Figure 31, Production time standard for a given operation

In figure 31, given the part number called X, manufactured with an operation called Y, a set of metrics can be defined:

1. The labor time is the time the operator takes to perform this operation, it can also be called manual time
2. The setup-time is the time required and taken to prepare the manufacturing processes for the production activity
3. AGBackflush: it is an accounting method used in JIT (Just in Time) production, where costing is postponed until goods are finished
4. Machine: is the time that the machine takes to complete the operation
5. Rework: is the activity of repairing a damaged part number

Getting back to the concept of earned hours, given the metrics in figure 31 the practical application is that to apply the operation Y of the manufacturing processes for one part number it should take: 1 h + 2.5 h = 3.5 h, this is the theoretical time (measured in hours) it takes to complete the operation which is by definition the earned hours.

On the other hand, the actual hours are the actual time (measured in hours) it takes to realize such operation.

Activity	Confirmed	Unit	R	To Be Conf.	Unit	Act. T...
Labor	19,900	HR	☐	21,600	HR	PROD
SET-UP	0,000		☐	1,500	HR	SETUP
AGBackflush	0,000		☐	0,000	HR	
Machine	0,000	HR	☐	0,000	HR	
Rework	0,000		☐	0,000		
			☐			

Figure 32, Earned hours vs actual hours

In order to better explain the situation, it is referred to figure 32, as a starting point to understand all the possible manufacturing scenarios of a production department.

Figure 32 has two columns, To Be Conf. column which is the earned hours for the specific operation X1 column. Confirmed column, which is the actual hours took to realize the specific operation on X1 column.

In terms of costs from the point of view of the machining department supervisors, the earned hours are the reference baseline hours to efficiency calculation and meeting the KPI’s (Key Performance Indicators), for the specific operation on X1 and three scenarios only can happen:

1. First scenario: the earned hours = the actual hours

This is the ideal case and there are some limitations which make it difficult to realize (machine breakdowns, lack of material, etc.)
It is the case in which the operation is performed in a specific time, which is exactly equal to the time assigned by the manufacturing engineering.

Example: for a specific operation on X2 (where X2 is a part number), the assigned time by the manufacturing engineering department is 10 hours in total; the operation X2 is realized in a specific time, which is exactly equal to 10 hours, which is the ideal theoretical situation.

2. Second scenario: the earned hours > the actual hours

At first sounds strange, but it can happen because the operator who runs the machine is skilled (manned machines). For what regards unmanned machines, maybe the CNC programmers released a faster program which makes it possible, then the manufacturing engineering will need modify the standard times (earned hours).

Activity	Confirmed	Unit	R	To Be Conf.	Unit	Act. T...
Labor	19,900	HR		21,600	HR	PROD
SET-UP	0,000			1,500	HR	SETUP
AGBackflush	0,000			0,000	HR	
Machine	0,000	HR		0,000	HR	
Rework	0,000			0,000		

Figure 33, Earned hours > actual hours case

In figure 33 as an example, the earned hours are = 23.1 h, actual hours are = 19.9 h, which means the process is efficient, because the operation is done in 19.9 h with respect to a standard of 23.1 h.

3. Third scenario: the earned hours < the actual hours

It can happen because of a series of reasons, like:
The machine faces a tool failure, due to a human mistake while planting the tools, loss of oil, etc.

Activity	Confirmed	Unit	R	To Be Conf.	Unit	Act. T...
Labor	0,000	HR		4,800	HR	PROD
SET-UP	0,000			0,000	HR	SETUP
AGBackflush	0,000			0,000	HR	
Machine	51,160	HR		44,000	HR	MACH
Rework	0,000			0,000		

Figure 34, Earned hours < actual hours case

In figure 34, as an example, the earned hours are = 48.8 h, actual hours are = 51.16 h, which means the process is not efficient, because the operation is done in 48.8 h with respect to a standard of 51.16 h.

This concept is the baseline of discussing the company KPI's (Key Performance Indicators), mainly this is the method that identifies the overall department efficiency.

2. <u>Efficiency and UOR (Utilization of Resources)</u>

After having defined the earned hours and actual hours, the discussion moves forward towards efficiency.
Efficiency is one of the main KPI's (Key Performance Indicators) along with UOR (Utilization of Resources) and productivity monitored to show how the production is going in each of the various departments.

The definition of each of the main KPI's (Key Performance Indicators) is discussed:

Metric Description	Calculation	Update Frequency	Code	Target 2019
Utilization of Resource (relative data)	$UoR\_r = \frac{PrH\ (Productive\ Hours)}{TH\ (Total\ Logged\ Hours)}$	D	UoR_r	95%
Utilization of Resource (absolute data) @ 07 apr 2019	$UoR\_a = \frac{PrH\ (Productive\ Hours)}{PH\ (Presence\ Hours)} = \frac{55,4 + 4,5}{299,8}$	W	UoR_a	95%
Efficiency	$E = \frac{EH\ (Earned\ Hours)}{DLH\ (Direct\ Labor\ Hours)} = \frac{1.232,8\ h}{1.055,8\ h}$	D	E	103%
Productivity	$P = UoR\_A \times E$	W	P	89%

Figure 35, Metrics formulas and target for 2019 in Turin production site

Efficiency:

The efficiency is one of the most important KPI's (Key Performance Indicators) since it gives an immediate idea about how the situation is and the number of problems that a production plant may face.
The efficiency is calculated as earned hours divided by the direct labor hours.
It is known, that the best interest of any organization is to maintain high efficiency rate to be competitive in the industry, and from here urges the need of continuously increase the efficiency.

Continuously increasing the efficiency in the machining department, can be implemented by:

1. Assess the inefficiencies in the manufacturing process and request the manufacturing engineering for more hours to realize pieces where the manufacturing process are inefficient if for some reason it is impossible to eliminate the inefficiencies. For example, manual operations where the time assigned is not adequate for such machining operation.
2. Alternatively, increasing the direct labor hours which can be challenging due to labor unions, eliminating wastes as possible, as explained in the ACE (Achieving Competitive Excellence) section.

UOR (Utilization of Resources):

It's the KPI (Key Performance Indicators) which refers to the process of making most of the resources at disposal, to achieve your target.

It can be increased by better utilizing the resources at our disposal because as illustrated in figure 35, the UOR (Utilization of Resources) is equal to the productive hours divided by the presence hours. The main goal should be focusing on increasing productive hours.

Productivity:

The productivity, as illustrated in figure 35 is UOR (Utilization of Resources) multiplied by efficiency. It is easy to see that in order to increase productivity, the UOR (Utilization of Resources) or the efficiency should increase.

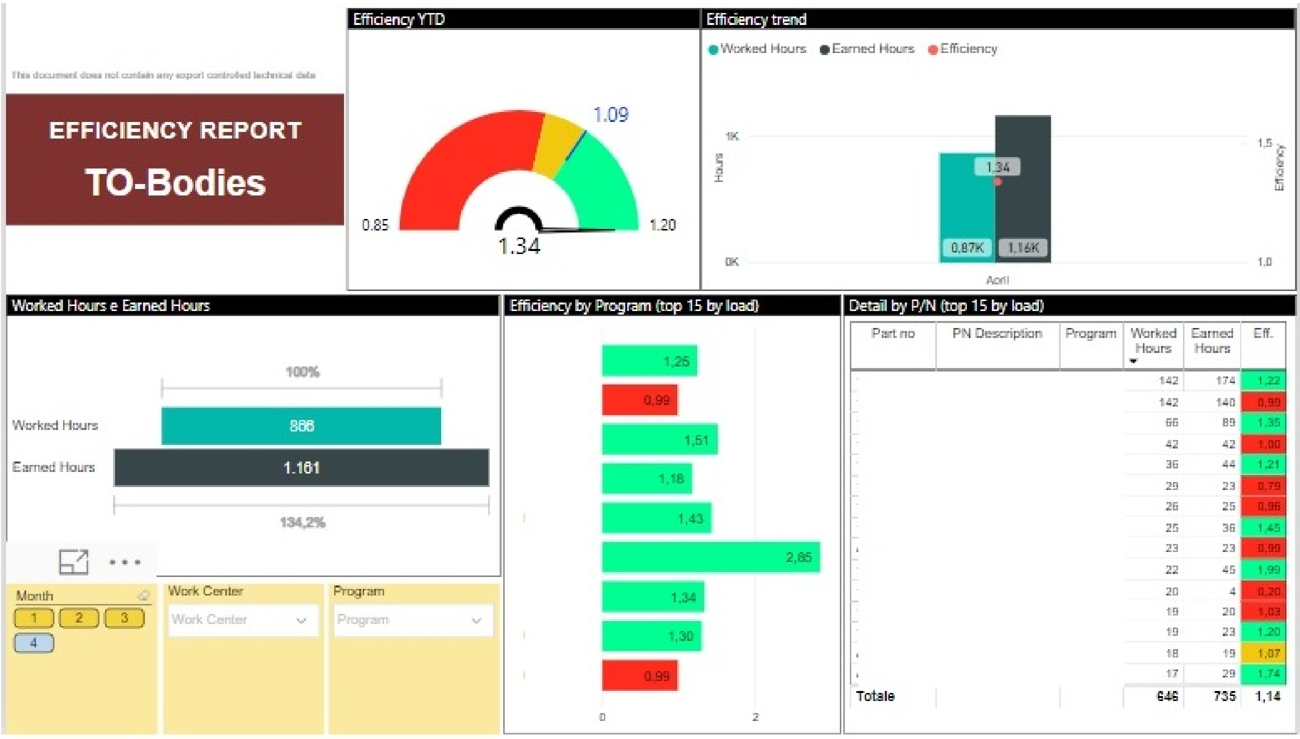


Figure 36, Efficiency trend in the machining department

Figure 36 illustrates the metric of efficiency in the machining department, where it is possible to compare data by month, understand which part numbers are causing the inefficiencies, and that enables us to keep the process under control and understand the potential opportunities to improve the process.

In figure 36, the efficiency of the machining department is at 134%, which is quite ambiguous and difficult to understand, because the cell cannot perform more than the target by 34%. In the next section a data analysis will be performed to understand where the problem relies and to identify potential improvement opportunities.

3. <u>Data management</u>

ERP (Enterprise Resource Planning) system is the integrated control of major business operations, through software and technology which collects and generate real time data. The data management in this case is important because it can allow the detection of the main problems and how to formulate a solution to it. In this section all the ERP's of the company interaction will be analyzed.

