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Master of Science degree
MECHANICAL ENGINEERING

Master Thesis

Improvement of the factory efficiency Applied case to Valéo

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«I sit there marvelling that we're going to reduce
the efficiency of some operations and make
the entire plant more productive.
They'd never believe it on the fifteenth floor. »
The Goal, E. M. Goldratt

« The two most important things in any
company do not appear in its balance sheet:
its reputation and its people »
- Henry Ford

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Paris, 25/02/2018

Maxime Fieurgant

Abstract

In this semester at Valéo Comfort and Driving Assistance (CDA) at Santena (Piedmont, Italy), there was an issue about the capability to deliver the entirety of the clients' demands. To satisfy our clients the choice had been made to do several continuous improvement sites. This master thesis is describing one of them, the last one that I've been part of.

The site improvement took place on the production line of Maserati's paddle shifts. The initial lead time was of 335 seconds per unit and at the end of the site the lead time is almost equal to 200 seconds. We have been able to diminish the lead time thanks to four major improvements over the process. The four of them are described in the second part of the master thesis. Doing so we have been able to increase the throughput with one less operator. Thus keeping the same workforce we relocate one worker hence increasing our overall efficiency and productivity.

The first part is a description of the evolution of the manufacturing processes from 1769 and the beginning of the first industrial revolution to nowadays. While the last part is about how may evolve from now the manufacturing world by looking at the Lean Manufacturing movement, the elements that make the success of a factory over its competitors and the emergence of the fourth industrial revolution.

Key words: Manufacturing, Industry, Lean, TPS, Ohno, Ford, Taylor, Industry 4.0, Big Data, Globalisation, Hoshin Kanri, Smart Factories.

Summary

Illustration table

Glossary

AGV: Assets Gross Value

CDA: Comfort and Driving assistance, business group of Valéo

DLE: Direct Labour Efficiency

DMAIC: Define, Measure, Analyse, Improve and Control. Lean method used for the improvement.

GDP: Gross Domestic Product

KOSU: coming from the Chinese, "Manual Time", correspond to the time used to produce a piece

NVA: Non-value added operations

OST: One Single Time, best KOSU ever made

QRAP: Quick Response Action Plan

QRQC: Quick Response Quality Control

Reuse: Bad part that we can't Rework. So we disassemble it and reuse some of subparts to produce other product.

Rework: Bad part that can be corrected by the modification of one subpart or the ad of an additional step to correct a deflect.

SAP: Company resource planning software, Systems Applications and Products for data processing.

TC: Tempo Cyclo in Italian, Cycle Time in English. Corresponds to the maximum time to produce a part.

TPS: Toyota Production System, created by Toyota and Taiichi Ohno

TRP: Taux Rendement de la production in French, uses to measure the efficiency of the workstation.

TSSC: Toyota System Support Centre

VA: Value added operations

Introduction

Western factories have offshored from the 1980s through to the 2000s. Manufacturing moved from developed countries, hence high-cost counties, to low-cost countries. China, India, Brazil, Russia, Mexico and East European were the main destinations. Following this, it has been taken for granted in Western countries that manufacturing would not have future there.

In 1986, Robert H. Hayes and Kim B. Clark, respectively professor and *alma mater* at the Harvard Business School, wrote that producers can outdo their competitors not by clever marketing but thanks to concrete actions on a practical level to update processing technologies.

In 1990, Daniel Jones and James Womack wrote "*The Machine That Changed the World*". In this book they described how the world would look if the lean principles were applied. Their vision was that it would dramatically improve productivity and quality. It would also enhance the involvement of employees and managers in the factories. In August 2017, at the event for the 20 years of the *Lean Enterprise Institute*, he said that he does not expect anymore "another Toyota". However the lean manufacturing is still the most used tool to improve efficiency and productivity because they need to keep their market attractiveness.

In this Master Thesis, we will look at the evolution of the production field from 1769 until now and particularly the elements that brought productivity and efficiency improvement. Then an applied case of efficiency improvement would be described at Valéo CDA Santena. In the last part we will discuss about the future of manufacturing thanks to the knowledges of the past and the observations made during the applied case.