<u>PowerMES</u>

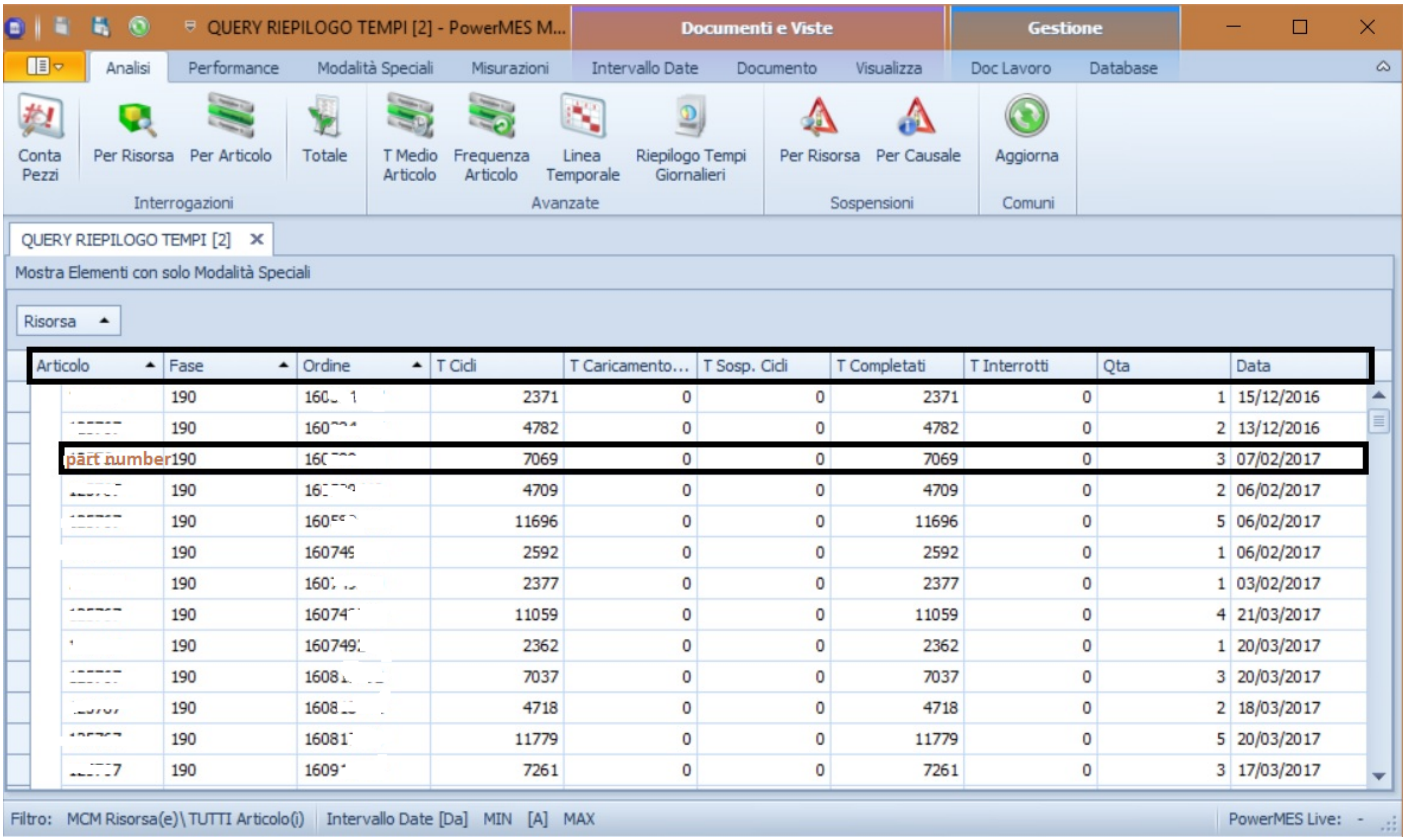


Figure 37, PowerMES interface

PowerMES is the software which extracts the information from the machines (number of hours, number of components produced by each machine, in which date are the components realized and in which operation is it) and relates each of them to a specific work order, as shown in figure 37.

PowerMES data interaction:

1. To realize a specific workpiece with a specific part number, work order and an operation, the operator recalls the specific CNC program using a software called PowerEdit, then loads it into the machine -PowerEdit and PowerMES are a part of the same package (TeamSystem)-, so basically when there is the string Dprnt in the

CNC program, is always associated to a specific part number and operation, PowerMES counts it and associates it to the specific work order. Figure 37 gives an example on how data is collected.

2. After that, PowerMES counts the time in seconds the time that the machine took to finish such operation and associates it to a specific work order.
3. Then using the interface, a report can be generated which shows for every machine the time needed in seconds, to realize a workpiece with a specific part number, work order and a specific operation.

Note: PowerMES is used only to monitor the time took by the machine to perform a specific operation, so it is counting only machine time (direct hours).

The reporting function is useful when it comes to monitor and controlling all the work activities happening inside the department, which is a great aid for the production supervisors.

The software has many interesting features like (interrogation), which is useful to perform analysis for a given part number and to understand if that specific part number in a determined operation is facing a production delay or else.

<u>AutoTime:</u>

AutoTime is the software that the company uses to count the confirmed hours, both direct and indirect hours (employees presence hours and the machine hours).

AutoTime is the link between the company ERP's (Enterprise Resource Planning) systems, because it contains both direct and indirect hours.

75D4O13010	EMPLOYEE	1585	48
75D4O13010 Totale		**1585**	**48**
75D4O13020	EMPLOYEE	186	572
	MACHINE	1156	
75D4O13020 Totale		**1342**	**572**
75D4O13030	EMPLOYEE	2589	825
75D4O13030 Totale		**2589**	**825**
75D4O13050	EMPLOYEE	1287	807
75D4O13050 Totale		**1287**	**807**
75D4O13060	EMPLOYEE	2103	53
75D4O13060 Totale		**2103**	**53**
75D4O13070	EMPLOYEE	6744	164

Figure 38, AutoTime report summary of hours by department

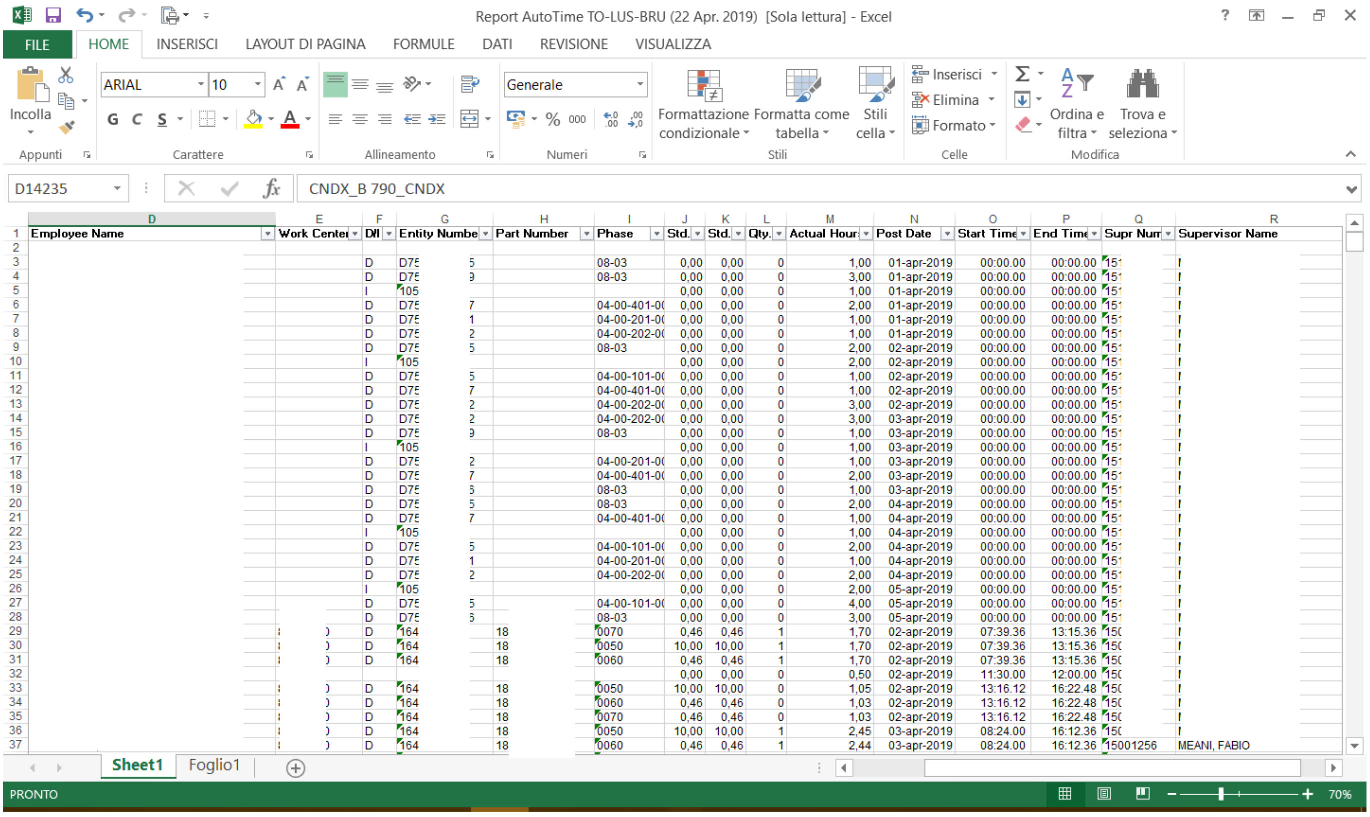
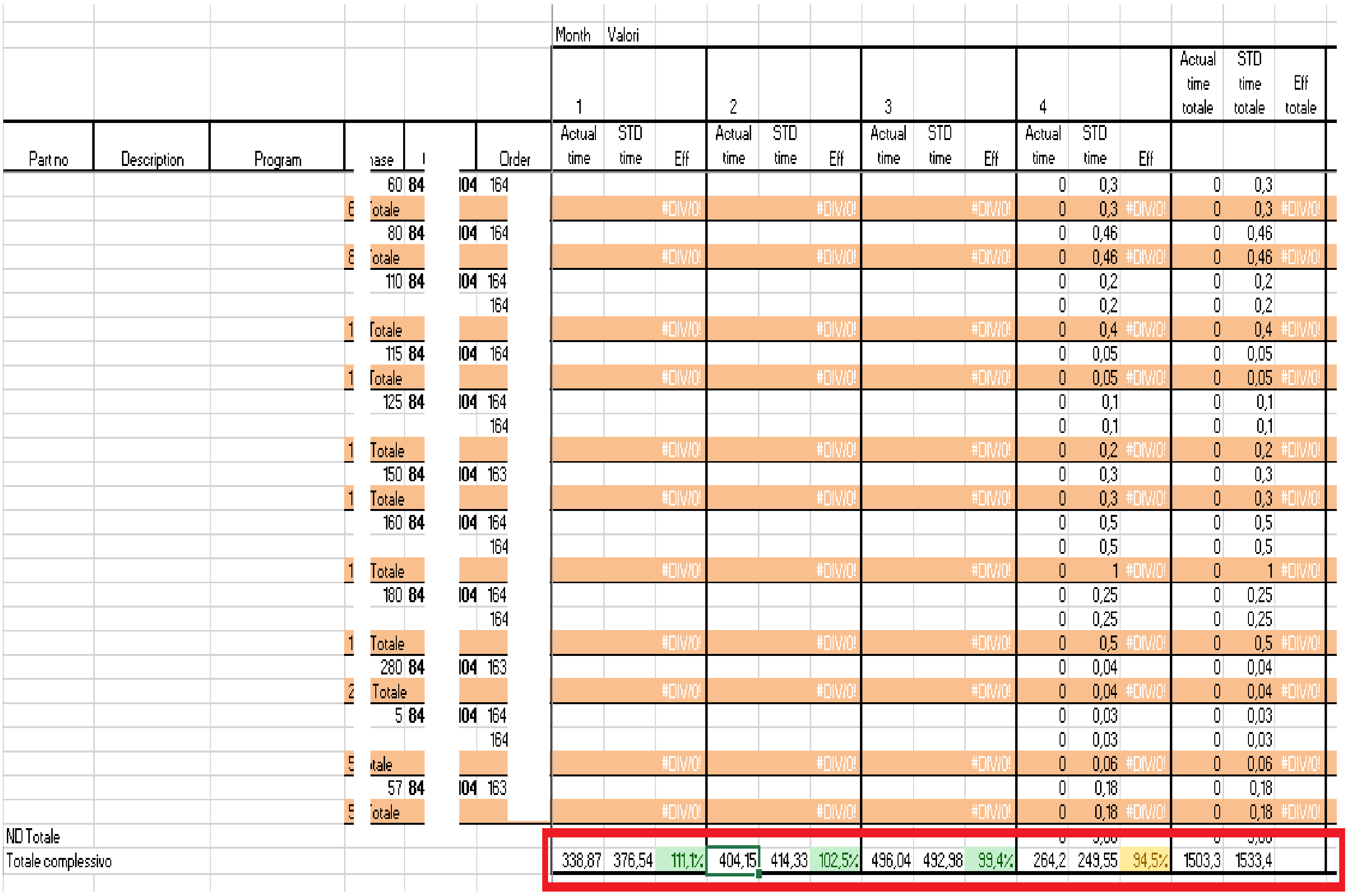


Figure 39, AutoTime report in an excel file

Every day, an automatic report generated by AutoTime is sent to all production supervisors, where the direct and indirect hours are identified, as shown in figure 38 and figure 39.

SAP:

Is the most important software because every department uses the data that SAP provides, starting from the planning department which needs to allocate a plan for each machine, in order to make a complete production plan.



							Month	Valori													
							1			2			3			4			Actual time totale	STD time totale	Eff totale
Part no	Description	Program	ase	I		Order	Actual time	STD time	Eff	Actual time	STD time	Eff	Actual time	STD time	Eff	Actual time	STD time	Eff			
			60	84	104	164										0	0,3		0	0,3	
			6	otale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,3	#DIV/0!	0	0,3	#DIV/0!
			80	84	104	164										0	0,46		0	0,46	
			6	otale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,46	#DIV/0!	0	0,46	#DIV/0!
			110	84	104	164										0	0,2		0	0,2	
						164										0	0,2		0	0,2	
			1	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,4	#DIV/0!	0	0,4	#DIV/0!
			115	84	104	164										0	0,05		0	0,05	
			1	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,05	#DIV/0!	0	0,05	#DIV/0!
			125	84	104	164										0	0,1		0	0,1	
						164										0	0,1		0	0,1	
			1	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,2	#DIV/0!	0	0,2	#DIV/0!
			150	84	104	163										0	0,3		0	0,3	
			1	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,3	#DIV/0!	0	0,3	#DIV/0!
			160	84	104	164										0	0,5		0	0,5	
						164										0	0,5		0	0,5	
			1	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	1	#DIV/0!	0	1	#DIV/0!
			180	84	104	164										0	0,25		0	0,25	
						164										0	0,25		0	0,25	
			1	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,5	#DIV/0!	0	0,5	#DIV/0!
			280	84	104	163										0	0,04		0	0,04	
			2	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,04	#DIV/0!	0	0,04	#DIV/0!
			5	84	104	164										0	0,03		0	0,03	
						164										0	0,03		0	0,03	
			5	tale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,06	#DIV/0!	0	0,06	#DIV/0!
			57	84	104	163										0	0,18		0	0,18	
			5	Totale					#DIV/0!			#DIV/0!			#DIV/0!	0	0,18	#DIV/0!	0	0,18	#DIV/0!
ND Totale																[illegible]	[illegible]		[illegible]	[illegible]	
Totale complessivo							338,87	376,54	111,1%	404,15	414,33	102,5%	496,04	492,98	99,4%	264,2	249,55	94,5%	1503,3	1533,4	

Figure 38, The excel file used to calculate the KPI's

Also, to perform the efficiency, UOR (Utilization of Resources) and productivity calculations, the needed information is extracted from SAP.

In figure 40, this excel file is an automatically compiled file, that extracts the data from SAP to calculate the efficiency for each single operation and part number. The number indicates the month, actual and standard are the earned and actual hours, and dividing them the result is the efficiency.

<u>Data exchange between the various ERP (Enterprise Resource Planning) systems:</u>

The data exchange mechanism can be summarized as follows: PowerMES counts the seconds of machining activities, and reports it to AutoTime, and AutoTime passes the information to SAP.

The problem begins when at some point; the difference between direct hours passed from PowerEdit to AutoTime exceeds 250 hours, which is strange, because now production supervisors should explain to the directors why they did not achieve the target.

So, a useful visualization of this data is implemented to keep an eye on this strange behavior in an excel file, as shown in figure 41.

	DATA	INCREMENTALE ORE POWERMES	CRISTOFORI MACCHINE	CRISTOFORI UOMINI	INCREMENTALI ORE DIRETTE AUTOTIME	INCREMENTALI ORE INDIRETTE AUTOTIME	TARGET	n° ORE UOMO [(E-B) + F]	N° ORE AUTIME DIRETTE / N° ore uomo (efficienza	N° ORE Power... / Ore indirett
3	01-mar	0,0	0,0	0,0	0,0	0,0	48,0	0,0	#DIV/0!	#DIV/0!
4	02-mar	0,0	0,0	0,0	0,0	0,0	48,0	0,0	#DIV/0!	#DIV/0!
5	03-mar	109,7	21,0	8,0	29,0	48,0	48,0	-32,7	-0,89	2,29
6	04-mar	148,9	85,0	16,0	101,0	83	96,0	35,1	2,88	1,79
7	05-mar	217,6	140,0	26,0	166,0	127,0	145,0	75,4	2,20	1,71
8	06-mar	285,5	140,0	36,0	176,0	169,0	193,0	59,5	2,96	1,69
9	07-mar	323,0	233,0	44,0	277,0	206,0	241,0	160,0	1,73	1,57
10	08-mar	387,4	233,0	44,0	277,0	206,0	289,0	95,7	2,90	1,88
11	09-mar	387,4	233,0	44,0	277,0	206,0	289,0	95,7	2,90	1,88
12	10-mar	413,5	297,0	59,0	356,0	248,0	289,0	190,5	1,87	1,67
13	11-mar	448,5	344,0	64,0	408,0	298,0	337,0	257,5	1,58	1,51
14	12-mar	496,1	384,0	73,0	457,0	327,0	385,0	288,0	1,59	1,52
15	13-mar	550,9	411,0	73,0	484,0	373,0	434,0	306,1	1,58	1,48
16	14-mar	637,1	425,0	78,0	503,0	421,0	482,0	286,9	1,75	1,51
17	15-mar	714,3	425,0	78,0	503,0	421,0	530,0	209,7	2,40	1,70
18	16-mar	734,7	425,0	78,0	503,0	421,0	530,0	189,3	2,66	1,75
19	17-mar	749,8	425,0	85,0	510,0	471,0	530,0	231,2	2,21	1,59
20	18-mar	796,7	425,0	93,0	518,0	499,0	578,0	220,3	2,35	1,60
21	19-mar	872,9	404,0	100,0	504,0	546,0	626,0	177,1	2,85	1,60
22	20-mar	933,8	438,0	100,0	538,0	589,0	674,0	193,2	2,79	1,59
23	21-mar	987,1	722,0	105,0	827,0	630,0	723,0	469,9	1,76	1,57
24	22-mar	987,1	722,0	105,0	827,0	630,0	723,0	469,9	1,76	1,57
25	23-mar	987,1	722,0	105,0	827,0	630,0	771,0	469,9	1,76	1,57
26	24-mar	1.140,9	840,0	192,0	1.032,0	670,0	771,0	561,1	1,84	1,70
27	25-mar	1.185,0	871,0	255,0	1.126,0	694,0	819,0	635,0	1,77	1,71
28	26-mar	1.243,0	1.009,0	268,0	1.277,0	727,0	867,0	761,1	1,68	1,71
29	27-mar	1.301,5	1.014,0	301,0	1.315,00	760,0	915,0	773,5	1,70	1,71
30	28-mar	1.361,6	1.111,0	315,0	1.426,0	807,0	963,0	871,4	1,64	1,69
31	29-mar	1.430,0	1.111,0	315,0	1.426,0	807,0	1.012,0	803,0	1,78	1,77
32	30-mar	1.455,0	1.111,0	315,0	1.426,0	807,0	1.060,0	778,0	1,83	1,80
33	31-mar	1.467,5	1.130,0	334,0	1.464,0	897,0	1.060,0	893,5	1,64	1,64

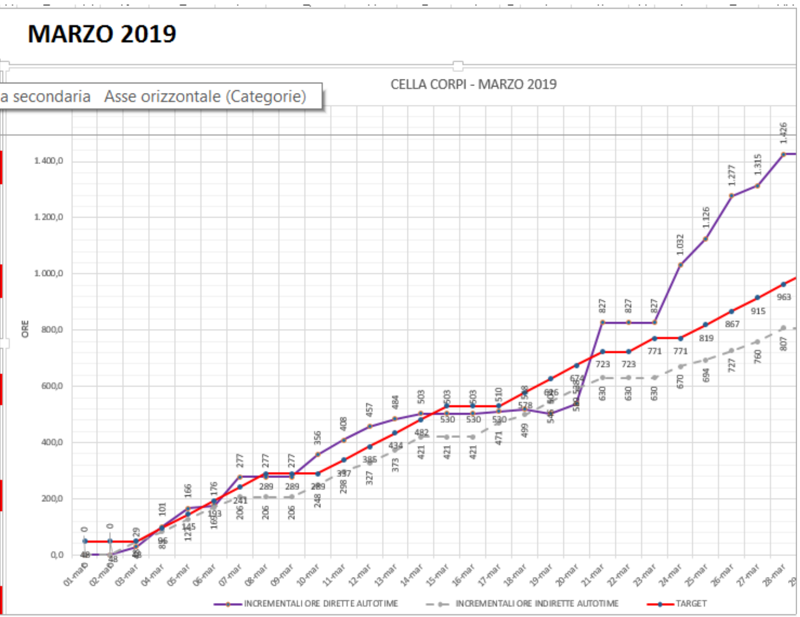


Figure 39, AutoTime hours vs PowerMES hours

As shown in figure 41, the idea is comparing the report of AutoTime with the report of PowerMES, in terms of direct hours of course, so it is easier to visualize the current situation.

(or example in 24 March, the machine AutoTime (denoted by Crist. Machine) – PowerMES = 1140 – 840 = 300 hours.
After this analysis, it is easy to understand that having 134% efficiency was not reasonable, and the problem is the misalignment of data exchange between PowerMES and AutoTime.

<u>Expected outcomes and efficiency calculation:</u>

After analyzing the situation, it is interpreted that having such high efficiency was not that much reasonable because the expectation is all the data is transmitted from PowerMES to AutoTime, which means the software are exchanging data correctly and the direct and indirect hours are stored in AutoTime correctly. However, that is not the case.

After having analyzed the file that calculates the efficiency, one more mistake is found:

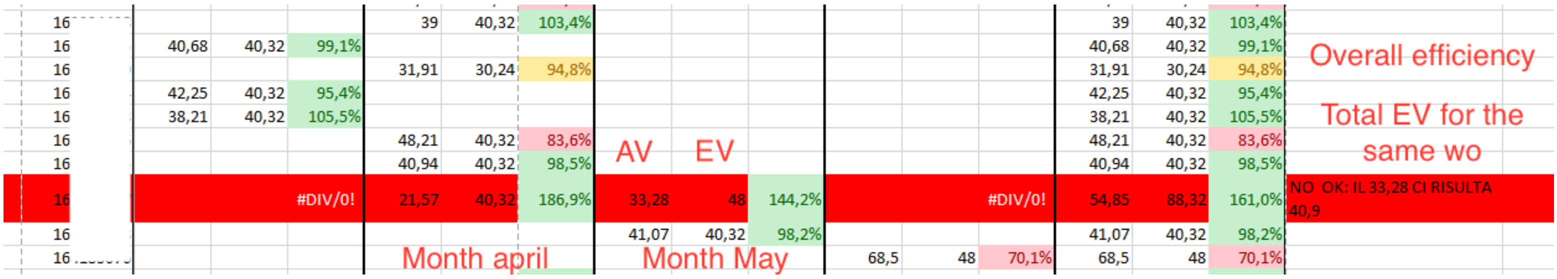


Figure 40, Efficiency calculation excel sheet for the part numbers

In figure 42 what happened is that the work order started on the day 29/04 and the machining operation was continued till the next month, as illustrated there are two different earned values, because in April (40,32 h) it was scheduled 3 pieces, and in May the remaining piece (48 h), so the EV was divided between the two months. But what does not make sense is calculating the overall efficiency, the system sums the two EV which gives for a single work order an efficiency higher than 100%, the EV should be only 48 h, not the sum of 40,32h + 48 h = 88,32 h.

This problem is solved immediately, thanks to the collaboration of the top management team.