The lessons of history from 1769 to now

Before 1769s the manufacturing was handwork. The pre-industrial world was a world of slow technological advancement and stagnant living standards. The civilization of each part of the world varied according to its own historical social and political life. Every civilization had limited production capabilities and an economy based on agriculture and used simple process of manufacturing with a really limited number of specialized crafts and a limited knowledge transfer between civilizations.

1- First industrial revolution

1-1. Steam Power technology

The Soho factory (Birmingham, England) was a peculiar one: the workforce was made of employed full-time workers rather than wandering journeymen. Also the manufactory was made of parts, with a high division of labour while others manufactories were still done by artisan without such division. Machines were implemented in Soho factory, in each division.

The Soho plant did not have enough waterpower to power all its machinery and using horse power was too expensive. From this situation Boulton, owner of the Soho manufactory, contacted James Watt with who thanks to their partnership, improved and shaped the steam power enabling its use in factory. In 1769, James Watt, Scottish inventor, mechanical engineer and chemist, used steam power technology to overcome the use of relatively weak men or tired horses.

The world was already becoming an industrialized place before the advent of steam power, the Englishman William Lee invented a knitting machine able to work 10 times faster than a human, in 1589. But thanks to steam power, world had expressed a growth quicker than ever before. Before the advent of steam power, factories had to be built in place suitable to provide wind or water power to drive their machines. Following the steam power emergence, it was possible to build factories anywhere, not just along fast flowing rivers. James Watt and Matthew Boulton created a partnership to scheme Watt's steam engine to any company that could use it, amassing great fortunes for themselves but also sharing research over vast distances. By the early 1800s, high pressure steam engines had become compact enough to be used elsewhere that in factories, thus transportation was developing quickly, first steam powered locomotive appeared in 1804 in Britain. Enabling goods transportation by something else than human's or animal's muscles. The first passenger to be travelled thanks to steam power was in the United States in 1807 for a 150 mile journey from New York to Albany which lasts 32 hours.

The fundamental change during this period was the evolution from putting-out system to the factory one, also called manufactory (from German *Manufaktur*). The change consisted in moving from a small number of workers working in a small workshop to pool hundreds of workers at one location under individual management. It resulted in a great increase in productivity that brought the traditional workshop-based manufacturing of the guilds, and guild-based workshop out of business quickly.

The concentration of labour has benefited to manufactories, bringing:

- A higher division of labour where each worker had to perform a single step in the production process, enabling the use of an untrained and therefore cheap worker with minimal training. It also increased the efficiency by reducing the number of scrap. The worker was less likely to forget a step and was more likely to master his process faster than in the previous work process where he needed to master all operations.
- Due to the increase of the quantity produced, it made sense to pay more attention on optimizing production. Most of entrepreneurs establishing manufactories had a great sense of business and were able to define the cost accounting, trying to understand the costs involved in their production and often aimed to systemically reduce costs. In the eighteenth century child labour was controversial but not forbidden, so boys provided a workforce cheaper than journeymen and even cheaper for girls.
- Manufactories created a material flow between the different stages of production, reducing the work in process compared to a guild worker processing a pile of products from raw material to finish product. This reduction of work in progress means less capital was spent in materials, freeing up money for other expenses. In the case of borrow money it would even save the company from the interest. Additionally less space was needed to store materials, less effort was needed to handle them and since materials got used more quickly, they were not spoiled by getting obsolete. The benefit of reduced work in progress is probably the least obvious and many manufactories did not pay attention to it. In fact even today a lot of companies still don't understand the benefit of reducing inventory.
- The factory system allowed a better control of the workforce with a direct supervision over the workers, allowing to diminish theft and idleness of workers. These are behaviours that are still happening nowadays but it is much less than in the putting-out system before the first industrial revolution.

Factories had an important issue about organization at that time. An employer was considered lucky if its workers completed the working hours or not stole raw materials or tools. Management wasn't yet a thing. As the Aristocracy who asked for total obedience from the peasants, the employer believed he knew what was best for workers. Thus the employer defined a lot of rules as the working hours, work conditions and saw no need to consult the workers for those choices.

The great improvement of manufactories was to group the workforce and hence to increase the division of labour but the techniques and tools were still the same. This concept of a factory with an important mechanical mass production is the primary driver of the modern manufacturing. The location of the first factory is a subject of debate, it may have been the Arsenal of Venice, or may date from ancient Rome, Chinese production sites, or early mining operations in South America.