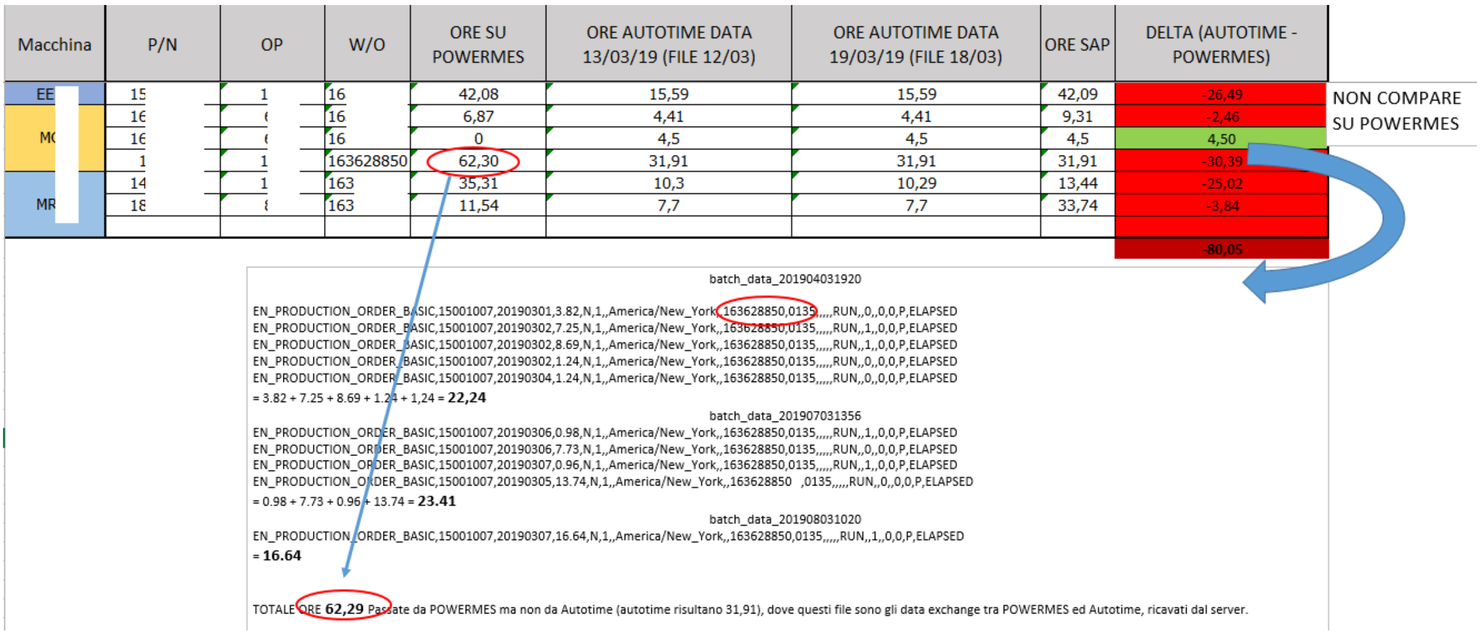
After fixing the mistake, an overall decrease in the efficiency in the whole plant is noticed, which reflected the reality and helped the top management team to take better corrective action, and to understand the plant situation and which part numbers operations they should improve.

In figure 41, comparing PowerMES with AutoTime there is a gap of 200 hours which means that data is unexchanged correctly. An investigation activity some part numbers is performed and checking whether the server exchanges the data or not and what are the possible causes of such problem.

The short-term goal is to resolve the problem as soon as possible in order not to create any further confusion and find the root cause of this problem. However, the long-term goal is to move to real time data, to take better decisions based on real time data, which is very useful (for managerial reasons). Also, for the planning department the implementation of this goal allows them to be more efficient in the planning process. It is considered as a first step to move to artificial intelligence data management.

<u>Part number Analysis (PowerMES data management):</u>

The SQL data server was extracted and checked, and the results are shown:



Macchina	P/N	OP	W/O	ORE SU POWERMES	ORE AUTOTIME DATA 13/03/19 (FILE 12/03)	ORE AUTOTIME DATA 19/03/19 (FILE 18/03)	ORE SAP	DELTA (AUTOTIME - POWERMES)
EE	15	1	16	42,08	15,59	15,59	42,09	-26,49
M	16	6	16	6,87	4,41	4,41	9,31	-2,46
	16	6	16	0	4,5	4,5	4,5	4,50
	1	1	163628850	62,30	31,91	31,91	31,91	-30,39
MR	14	1	163	35,31	10,3	10,29	13,44	-25,02
	18	8	163	11,54	7,7	7,7	33,74	-3,84
								-80,05

NON COMPARE SU POWERMES

batch_data_201904031920

EN_PRODUCTION_ORDER_BASIC,15001007,20190301,3.82,N,1,,America/New_York,,163628850,0135,,,,,RUN,,0,,0,0,P,ELAPSED
EN_PRODUCTION_ORDER_BASIC,15001007,20190302,7.25,N,1,,America/New_York,,163628850,0135,,,,,RUN,,1,,0,0,P,ELAPSED
EN_PRODUCTION_ORDER_BASIC,15001007,20190302,8.69,N,1,,America/New_York,,163628850,0135,,,,,RUN,,1,,0,0,P,ELAPSED
EN_PRODUCTION_ORDER_BASIC,15001007,20190302,1.24,N,1,,America/New_York,,163628850,0135,,,,,RUN,,0,,0,0,P,ELAPSED
EN_PRODUCTION_ORDER_BASIC,15001007,20190304,1.24,N,1,,America/New_York,,163628850,0135,,,,,RUN,,0,,0,0,P,ELAPSED
= 3.82 + 7.25 + 8.69 + 1.24 + 1,24 = **22,24**

batch_data_201907031356

EN_PRODUCTION_ORDER_BASIC,15001007,20190306,0.98,N,1,,America/New_York,,163628850,0135,,,,,RUN,,1,,0,0,P,ELAPSED
EN_PRODUCTION_ORDER_BASIC,15001007,20190306,7.73,N,1,,America/New_York,,163628850,0135,,,,,RUN,,0,,0,0,P,ELAPSED
EN_PRODUCTION_ORDER_BASIC,15001007,20190307,0.96,N,1,,America/New_York,,163628850,0135,,,,,RUN,,1,,0,0,P,ELAPSED
EN_PRODUCTION_ORDER_BASIC,15001007,20190305,13.74,N,1,,America/New_York,,163628850 ,0135,,,,,RUN,,0,,0,0,P,ELAPSED
= 0.98 + 7.73 + 0.96 + 13.74 = **23.41**

batch_data_201908031020

EN_PRODUCTION_ORDER_BASIC,15001007,20190307,16.64,N,1,,America/New_York,,163628850,0135,,,,,RUN,,1,,0,0,P,ELAPSED
= **16.64**

TOTALE ORE **62,29** Passate da POWERMES ma non da Autotime (autotime risultano 31,91), dove questi file sono gli data exchange tra POWERMES ed Autotime, ricavati dal server.

Figure 41, Data exchanged on the SQL server compared to PowerMES

PowerMES (the machining time) turns out to be 62.30 hours. But AutoTime states that the time obtained is 31.91 hours, also obviously says SAP because SAP input data is from AutoTime.

Extracting the text data from the SQL database, which is denoted by batch data, the time obtained is 62.30 hours as PowerMES says, but this data seems that it was never sent to AutoTime and it was not the only case.

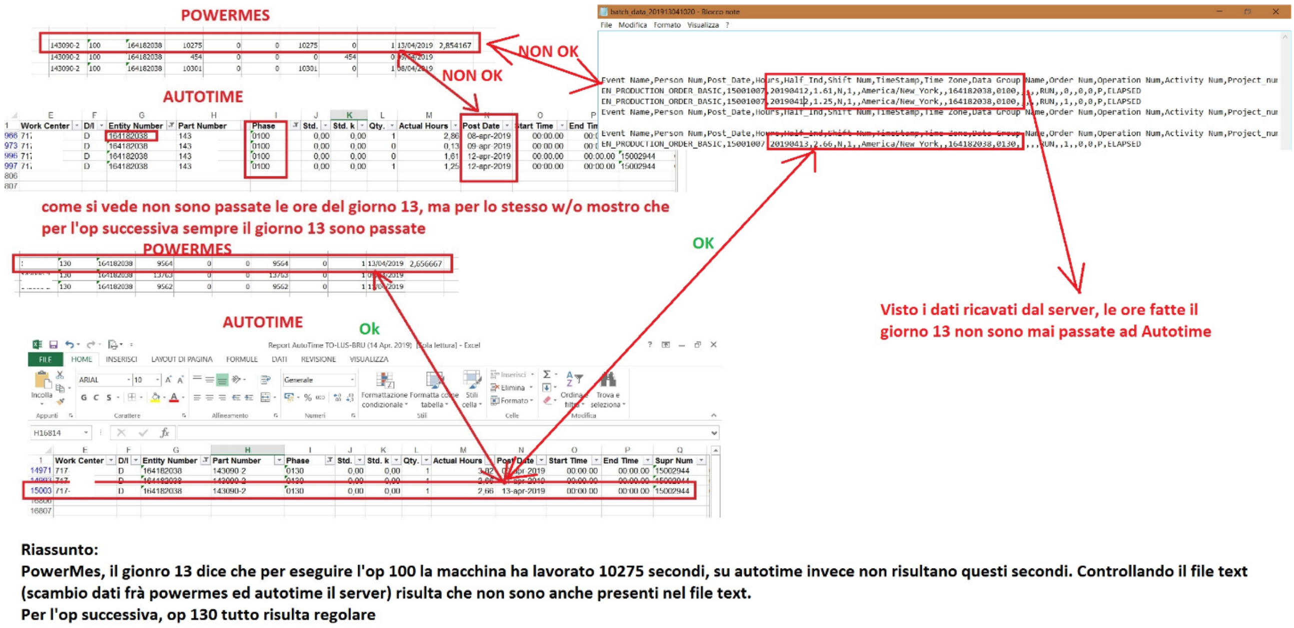


Figure 42, Analysis of an anomality in the data exchange

In figure 44, there is an interesting case because for the same part number that has two different working phases, the first phase there was a misalignment as explained, but for the second case the data exchange was correct.

After such analysis, of data exchange, a request is made to the IT (Information Technology) department and the plant manager to have a meeting to discuss the results and inform the manager responsible for AutoTime data management of such abnormalities.

<u>Reflections and solutions:</u>

After the root cause analysis, it turns out that the main reasons for such abnormalities are:

1. The operator makes a mistake in registering the work order on the software
2. There is a mistake in the string of the program (for a given part number and an operation, the string to count the hours is wrong)
3. The unexplained error of PowerMES data management. (the software company now is working on the resolution of this problem)

4. Sometimes the server was down

Since the problem and the root cause is done, the corrective action plan is defined:

1. An adequate training is given to the operators in order to minimize human mistakes in entering the work order, also automating the process of entering the work order by a barcode gun
2. Contacting the manufacturing engineering to correct all wrong program strings and to perform a daily control of all part numbers worked, to make sure the data is consistent to avoid mistakes
3. Reporting the problem to the IT (Information Technology) software vendor and fixing an appointment to discuss the abnormalities
4. Requesting the internal IT (Information Technology) team to generate an automatic email message in case the server is down so the whole plant is aware of the situation

<u>Chapter 3</u>: Business plan implementation to improve the efficiency in the machining department

1. <u>Introduction</u>

The starting point to perform the analysis is typically the priority processing, because not all the part numbers have the same strategic importance and profit margin.
The current situation characteristics can be summarized by data ambiguity and complexity.

Figure 43, Efficiency report of Turin plant

In figure 45, the efficiency report of the overall Turin plant is illustrated. The report is structured in two main sections; the first section is the efficiency trend by program, and the second section evaluates the overall efficiency by part number.

Just the first part number, have nearly 2000 machining hours, -as average in a year this part number would need 4,800 working hours-, also the first part number have very high machining times on a CNC machine, so the business plan is developed in order to try to reduce the cost of producing the first and most important part number.
The analysis as shown, is performed on the first and most important part number, because it is the biggest contributor in terms of machining hours

and profitability. Some very interesting facts about the situation is that another part number has a similar machining process and the demand can be considered stable at least for 5 years. If only the two-part numbers are combined, machining time is expected to raise to nearly 10,000 machining hours per year.

The main idea behind this reasoning is reducing the cost of production for the most important part number, a quick cost analysis is implemented as follows;

The goal is to save 10% of the overall machining hours per year, so the theoretical target is:

$$Saving\ Target\ In\ Hours = Total\ Machining\ Hours\ per\ year * \ Target\ Saving$$

$$Saving\ Target\ In\ Hours = 10.000 * 10\% = 1.000\ Hours$$

The hourly cost of production for the Turin plant is estimated to be 100€, hence the total savings in €, can be calculated as:

$$Saving\ Target\ In\ € = Saving\ Target\ In\ Hours * Hourly\ Cost\ of\ Production$$

$$Saving\ Target\ In\ € = 1.000 * 100 = 100.000€$$

Analyzing the current situation for the two-part numbers, with the help of the cost reduction manager to perform the cost analysis, the following situation is found, and some ideas were suggested to reduce the two-part number machining time:

1. The average auto (machine) time the first part number was about 50 hours only for the operation 50, that was due to the fact that the CNC program was implemented for a machine with only 3-axis while the program runs on a machine with a 5-axis, and the opportunity is here, by rewriting the CNC program to a more efficient one exploiting the availability of a 5-axis machine.

2. Waste in the process is identified, because it was difficult to find the appropriate utensils in the tool warehouse and mounting them took as average 30 minutes. Also, the lack of the concept of average tool life, which leads to many machine breakdown and line stoppage. The opportunity lies in eliminating the non-value adding activities identified above, by reorganizing the machine tool warehouse and introduce the concept of average tool life.
3. Make a preventive maintenance plan for the machines producing the two pieces using AI (Artificial Intelligence).
   Due to the high cost of harmonizing data exchange system, it was decided to postpone this activity, till a reliable set of data is available.
4. Implementing cell design methodology, and one-piece flow production techniques.

Summarizing the action plans, to formalize the business plan:

1. Rewriting CNC programs to more efficient ones
2. Re-organization of the utensil tool warehouse and decide whether to invest in improving the tool warehouse or outsource the activity
3. Introduce the concept of average tool life

2. <u>Analysis of the actions in the business plan</u>

2.1. <u>Rewriting CNC programs, to more efficient ones</u>

Since the CNC program running on the part number is 40-year-old, and the machine available is a 5-axis machine this advantage can be exploited to reduce the machining time because the old program recalls only one single utensil, and it machines one face of the cube at time.

The number of utensils used on this part number is 70 utensils, exploiting the 5-axis machines capability of manufacturing the part number and recalling more than one utensil at time, the machining time could be reduced by 1 hour only by optimizing the utensil recalling function, for the automatic machining process that lasts 48 hours. Then the efficiency is improved by 2%, so the machining time is 47 hours.

If rewriting the CNC program is fully considered (reverse engineering the CAD available) the estimated time needed to rewrite it, asking the CNC programming analyst is 1 month and both the CNC programmer and the operator should be doing the work, this means two resources are needed plus the time to perform various tests which means also the machine will not be productive.

Given the conditions described, the machining team proposed to ask how much it costs if the project is developed by an external company, compare it to the internal development cost and then make a decision on how the project is implemented.

<u>Internal development cost analysis:</u>

To implement the 2% saving in machining time, given the cost of an internal CNC programming resource: 2.000€ per week as a fixed cost and the cost of an operator overtime if the project is implemented after working time plus the machine cost, to avoid the need of stopping the production process: 4.000€ per week, the total cost of development is:

$$Total\ Development\ Cost = Fixed\ Costs + Variable\ Costs$$

The total number of resources needed are 3, two CNC programmers, and one-line operator, so the total development cost is

$$Total\ Development\ Cost\ per\ week = 2 * 2.000 + 4.000$$
$$= 8.000\text{€ per week}$$

The development is expected to take two weeks, hence the total cost will be 16.000€, to develop the program internally.

The total machining hours, for those two-part numbers in this operation accounts to 5.000 hours per year, and given the cost of running the machine is 100€ per hour, the total savings in euros:

$$Total\ Saving\ in\ € = 5.000 * 2\% * 100 = 10.000\ € \text{ per year}$$

Since the demand is stable in 5 years, a total saving of 50.000€ over 5 years is achieved.

The ROI (Return of Investment) is calculated as follows

$$ROI = \frac{Net\ Income}{Cost\ of\ Investment} = \frac{50.000}{16.000} = 3.12$$

Which shows a very high ROI over 5 years of net income.

For what concerns the external consultancy offer expected, since those two part-numbers are considered a highly strategical important part-numbers, to protect the machining process industrial secret, the management team decided not to outsource the activity of development and to implement the whole process internally.

The activity was slightly postponed to few months later, in order to guarantee the machine availability and not to cause any delay in processing customer orders.

2.2. Re-organizing utensil tool warehouse

The concept of 5s explained in ACE (Achieving Operational Excellence), is applied to re-organize the utensil tool warehouse, as the operators face difficulties to get the right utensil from the warehouse, and sometimes they need to ask each other's where that specific tool was and here waste is identified.

The re-organization is necessary in order to optimize the production, facilitate the production process and improve both efficiency and utilization of resources.

The lean management thinking approach can be applied to manage the tool warehouse and here lies a very big potential for process improvement.

Warehouse utensil management:

The clever management of the warehouse utensils is becoming a necessity in order to achieve optimal production levels, eliminate waste and be more competitive, as illustrated before.

In this case study, the company under the analysis, is specialized in suppling actuation systems, the company is considered as a big aerospace OEM's (Original Equipment Manufacturer).

What makes this company different from many other companies, that a full mass production or JIT (Just in Time) production technique cannot be implemented, because ten part numbers have a very stable demand, while the rest 3000 part numbers, customer demand is constantly changing, from here arises the necessity of a particular way of implementing various production techniques with a special design for the warehouse utensil management system.

The theoretical framework is discussed in the next section, after having defined an appropriate framework to use as a reference, based on the company needs.

Tools management:

The tools management workflow is important because it is defining how the various steps are applied, till the tool is in the hand of the operator or in the machine to manufacture the parts. Raw materials are shipped by the logistics in the shop floor area and the processing cycle is included along with an assigned work order.

Processing cycle is the document that contains all the necessary operations defined one by one, with all the detailed technical drawings and the utensils needed to machine the particular part number in each operation individually.

Generally, the formulation of the processing cycle is the manufacturing engineering department.

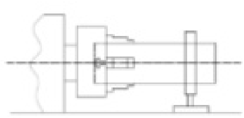
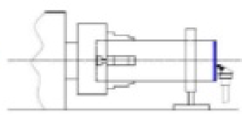
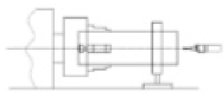
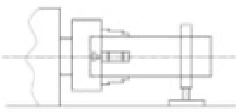
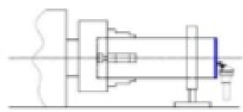
Materiale AISI 316		Stato di fornitura	SEMILAVORATO		
Rm (N/mm²) 700	Durezza 215	Massa grezzo (kg) 208	Quantità 1		
N.:	OPERAZIONE	Macchina	Utensili, attrezzi e strumenti (nome e codice completo)	Tempo (s)	Disegno del pezzo
1	Bloccaggio pezzo su piattaforma autocentrante con 3 morsetti sul profilo 2 e lunetta fissa	Tornio parallelo tradizionale SIBIMEX CU800		36	
2	Tornitura esterna di sfacciatura del profilo 2 con n° 1 di passate di sgrossatura con profondità di passata di 1 mm	Tornio parallelo tradizionale SIBIMEX CU800	Utensile: C5-DCLNR – 35060-16-M Inserto: CNMG 160612 – MF4	423	
3	Centratura del pezzo	Tornio parallelo tradizionale SIBIMEX CU800	Punta a centrare senza piano in HSS 83100 da 12,5 mm	111	
4	Rotazione e bloccaggio del pezzo su piattaforma autocentrante con 3 morsetti sul profilo 2 e lunetta fissa	Tornio parallelo tradizionale SIBIMEX CU800		36	
5	Tornitura esterna di sfacciatura del profilo 2 con n° 1 di passate di sgrossatura con profondità di passata di 1 mm	Tornio parallelo tradizionale SIBIMEX CU800	Utensile: C5-DCLNR – 35060-16-M Inserto: CNMG 160612 – MF4	423	

Figure 44, Example of a processing cycle

In figure 46 the processing cycle is illustrated.

The processing cycle should include the following information: the material name, the weight of the raw material, the operation description, number, time, drawing, in which machine it should be implemented, and the name of the tool needed to perform the operation.

The tool warehouse is considered the heart of the shop floor, because when the operator reads the processing cycle, he needs to ask the presetting, to pre-setting those determinate utensils' needed (the utensils pre-determined by the manufacturing engineering), so he can load them into the machine and begin the machining cycle.

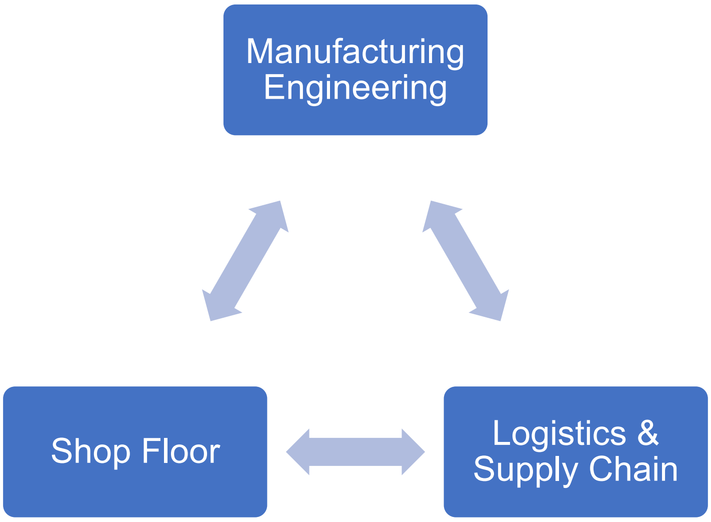


Figure 45, Different departments relationship in the production process

In figure 47 the departments involved to perform the machining processes are illustrated. At first the logistics supplies the part into the plant, after that the role of the manufacturing engineering is to define the processing cycle, and finally the shop floor can manufacture the parts only after receiving the raw material. The processing cycle is considered the instruction manual for the operators to perform the whole process.

<u>Presetting:</u>

Usually the presetting is very near to the tools warehouse, obviously because the tools before going to work on a part-number needs to be checked and measured, in order to identify if there is any wear in the utensil and is it conforming or not. Presetting is considered as the shop floor backbone.

Presetting measures the tool offset, in order to obtain the correct dimensions, on the workpiece. The tools setting in advance, at a place away from the machine tool holder in the given holder is known as pre-setting of the tools. The pre-setting device is used to perform the pre-setting by radial and axial position in the tool tip on the tool holder. To preset axial and radial location of the tool tip on the tool holder, a pre-setting machine is used.

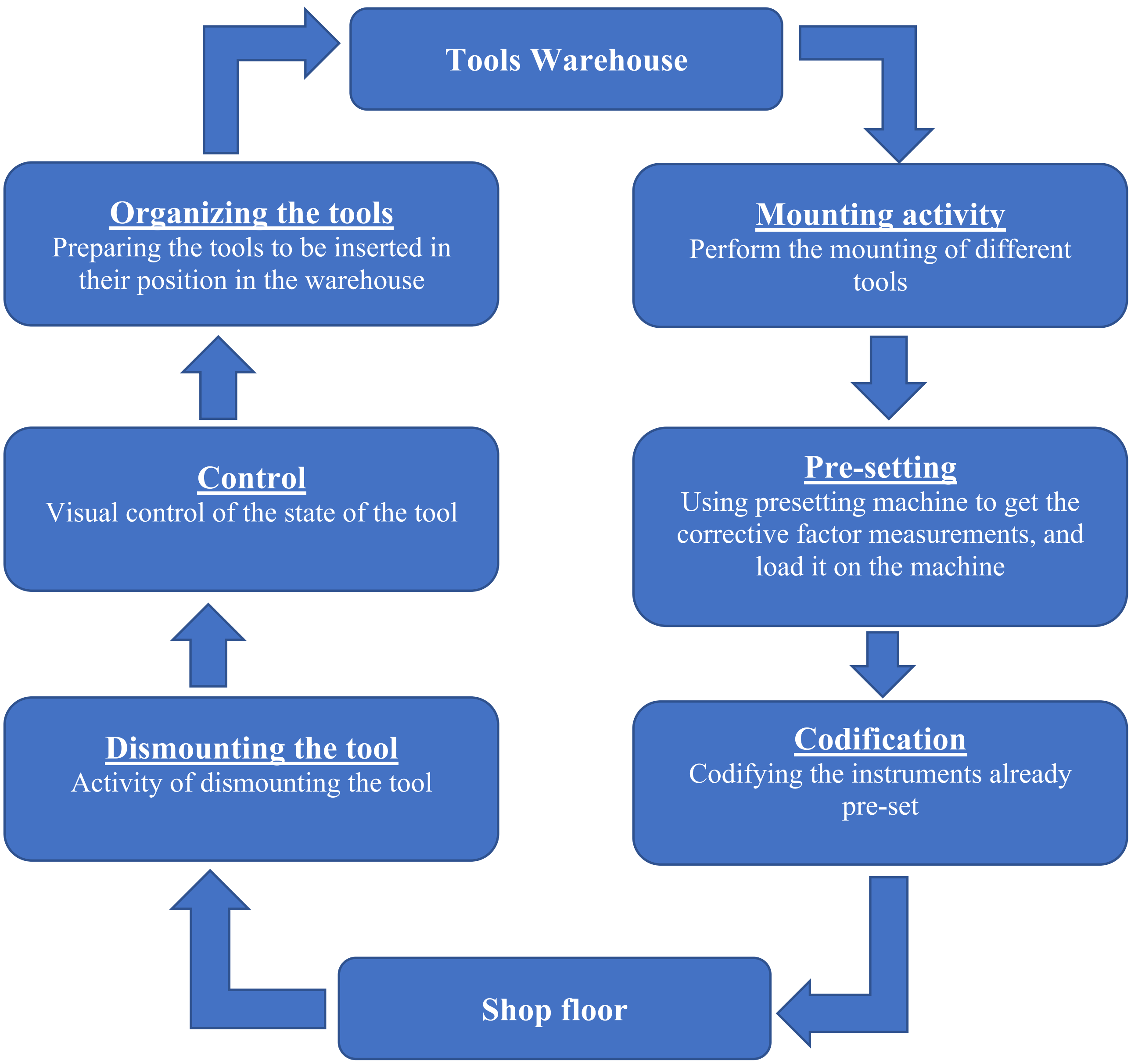


Figure 46, The process of tools management illustrated

In figure 48 the whole process of tools management is illustrated, and each point is addressed separately in the next section.
The tools in the warehouse are well ordered, and this is the starting point of the process.