Following the steam engine a set of new industries took place. The apparition of steam engine did change the face of manufacturing industry and thus the world, definitely increasing the wellbeing of the civilization.

1-2. Technological Advances

The industrial Revolution between 1769 and 1850, it was the biggest change that human life experienced since the Neolithic revolution. The invention of steam engine provided near-unlimited power anywhere and the increase in mechanization put this power to productive use.

Then during the period from 1850 to 1950, the changes of the industrial revolution emerged from metalworking and textiles to more or less all manufacturing areas, and greatly increase its speed and productivity. This second period is also known as the "Second Industrial Revolution". America usually focuses the Second Industrial Revolution on its successes with the assembly line and scientific managements, while Europe defines it more through its own strengths in this period with the steel, chemical and electrical industries. Regardless of the definition, mass production appeared around 1900. It affected almost all products of everyday life and increase prosperity and the quality of living for these civilizations.

The steam engine was a huge factor of the industrial revolution but comes with drawbacks such as the limitation of type of power. Mechanical movements experience losses during the transmission of the power by the driveshaft, energy and time loss due to the start of the engine and also the fact that the steam engine is dirty, hot and smelly and made the working environment not really suitable for daily work. That's why electrical energy has been also a revolution, easiest to transport, way much cleaner, can be scaled up or down to match with the demand and can be stored. In 1800, Volta invented the battery. However the batteries were too expensive to be used everywhere, thus the use of electricity was limited until the introduction of the first generators in the 1850s. Thanks to this access to cheaper energy, the factories were able to solve one of the biggest problem of that time: light! Before the system used to light the factory was to burn gas which was really cautious. As the demand electricity increased, commercial suppliers started to build power stations.

Electricity completely modified the world and our civilization, moreover that light and movement, it also brought new manufacturing technologies. For example thanks to electricity we are able to produce pure aluminium that was before really expensive even more than gold. Aluminium is one of the three elements more present on the surface of the Earth but in its oxidized form. Several others processes appeared such as coating, electroplating, welding…

About the transport of goods, electricity has been a revolution. The appearance of mass production means that large material flows were not transported thanks to muscle power anymore, we may found in some factories such rate as half of the workforce that were carriers and haulers. Overall electricity provided a clean and safe source of power that could be transferred into many other forms of energy, and nowadays the rate of carriers and haulers is really low.

2- Scientific improvements of the workshop

In the past coordination of the work on the shop floor was based purely on experience. The quantity produced depended on the mood and the speed of the worker. Mathematics were at best used for basic cost accounting. The first experience of shop floor management can be found, with Leonardo Da Vinci when he was working along the river Arno, in Italy. He studied the process of shovelling. He found that a worker can handle 500 shovels of soil per hour and that the process was made of 4 operation: loading the shovel, preparing to throw the soil, throwing the soil and returning the shovel. Da Vinci also noticed that some workers can do the same work 30% quicker but they tire quicker. In the end of the nineteenth mechanical products required the most operations to be manufactured thus mechanical engineer started to be interested in manufacturing management.

2-1. Scientific management, planning vs doing

Frederick Winslow Taylor, American mechanical engineer developed studies among the manufacturing management and is the single person responsible for bringing scientific management into practical use. When he began to study the scientific management he was working at Midvale Steel.

Soldiering consists in slowing down the rate of production to secure a minimal quantity of work for the fellows workers, it was really common at that time. Taylor began as a lathe operator and did soldiering himself, but when the company management set him as a foreman he faced this behaviours. To erase soldiering, he fired a lot of workers hoping to find some that will fit with the required rate of production but when he understood that it wasn't going work, he decided to pay the wages by product made doing so if the workers fit with the required quantity to produce they would earned a biggest wage than before but if they didn't improve their rate they would only have half of their usual income. After a period of opposition from the workers, they agreed and fit with the required rate, but to show theirs disappointments to management they started to break intentionally (or not) tools, materials, machines... The answer of Taylor was that anyone who broke something had to pay for it, and the price would be retained on his wage. After three years, Taylor finally won the conflict with his workers and achieved a stable and higher output without soldiering anymore.