<u>Mounting activity:</u>

Mounting activity is the first operation in the process of tools management given the processing cycle instructions, as seen in figure 48, the operator easily brings the tool needed since they are well ordered and can know which utensils are mounted on the specific machine, and checks the geometric tolerances of the tools to guarantee the correct manufacturing process on the CNC (Computer Numerical Control) machine.

The utensil specifications are crucial, for a correct mounting activity.
The classification of utensils is:

1. The tool holder:

It is the tool or equipment used to clamp the utensil to the machine spindle, in fact they are also called clampers, they have different shapes and weights, based on the utensil it will be mounted on.
In figure 49 an example of the tool holder, is shown.

Figure 47, A simple tool holder. Source: Shunk

2. The spindle:

The spindle is the rotating component of the CNC (Computer Numerically Controlled) machine, where a shaft is present in its heart. The spindle is also called the machine arm. Any machine may have several spindles. The main spindle is usually the biggest spindle, there are also other spindles like: headstock and tailstock on a lathe, for example. Using the term “The Spindle” without any other clarifications means that the main spindle is intended. Machines that have more than one spindle, are called multi-spindle machines.

The classification of the spindle is by the technology used, various types of spindle technology exists like electromechanical clamping, pneumatic clamping and manual clamping systems.

Mainly, the type of spindle used in the company is the high-speed spindle, there are two types of high-speed spindles;

1. Belt driven spindle
2. Integral motor spindle

The main difference between the belt driven spindle and the integral motor spindle, is that in the belt driven spindle is powered by an external motor in the pully-belt system, while the integral motor spindle the motor is stored inside the machine.

The main advantage of using the belt driven spindle is the low cost of maintenance and easier substitution in case of motor failure, but some disadvantages are the low maximum speed that can be reached. On the other hand, the main advantages of the integral motor spindle that it can reach very high speed, but the disadvantages are the complexity of maintenance activity and spindle alignment.

Finally, in figure 50 a pneumatic (integral motor) CNC (Computer Numerically Controlled) spindle (chuck) is shown.

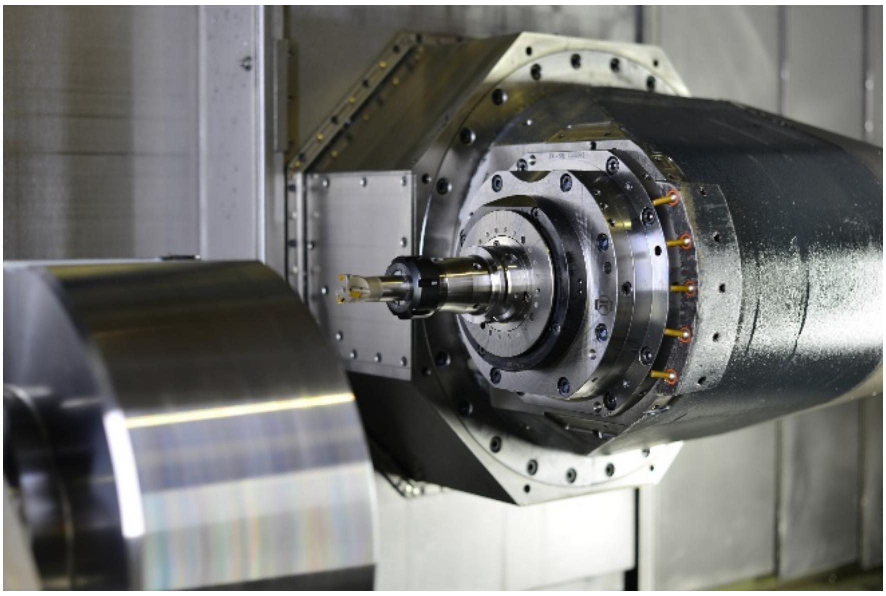


Figure 48, A pneumatic CNC spindle

3. Tool holder extension:

It is often used in many productions processes because sometimes the depth of the cut should be deep, it’s mainly to guarantee more length of the tool to cut into more deep areas.

In figure 51, a tool holder extension for a milling machine is provided.

Figure 49, A tool holder extension for a milling machine

4. Utensil or insert:

Is the tool by which the cutting is implemented. Single point tools are usually used in turning operations, and multipoint tools that are used in drilling and milling operations.

Various machining processes could be implemented, as an example: drilling, milling and turning.

Utensils used in the drilling process:
Solid carbide tips, insert drills, spade drills and gun drills.

Utensils used in the milling process:
Helical cutters, offset tooth cutters, double angle cutters, flat cutters, end mills and chamfering cutters and front cutters.

Utensils used in the turning process:
Roughers, finishers, cutters or fillets.

In the end, the mounting activity is performed by the operator but after the tool is mounted, a need to check the geometric tolerances of the tool should be performed and making sure that the real measurements of the geometric tolerance is equal to the geometric tolerance imposed in the processing cycle.

Pre-setting activity:

It's a crucial step, before mounting the tool into the machine, because if the tool for example has suffered wear, the next part numbers produced should not be machined with that tool because the tool cannot be performing as defined by standard, in some cases due to the wrong utensil geometric tolerance, more than one-part number can be considered as scrap.

The pre-setting activity is performed manually, or automatically depending on the pre-setting machine available.

Figure 50, Speroni automatic pre-setting machine Source: Speroni

In figure 52, for example this is the Speroni automatic pre-setting machine which allows the correct measurement of the utensil, and calculates automatically the corrective factors which are (length and radius) that are applied to the specific utensil, and send the corrective factors which compensate the wear of the utensil, then directly transmit the data to the machine in case it is a CNC (Computer Numerically Controlled) machine.

In case in which the utensil is not in good working condition, the machine will display a pop-up telling the line operator that the utensil is not in good working condition, and then the operator can either re-sharpen the tool, or change the utensil with another new one.

After performing the pre-setting activity, all the utensils are loaded on a CNC (Computer Numerically Controlled) trolley in as the one indicated in figure 53, ready to be mounted on the machine to manufacture that part number.

Figure 51, Example of a CNC tool trolley

<u>Codification and tracing the tools:</u>

To codify, manage and trace the tools; the company uses a software called IndySoft, which traces the tools, count how many tools there are in stock, define the minimum order quantity and have the specific tool design for the special utensils.

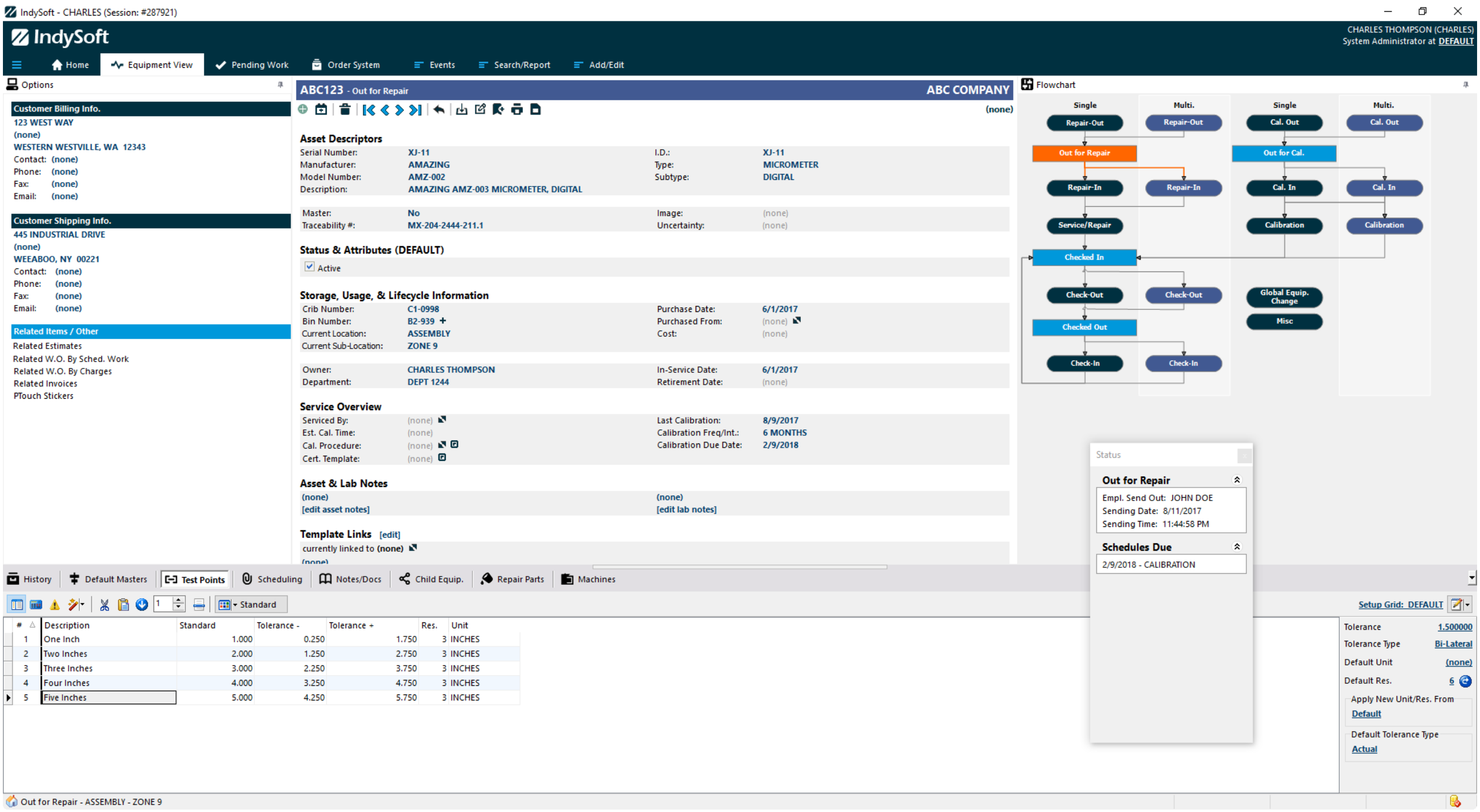


Figure 52, IndySoft interface

In figure 54, an interrogation was made to give an example of the process. In this case it's a digital micrometer, used in the measurement operation. The equipment overview interface, it gives information about the tool serial number, manufacturer, type and description.

In the second section the storage, usage and lifecycle information are described. For example, the sub-location field indicates in which drawer the tool can be found and for what regards the service tab, the last time the micrometer was calibrated is shown.

If a utensil is interrogated instead of a micrometer, in addition to the information available also other types of information are shown, like the utensil mechanical drawing.

Using a serial number for each part is a quite old technique, in the following section other techniques are illustrated, because a potential improvement can be achieved, if moving into a new system.

Barcode technology:

Figure 53, Barcode example

The barcode is a sort of bar data visualization. It is composed by a series of bar and space arranged regularly and a corresponding character, the barcode itself indicates certain information.

The information indicated changes by changing the width of the bar space, hence the number changes. In figure 55 a bar code example is given.

Nowadays the barcode technology is available for everyone, with the diffusion of the optical devices which are cheap and can easily scan the bar codes. The company uses this technology to identify work orders. The top management team is considering the implementation of barcode technology also to the utensil management.

Data matrix:

Figure 54, Data matrix example

It is a two-dimensional code consisting of black and white cells or dots organized in either a square or rectangular pattern. The information encoded is either text or numeric data. The maximum data size that can be stored in the data matrix is 1556 bytes.