A foreman at that time coordinated the work of a small team made of 5 to 25 workers, most of his work was on administrative issues and problem solving. Taylor was really critical about his own role, he thought that his work was easily outwitted by the collaborative intelligence of his team of workers. Moreover a foreman, like Taylor, was a skilled worker who got promoted, who had the tendency to side the workers against the factory owners. The others foremen were reticent to Taylor's approach based on hard measured data which reduced considerably their power and brought the role of foreman at the extinction. His idea was to modify the role of the foremen, splitting them in eight different role:

- *The gang boss*, provides the work and teaches how to do set up efficiently
- *The speed boss*, responsible of man and machine working speed after the set up has been done
- *The inspector*, controls for quality
- *The repair boss,* manages the maintenance of the machines
- *An order of work and route clerk,* defines the production sequence
- *An instruction card clerk*, responsible for the standard procedures of the process
- *A time and cost clerk*, for taking care of attendance and salaries
- *A shop disciplinarian*, responsible for work behaviour standards and the role of peacemaker.

This implementation of the eight roles of a foreman never took place as seen by Taylor but many of them are nowadays performed by different organizational structure. It leads to a division of labour on the management level.

After a couple of experiences, in 1893, Taylor became the first management consultant focusing on shop management and cost reduction. There was a great demand for his services and did a small fortune in consulting. Moreover the job of consultant enabled him to spend times on research and scientific publications. He found that reducing work hours in many cases improved productivity and the workers were able to do the same amount of work in less time given enough rest. It was at Bethlehem, Palestine, where Taylor did his most famous advancement on scientific management with the pig iron. The plant had 80,000 tons of pig iron stored in a yard, which had to be loaded by hand in railroad for sale. A group of 75 men were assigned to do the loading part, consisting in picking up 40 kg piece of iron from the pile, walk to the railroad car and then drop the pig iron before returning to the pile. The reflexion made by Taylor was that "*it would be possible to train an intelligent gorilla so as to become a more efficient pig iron handler than any man can be*". Taylor defined this idea as the perfect setting to demonstrate his scientific management approach.

At the beginning of his experiment, workers were loading 12.5 tons per day per person, according to his calculus Taylor defined that a worker should be able to load 47 tons per day. He selected Henry Noll, alias M. Schmidt (fake name created by Taylor during the study), and told him exactly when he should work, the speed rate and when he should rest. Schmidt was able to load 47 irons per day without exhausting him after a quick period, doing so he also convinced all other workers to follow his standard, who by the way increased their wage by two-third. We should take into account also that the story is the one told by F. Taylor and thus numerous sources consider it beautify, that the achievement and the number showed by Taylor weren't the real ones.

Taylor's work stopped the usual guesswork but taught people to follow scientific measurement. During all implementations he made, he noticed that workers were always reticent to the improvement, and more generally to changes. Also communication wasn't the strong suit of Taylor and it had had a massive negative impact on his scientific management. Workers used to think, and nowadays yet, his approach was to cut wages and to put pressure on workers while most of his work brought an increase in the wages. Taylor wanted to coordinate the worker with a task where they excelled while he cut wages only of worker that worked slowly than they could. A mistake that may have done Taylor was to consider humans as machines, shutting done their creativity stating *"You are not supposed to think. There are other people paid for thinking around here"*. The workers were afraid of Taylor work calling it the *tyranny of the clock*, leading every modification to bad response from the workers and hence leading the term *Taylorism* to a negative connotation nowadays.

2-2. Fordism

Until the 1840s, manufactories in the United States were small workshop with low number of employer (less than 100) so the owners needed only one level of management made of foremen. Until the end of the nineteenth, manufacturing was local and all the suppliers were localised nearby the manufactory. However, at this time mechanization advancement and automation increased productivity, reduced the cost of goods and made transport cheaper. Thus it became more difficult to sell supplies in nearby markets; making it more reliable to sell to long distance market.

Henry Ford is another famous name thanks to manufacturing, and specifically his Model T. He is considered as the father of the assembly line. Ford not built the first assembly line, we can find several of them during the age, and it is something that has improved continuously over the years. The assembly line in its most basic definition would be a number of manufacturing steps performed in close proximity by different workers, where the workplaces are arranged in the sequence following the manufacturing steps. The fundamental change that made Henry Ford was to add interchangeable parts.

After a couple of fail experiences, Henry Ford created his third automobile company, which would be this time the most successful automobile company of the century. His problem was about the organization that's why over the first years he tried several organization system. He tried to have one worker to do one car rather than 20 workers on one car, to have materials supplied by workers rather than the worker to go away from the car to seek for materials… The first upgrade from the Ford Company was the Model N, which was the first car designed for interchangeable parts. Of course it was the plan and it wasn't reachable at first and time pass before succeeding to a true interchangeability capability. In 1908, Ford created the famous Model T, made of interchangeable part as the previous one but this time it was also designed for easy manufacturing and low cost. The car was made of basic mechanics it meant that it was easily repaired. Cars were assembled in one spot with the supplies coming to the cars for assemble. Workers had different tasks and when they were done with one car they had to walk to the next car and so on. The problem was that to coordinate all those steps wasn't easy and the process was inefficient, even worse some operations were done without knowing if the previous had been completed or even began. Numerous losses are now seen on the manufactory between the time spent to walk to one place to another, wondering if the previous operation had been completed, undo some part to be able to complete the previous operations…

Ford improved his factory year after year, he managed to make the supplies arrived to the top floor and the finished car to leave on the ground floor using the gravity chutes to improve the flux. Around 1910 the first assembly line appeared in Ford factories. The productivity skyrockets following the arrival of assembly line, overall productivity increased between 50% and 1000% according to the rapport depending on the production line. The workforce went from workers that needed to know the whole manufacturing process of the car to the specialization of one part, making the workforce needed less experimented and by consequent less expensive. Due to the working conditions asked by the Ford management, the turnover was really high and most of the workers were unskilled immigrants.

Fordism and Taylorism have a lot in common, even if Ford claimed to have never heard about Taylor scientific management, the approaches were different. While Taylor wanted to improve the efficiency of the workers, Ford was looking for improving the flux and increasing the mechanization. In the previous example of the pig iron, Taylor organized the work of the worker to improve his efficiency while Ford would have set a conveyor belt which would have replaced the worker needed.

An error made by Ford may be a similar one to Taylor. Taylor wasn't interested about the ideas brought by the worker but Ford went further and was looking for machines, he notable sighted *"How come when I want a pair of hands I get a human being as well?"*, the conditions were so hard that in the beginning of the 1910s the annual turnover was equal to 370%, thus Ford had to hire and train more than 50,000 men every year to have a constant workforce of more or less 13,000 men. Obviously productivity suffered significantly of this turnover. To solve this issue in 1914, decided to diminish from 9 to 8 the number of hours worked daily and double the wage of his workers for workers that have been working for Ford for at least 6 months. At the end of the day it didn't apply for more than 10% of the workforce. Anyway the turnover dropped from 370% to 20-50% and productivity increased of 15%, with the workers who suddenly became proud to be part of Ford Company.

When Ford started Ford Company, he purchased most of the components of the car from suppliers, but over the years he insourced the suppliers, principally to control its supply chain, to diminish the production costs and to insure the quality of the components. Moreover Ford needed to be in control of everything but the supply chain was too complex for a single man to handle and may has been one of the reason of the Ford's decadence after the 1920s.

Ford never made an improvement of his Model T, he managed to make it always cheaper going from 850$ in 1908 to only 260$ in 1925, taking into account the inflation, the price dropped of 85%. While Ford wanted to keep the car an easily manufacturing one, confident that one universal car would satisfy the needs of everybody. Other brands started to improve the comfort, security, information such as a fuel gauge on their car and Ford started to lose its monopoly over the market. It is in 1923 that Ford accepted to demean to his famous rule, *"Any customer can have a car painted any colour that he wants so long as it is black"*, and offered the Model T in various colours. Anyway the Model A should have been the following car from Ford but because of his need of over control and the desire of perfection, the construction was repeatedly delayed because of minor changes. The last Model T was built on May 26 1927 and the first Model A was sold only in December 1927 meaning that the factory was stopped for over 6 months, leading to the firing of a lot of workers, foremen and managers and hence a loss of the knowledge on the assembly line of the Model T. The launch of Model A wasn't a success, then the Model B took place and in august 1931 the plant closed.