The length of the encoded information depends on the number of cells within the matrix. Error correction codes are used to increase reliability because even if there is one or more than one damaged cell which they contain no data, the original information can still be accessed.

Laser machines are usually used to mark the data matrix. The advantage of using a data matrix, is that even if the data matrix is damaged or cleared which usually happens in any machine shop, the device can still recognize it. The cons of using data matrix is the time required to implement the new data matrix system, since it is, time effort consuming, and costly.

RFID (Radio-Frequency Identification):

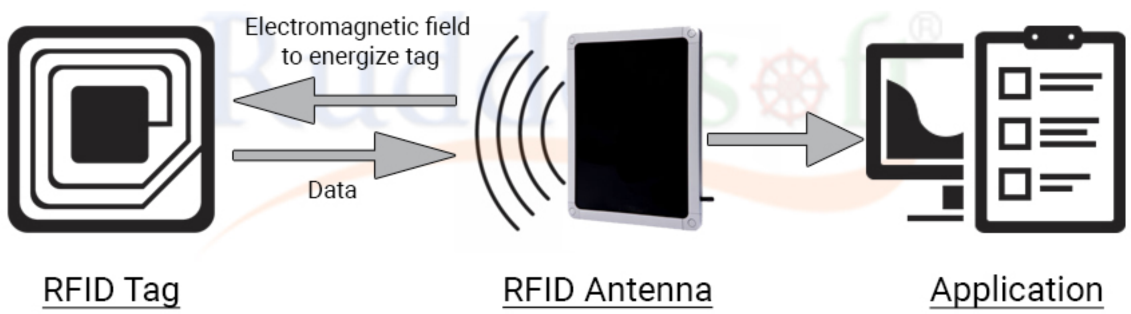


Figure 55, How RFID works

RFID (Radio-Frequency Identification) is the technology where data is encoded in RFID tags and the data exchange can be captured via an antenna (radio waves). RFID is similar to barcoding, in that data is retrieved from a tag or label by a system that stores data in a database.

A protective material is placed above the RFID tag to protect it. This type of technology can take under control the stock levels and allows an advanced way to manage the utensils.

In figure 57 the process is explained, where the antenna is connected to an application, it reads the data from the RFID tag, and transmits it.

Using this technology implies many advantages, the first it that the technology is cheap compared to other technologies, and an optical reader for example is not needed in comparison with the bar code technology.

After defining the process, the weaker point in this company was the tools management, since the Indy Soft software is updated manually by the operators which is a great loss of time and the risk of human error is present, once the concept of average tool life is implemented, some radical strategic decisions to improve the warehouse will be discussed.

2.3. Average tool life concept implementation:

Theoretically, the average tool life can be calculated using Taylor's formula, but due to the special circumstances that the work centers do not machine only one type of material, and some utensils can machine more than one metal, a practical method to evaluate the average tool life is modeled:

There are 5 work centers, the analysis is implemented for only one of them, since the machined pieces there 97% of the time, are the same. The list of utensils running on this particular work center are extracted from the software, let's call this work center as work center X.

To make sure that the analysis as precise as possible, not only the quantification of the number of utensils that are in stock is performed, but also the number of utensils that were bought.

The reason why this data is needed is that because computing the difference between the two numbers for each single utensil, the number of used utensils during a time period of two year is available.

Because the CNC machine programs are available, the calculation the machining time for a specific utensil, in the time period of 2 years is possible (because the theoretical time for the utensil in the machining process is known).

Using a specific ERP (Enterprise Resource Planning) program called PowerMES, the total machining time and number of part numbers can be calculated but has to be split by utensil.
After a very long manual work, because the systems are not integrated, in the following table average tool life for each utensil is calculated:

N. UT	UT in Magazine 2017	UT in Magazine 2018	Difference	Total machining hours	Average tool life in hours
1	1	0	1	29	29,0
2	9	4	5	48	9,6
3	2	1	1	36	36,0
4	4	0	4	40	10,0
5	8	0	8	37	4,6
6	6	1	5	38	7,6
7	5	1	4	38	9,5
8	5	5	1	36	36,0
9	4	2	2	38	19,0
10	17	0	17	80	4,7
11	1	4	3	44	14,7
12	1	4	3	50	16,7
13	4	6	2	39	19,5
14	3	3	1	41	41,0
15	10	6	4	40	10,0
16	3	2	1	42	42,0
17	3	8	5	39	7,8
18	2	7	5	43	8,6
19	4	6	2	48	24,0
20	3	6	3	41	13,7
21	2	4	2	50	25,0
22	3	4	1	43	43,0

23	4	1	3	39	13,0
24	2	3	1	38	38,0
25	1	1	1	36	36,0
26	3	3	1	47	47,0
27	2	7	5	45	9,0
28	4	6	2	40	20,0
29	2	7	5	43	8,6
30	6	4	2	36	18,0
31	5	7	2	35	17,5
32	4	10	6	36	6,0
33	8	5	3	49	16,3
34	4	8	4	36	9,0
35	8	10	2	40	20,0
36	4	6	2	35	17,5
37	1	2	1	35	35,0
38	4	3	1	45	45,0
39	3	10	7	39	5,6
40	3	1	2	42	21,0
41	9	9	1	39	39,0
42	2	5	3	35	11,7
43	2	3	1	36	36,0
44	6	8	2	50	25,0
45	11	12	1	44	44,0
46	3	4	1	50	50,0
47	4	6	2	39	19,5
48	4	6	2	43	21,5
49	3	3	1	50	50,0
50	9	7	2	36	18,0
51	3	7	4	38	9,5
52	2	6	4	48	12,0
53	3	5	2	37	18,5
54	6	1	5	36	7,2
55	8	5	3	36	12,0

56	20	12	8	37	4,6
57	3	5	2	43	21,5
58	2	1	1	36	36,0
59	5	1	4	40	10,0
60	4	2	2	46	23,0
61	3	6	3	36	12,0
62	8	6	2	43	21,5
63	30	10	20	89	4,5
64	4	8	4	39	9,8
65	3	4	1	38	38,0
66	8	2	6	40	6,7
67	3	6	3	47	15,7
68	4	2	2	47	23,5
69	2	3	1	44	44,0
70	5	2	3	36	12,0
71	5	8	3	41	13,7
72	0	1	1	46	46,0
73	5	8	3	47	15,7
74	5	1	4	35	8,8
75	5	2	3	39	13,0
76	2	3	1	50	50,0
77	3	2	1	42	42,0
78	4	7	3	36	12,0
79	6	1	5	35	7,0
80	6	3	3	41	13,7
81	5	4	1	48	48,0
82	2	3	1	36	36,0
83	11	6	5	40	8,0
84	8	7	1	37	37,0
85	5	2	3	38	12,7
86	3	8	5	38	7,6
87	8	1	7	36	5,1
88	3	6	3	38	12,7

90	7	9	2	44	22,0
91	4	4	1	50	50,0
92	4	2	2	39	19,5
93	1	2	1	41	41,0
94	3	1	2	40	20,0
95	4	9	5	42	8,4
96	2	6	4	39	9,8
97	1	6	5	43	8,6
98	1	2	1	48	48,0
99	24	2	22	121	5,5
100	6	4	2	50	25,0
101	15	5	10	43	4,3
102	1	8	7	39	5,6
103	3	7	4	38	9,5
104	1	4	3	36	12,0
105	4	1	3	47	15,7
106	1	2	1	45	45,0
107	3	5	2	40	20,0
108	2	3	1	43	43,0
109	21	12	9	36	4,0
110	4	1	3	35	11,7
111	2	5	3	36	12,0
112	6	5	1	49	49,0
113	1	7	6	36	6,0
114	4	5	1	40	40,0
115	1	3	2	35	17,5
116	3	8	5	35	7,0
117	1	6	5	45	9,0
118	2	10	8	39	4,9
119	4	4	1	42	42,0
120	2	3	1	39	39,0
121	1	8	7	35	5,0
122	6	7	1	36	36,0

123	4	10	6	50	8,3
124	5	8	3	44	14,7
125	3	4	1	50	50,0
126	9	4	5	39	7,8
127	3	6	3	43	14,3
128	2	1	1	50	50,0
129	2	8	6	36	6,0
130	3	2	1	38	38,0
131	3	8	5	48	9,6
132	3	10	7	37	5,3
133	5	7	2	36	18,0
134	2	5	3	36	12,0
135	3	10	7	37	5,3
136	4	9	5	43	8,6
137	8	1	7	36	5,1
138	1	7	6	40	6,7
139	2	9	7	46	6,6
140	1	2	1	36	36,0
141	20	4	16	90	5,6
142	9	5	4	46	11,5
143	1	4	3	39	13,0
144	4	5	1	38	38,0
145	48	9	39	134	3,4
146	4	9	5	47	9,4
147	2	5	3	47	15,7
148	4	1	3	44	14,7
149	11	10	1	36	36,0
150	2	4	2	41	20,5
151	4	7	3	46	15,3
152	17	3	14	124	8,9
153	2	6	4	35	8,8
154	7	8	1	39	39,0
155	1	3	2	50	25,0

156	3	5	2	42	21,0
157	2	9	7	36	5,1
158	20	5	15	76	5,1
159	6	4	2	41	20,5
160	3	2	1	48	48,0
161	8	1	7	36	5,1
162	7	5	2	40	20,0
163	7	4	3	37	12,3
164	10	2	8	38	4,8
165	1	7	6	38	6,3
166	5	2	3	36	12,0
167	3	5	2	38	19,0
168	1	3	2	49	24,5
169	7	9	2	44	22,0
170	5	1	4	50	12,5
171	2	5	3	39	13,0
172	5	10	5	41	8,2
173	2	2	1	40	40,0
174	2	3	1	42	42,0
175	18	8	10	84	8,4
176	10	3	7	43	6,1
177	6	7	1	48	48,0
178	3	1	2	41	20,5
179	2	9	7	50	7,1
180	1	8	7	43	6,1
181	1	3	2	39	19,5
182	9	8	1	38	38,0
183	3	7	4	36	9,0
184	30	6	24	184	7,7
185	19	8	11	45	4,1
186	7	6	1	40	40,0
187	1	3	2	43	21,5
188	2	8	6	36	6,0

189	3	1	2	35	17,5
190	1	8	7	36	5,1
191	2	7	5	49	9,8
192	29	9	20	88	4,4
193	6	2	4	40	10,0
194	11	8	3	35	11,7
195	3	6	3	35	11,7
196	1	7	6	45	7,5
197	2	8	6	39	6,5
198	3	4	1	42	42,0
199	2	8	6	39	6,5
200	1	4	3	35	11,7
201	1	5	4	36	9,0
202	5	3	2	50	25,0
203	4	10	6	44	7,3
204	2	6	4	50	12,5
205	24	7	17	67	3,9
206	1	1	1	43	43,0
207	1	9	8	50	6,3
208	1	10	9	36	4,0
209	2	3	1	38	38,0
210	2	4	2	48	24,0
211	2	5	3	37	12,3
212	3	6	3	36	12,0
213	1	9	8	36	4,5
214	10	7	3	37	12,3
215	8	2	6	43	7,2
216	2	2	1	36	36,0
217	6	9	3	40	13,3
218	3	4	1	46	46,0
219	3	7	4	36	9,0
220	1	5	4	43	10,8
221	5	6	1	46	46,0

222	7	10	3	39	13,0
223	20	10	10	86	8,6
224	3	1	2	40	20,0
225	4	9	5	47	9,4
226	11	2	9	47	5,2
227	11	10	1	44	44,0
228	1	1	1	36	36,0
229	5	4	1	41	41,0
230	9	1	8	46	5,8
231	6	3	3	47	15,7
232	1	9	8	35	4,4
233	2	3	1	39	39,0
234	4	10	6	50	8,3
235	2	7	5	42	8,4
236	3	6	3	36	12,0
237	2	5	3	35	11,7
238	1	3	2	41	20,5
239	1	1	1	12	12,0
240	6	4	2	20	10,0
241	11	10	1	28	28,0

The reason why there is no negative utensil difference, is that there is a line operator responsible to make sure all needed tools are available.

Since it is not so easy to interpret the result numerically, a quality control chart is implemented in figure 58, in order to better visualize the results. The parameters are the 2 sigma control limits, 95% confidence interval, with average of 19.1, standard deviation of 13.96, UCL (Upper Control Limit) of 47,01 and LCL (Lower Control Limit) of 0 since negative value do not make any sense.