2-3. General Motor success over Ford

General Motor was founded in 1908 and succeed where Ford failed, in fact GM based their development on the fact that every car does have to be different. Alfred P. Sloan, GM's president in 1920, said *"a car for every purse and purpose"*. Also GM solved the changeover problem of Ford, planning it, it took 20 days in 1929 to change the model produced on the line against the six months of Ford. Sloan showed also strength to decentralize the company power; when Ford needed to see every detail of the car and of the manufacturing process in the plant. GM multiplied the number of plants in the Detroit region to manufacture its components resolving also the changeover issue.

Sloan diversified the activities of the brand and specialized some of them to a sector. For example from these years Cadillac, the renamed second company found by Henry Ford, aimed at the luxury market while Chevrolet at the low-end market. Ideas imagined by Sloan are now standard management practice in industry with product which have a planned obsolescence.

GM continued to prosper over the years and Ford adapted the advantages of flexibility after a difficult path.

3- The new manufacturing models

To begin this part, I want to introduce the Arsenal of Venice that was ages beyond its time over the management and the skills showed to manufacture ship.

3-1. The Arsenal of Venice

The purpose of the first manufactories wasn't to make them more profitable but, because there was no other way to produce certain product that can't be manufactured in small workshop. Shipbuilding is an example, a single workshop did not have the labour and monetary resources available to build a ship. So one of the first, if not the first manufactory was a government-owned shipyards.

The story of the Arsenal of Venice describes well the evolution of the production field, it has been established in 1104 as storage for ship supplies, and then in 1320 it was able to build not more than six ships per year, at this time it was still a guild-based workplace. In the sixteenth century, the Arsenal was considered at its peak and was the largest industrial complex in Europe. In 1570 during the Ottoman-Venetian war, they built 100 ships in two months. 4 years later the King Henry III of France visited the shipyard, and watched the outfitting of an entire ship while eating, even if the meal might have lasted for several hours. In comparison, in others places of Europe, at the same age, to outfit a ship several months were needed. The flux of the Arsenal of Venice showed productivity and efficiency that would not be equal for a while after it.

Venice used a number of different ways to achieve this productivity but technological advancement had only a small part in this. The Venetians analysed the process and created process different from the other place of the world; improvement of the fluxes. For example while the common way to build a ship was the one of the Roman technology that first built the hull of the ships and then added frame. The Venetians built firstly the frame and then added the hull on to the frame, requiring less wood and less time. Moreover the most important change for the throughput was through organizational changes, with the ship came to the worker rather than the worker to the ship. All the steps were analysed and then defined in a precise order and the system was continuously evolving over the centuries. Doing so it corresponds of one of the first analyse of flux.

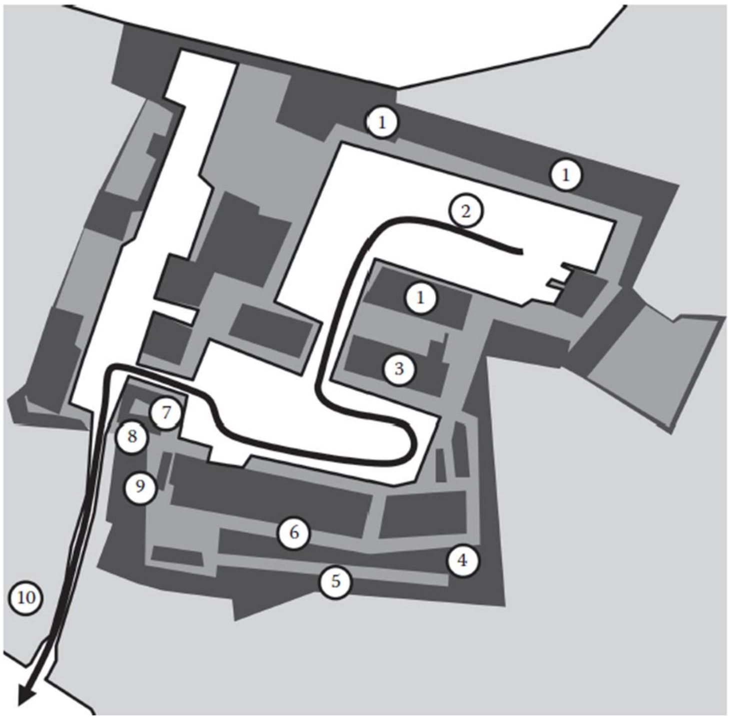


Figure 1: Arsenal of Venice

Material flow in the Arsenal of Venice:

1) Hull
2) Caulking
3) Masts
4) Ammunition
5) Ropes
6) Cannons
7) Sails
8) Anchors
9) Rudders
10) Bakery

Venice had its own forest offering a stable, efficient supply of wood and managing by themselves the quality of the material flowing. On the arsenal of Venice, subassemblies were made and the location of the building operation was define near the stop of the building ship, doing this reduce the waste over transportation of heavy guns. Due to the large demand during wars, many components were mass-produced and of course they weren't standardized parts interchangeable but only small adjustments were necessary to customize every part until it fit.

The Arsenal of Venice also faced several problems, most of them were about worker management. At first it was organized following the guild masters, who organized their part of the work. It was an extremely unstructured process made of highly independent and constantly changing subgroups. A supervisor could manage between five and twenty five people depending on the complexity of the tasks. The shipyard lost its significance with the decline and fall of Venice Empire at the end of the eighteenth century and is now a training place for Italian naval officers.

3-2. World wars

I intentionally pass over a part of the World Wars period because the situation made that the countries, for most of them, switch to a "centrally planned wartime economy", giving rise to a set of rules over the manufactories that can't be applied to the manufactories of nowadays. Of course from the manufacturing point of view, a lot of development occur during this period by the race to maximize the production of weapons, trucks, ships…

Anyway to increase the output and maximize the efficiency because the means were limited, three majors systems appeared:

- Training within industry, TWI
- Statistical process control, SPC
- Operations research, OR

Training within industry

This effort came from the fact that during the First World War the United States had a shortage of skilled workers. The answer was to create standard training methods. Charles R. Allen was during the WWI an instructor, he is famous being the head of the group that set up the shipbuilding training. It was made of four steps: Preparation, Presentation, Application and Inspection (or Test). The four horsemen of TWI, Channing R. Doley, Walter Dietz, Mike Kane and William Conover developed four training programs from Allen's approach:

- Job Instruction (JI), teaching supervisors how to train workers effectively
- Job Methods (JM), teaching workers how to improve their work
- Job Relations (JR), teaching supervisors how to interact with workers on a fair and rational basis
- Program Development (PD), as an overarching training for the trainers

TWI service significantly reduced training times and provided much-needed skilled workers to the war industry. The most famous example is about lens grinders. During the war it was a job that needed a lot of skilled workers. Whereas usually the training of a worker lasted for several years, thanks to TWI the formation lasted only four months. It was used to train over 1.7 million people throughout the war in 16.500 plants. This model was "improved" by Mike J. Kane in 1940 and made it a seven step instruction:

1) Show him how to do it
2) Explain key points (how and why)
3) Let him watch you do it again
4) Let him do the simple parts of the job
5) Help him do the whole job
6) Let him do the whole job – but watch him
7) Put him on his own

After WWII this program has been dropped. The comeback of soldiers had for effect to make available a large workforce quantity. TWI experts moved to Japan to find jobs where it was needed, among them W. Edward Deming and Joseph Juran who will significantly helped the creation of Lean Manufacturing principles.

How to Get Ready to Instruct

Have a timetable—
How much skill you expect to have, by what date

Break down the job—
List important steps
Pick out key points (Safety is always a key point)

Have everything ready—
The right equipment, material, and supplies

Have the workplace properly arranged—
Just as the worker will be expected to keep it

Job Instruction Training
TRAINING WITHIN INDUSTRY
Bureau of Training
War Manpower Commission

KEEP THIS CARD HANDY

How to Instruct

Step 1—Prepare the worker
- Put him at ease.
- State the job and find out what he already knows about it.
- Get him interested in learning the job.
- Place in a correct position.

Step 2—Present the operation
- Tell, show, and illustrate one IMPORTANT STEP at a time.
- Stress each KEY POINT
- Instruct clearly, completely, and patiently, but no more than he can muster.

Step 3—Try out performance
- Have him do the job—correct errors
- Have him explain each KEY POINT to you as he does the job again.
- Make sure he understands.
- Continue until YOU know HE knows.