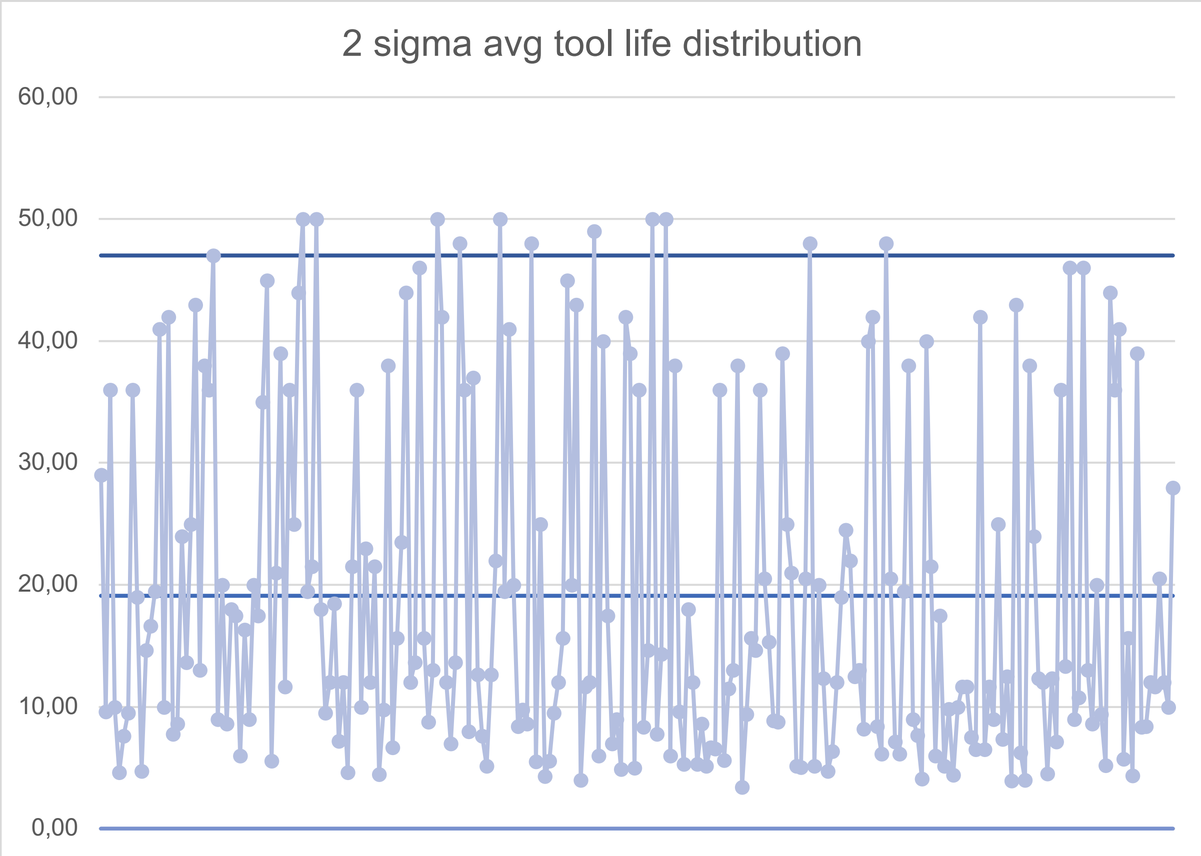


Figure 56, Quality control chart to visualize average tool life

Also, the following histogram is useful to better read data:

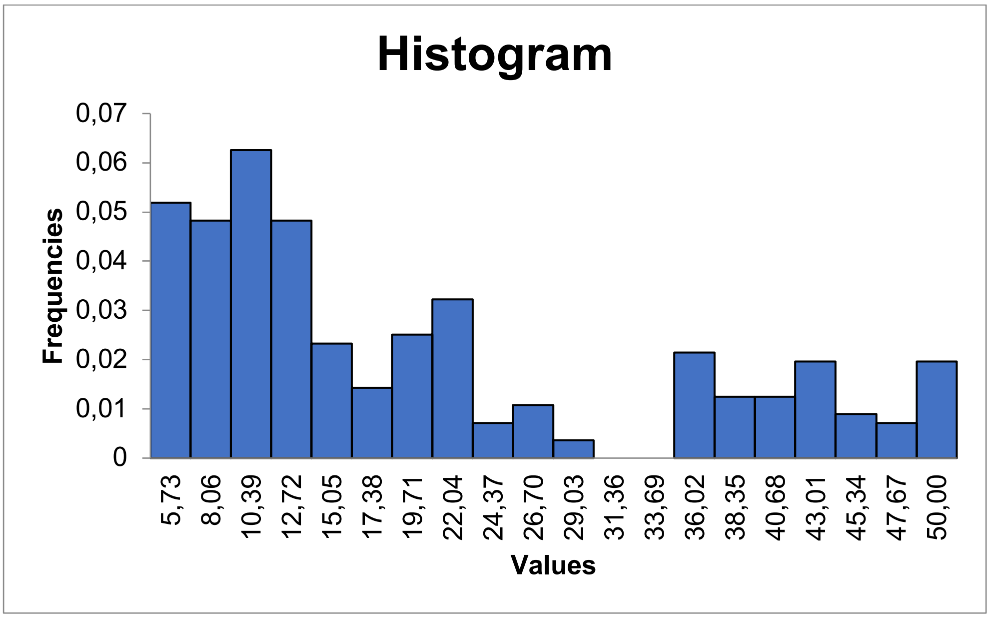


Figure 57, Histogram to visualize the average tool life

It turned out that 12 utensils are super performing. Such analysis is effective to understand the better performant utensil from the less performant ones, and to predict when the utensil will fail based on past data.

After having identified the average tool life for each utensil, a restriction of tool life check is implemented on the work center X, since the data suggests the average tool life should be multiplied by 90%, and such restriction is imposed in the work center X, where now the line operator has a production constrain, because on the machine for each tool the data obtained is inserted, and before allowing the operator to run the program the machine will ask if the line operator is sure about continuing the machining process while an utensil has exceeded its average tool life. This analysis should result in higher efficiency and lower stopping-machine due to tool failure.

3. Assessing the situation and strategic decision making

The dilemma of whether to keep key functions in-house or outsource them, is becoming a very ambiguous question in this case, should a reconstruction program to manage the warehouse of utensil by installing a new software that can track average too life or integrating the existing systems be implemented in house or outsource the whole process?

In figure 60, the following strategic framework helps to understand if the process should be outsourced or kept in house.

Such framework, described in the image, can help us to decide, whether a process/activity is strategic, core or to be outsourced.

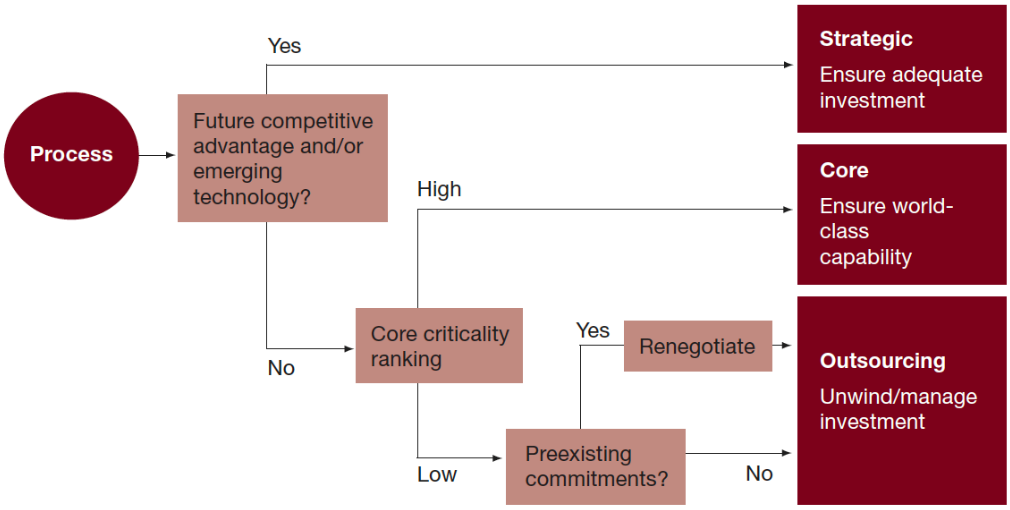


Figure 58, Source: Make or Buy: Three Pillars of Sound Decision Making," published in Sourcing Reloaded: Targeting Procurement's New Strategic Agenda (Strategy&, 2008)."

Applying the framework:

Tool warehouse management cannot be a source of future competitive advantage. It is not an emerging technology, which means specialized suppliers are found easily on the market.

Is the activity, a core competency? It can be argued on that, because it's critical for operational efficiency, but the company does not only have the machining department since it also includes special processes, heat treatments, assembling activities.

The activity of tool warehouse management is important, but not a core competency of the company.

Are there any preexisting commitments? Yes, because the warehouse is managed by a broker which sells only the utensils, and the company is responsible to do the management activities. Luckily the contract will expire in few months, which means a renegotiation is expected soon or completely outsource our activities.

The part numbers manufactured in the shop floor, are considered cash cow products. In order to get an approval, the investment should be evaluated carefully.

Risks associated with the decision to outsource completely the tools warehouse management: lower utensils quality, performance and reliability, compared with the current supplier. The risk can be mitigated by accepting only offers from companies with a high reputation.

Outsourcing a broken process: The risk is that the broker will ask for a premium to repair the broken process, and due to the high importance of the activity the broker adoption to our business model needs can be challenging. However, the risk is mitigated by imposing our studied solution of the process, while the broker will execute our strategy.
In the end, the decision of outsourcing the process, is made, because the activity is not considered a core competency of the company (the company core competency is precision mechanics manufacturing).
An open competition is organized, in order to determine the most suitable broker.
Three companies participated in the open competition, each one with pros and cons.

Company A (the current supplier):
The current supplier has a high reputation for tools suppling 24/7 assistance, plus they know the business needs already and there is no need to explain the whole process for them. Some cons are that they have high cost with respect to the service offered, they won't provide special utensils, re-sharpening the tools is expensive, they can offer management of high rotating volume utensils only and they cannot offer data monitoring/integration that implies the average tool life.

Company B:
Best in the market for precision utensils, very high reputation, 24/7 assistance, they provide specialized solutions that can help reducing costs and they offer programming the machining process free if you buy their utensils, re-sharpening the tools is at a moderate price, extraordinary data integration system that can help monitoring the average tool life, management of both high and low rotating volume utensils, full data monitoring. The cons are very high cost. Only two options are available to use their software of managing the tools:

2. Either the company buys the automatic tool distributor and software they provide, in order to own the right of the data
3. Leasing the automatic tool distributor and be given the right to use the software, but the data is not anymore, a property of the company, it becomes a property of the broker

Company C:
A small family company that has a very low cost with respect to the service offered, they can provide assistance in the development of CNC programs. The cons are that they have no market reputation, 24/7 support is not available, cannot offer a data management specialized software, they do not sell all types of utensil needed.

After having received the offers, the reconstructing program implemented is the following:

1. The supplier should install an automatic tool distributor, as illustrated in figure 61
2. The supplier should be responsible to refill whenever needed the utensils and make the full management (data integration and average tool life), accessible to all employees in the company
3. The full management system should be as following: on a real time, basis, any employee consulting the system should know how much utensils are used to manufacture a determinate part number, on which machine and for how many minutes it worked, using a specialized information software system
4. Automatically generate a monthly report on average tool life for each utensil on each machine

Figure 59, Automatic tool distributor for company B

Company C, is not a very good choice, even imposing strong contractual clauses and penalties on the small company, they still can fail and cause a fatal damage to the production if this happens, so the top management team excluded it from the competition.

Company A is a good candidate; however, they want to sell to the company their new machines, which is a heavy investment, the company do not want to undertake.

Company B is the best choice, but the problem of data ownership can create a switching cost, that can lead to an opportunistic behavior. Renegotiating the terms with the company seems the best solution available, in order to benefit from big cost savings related to the better management of the tool warehouse.

In such complex situation, the top management team decided to postpone the decision, and extend the contract 6 more months with company a, until, either a better supplier is found, or getting better agreement terms with company b, the top management is also considering paying some higher royalty fees, in order to own the data, but only after a second round of negotiation, the decision will be made.

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List of figures