Step 4—Follow up
- Put him on his own. Designate to whom he goes for help.
- Check frequently. Encourage questions.
- Taper off extra coaching and close follow up.

If the worker hasn't learned, the instructor hasn't taught.

Figure 2: Example of TWI card

Statistical process control

Another problem was about the quality of the product manufactured. The SPC, created by Walter A. Shewhart during the 1920s, aimed to improve the quality monitoring process using statistical tools to ensure compliance with specifications and to enable the detection of quality problems early on. As the TWI, it was developed for the aircraft manufacturing and from the beginning had been a huge success, significantly reducing defects in U.S. production.

SPC is an analytical decision making tool which allows to see when a process is working correctly and when it is not. Variations is present in any process, some of them may be a natural phenomenon while others need a correction which is the key to quality control. The process control charts are usually simple-looking connected-point charts on an x/y axis with x-axis usually representing time. Ranges are defined for the normal functioning zone, while the measurement of criteria is set on the y-axis, correction is applied when the measure is out of the range.

As TWI, after the WWII, the resources in the United States were huge and they felt no need to still apply SPC. Consultant and experts of SPC didn’t have job opportunities yet, that’s why a lot of them went to Japan where theirs knowledges helped to structure the TPS and will give an important advantage in the future as part of the Total Quality Management.

Operations research

During the world wars, scientists extended the methods of Taylor using analytical methods to support their decision making, which was initially for military use, naming it Operations research. After the war, OR started to take place in the industry and showed result for limited range of complexity choice. Most of the results have been achieved during the 1950s. The mathematics are highly complex for limited results. Nevertheless, companies still use it to solve limited complex problem.

OR is applied to conduct and coordinate the activities. The process begins by observing and formulating the problem, including collection of all relevant data. Then a scientific model is shaped, to abstract the essence of the real problem. Then experiments are done to test the hypothesis made of the problem. The OR usually attempts to find the best solution, referred as the optimal solution. OR is done by a group of individuals having diverse background and skills.

3-3. Computer in Manufacturing

First industrial revolution took place thanks to the emergence of the steam engine and the mechanization, then we had the electricity and the mass production. Manufacturing still needed human brain to control, organize and guide the tools. The 1940s corresponds to the invention and subsequent rise of electronic computers. The first one was from Germany in 1941, and then

Britain followed in 1943. Even if at the beginning computers were for military uses, at the end of the 40s computers entered in factories. After an adaptation period, made of several bugs, losses of products, managers started to reduce the workforce. They increased by 250% their efficiency between 1947 and 1966, in the American chemical industry.

John Parsons is the pioneer of numerical control for machine tools, he was the first to use computers in manufacturing. After WWII, he was making rotor blades for helicopter for the US military. Numeric control consists in calculate the locations and then thanks to actuators simply move the machine to these locations. First Parsons and his employee Frank Stulen built the part of the actuators which was really slow and that's why Parsons had the idea of automating the tool control. Thanks to a collaboration with the Massachusetts Institute of Technology, the first two axes numerical control machines were commercialized in 54/55 under Parsons' license whereas the MIT developed the first 5-axes NC in 1955, making it the first machine to have control on more axes than a man possibly can. The next improvement was to link directly the computer to the machine, to limit errors giving the name of Direct Numerical Control (DNC) and finally integrate the computer into the machine resulting in a Computer Numerical Control (CNC).

While the implementation of these machines reduced the direct labour cost, it increased the indirect one with maintenance and programming needs. Following this evolution, robots were trying to appear. Roger Smith who is nowadays father of robotics, has been fired from GM in 1990 after General Motors invested $45 billion into robotics without success. In fact GM might have bought Toyota and Nissan for that kind of money at this time.

Scientific management aims to understand manufacturing and managements thanks to numbers, the next idea was to extend it to material supply, making birth of planning assisted by computer. The problem was the complexity of modern products, a car for example is at least made of 10,000 different components. The creation of Material Requirement Planning, MRP, was to answer this problem, this software enable the plan of supplies directly. Factories hugely benefited from this evolution meaning that the inventories collapsed, reducing the opportunity cost in the plant. It was Joseph Orlicky in 1964 who developed a computer system that not only kept track of inventory but also helped with planning production and orders for new materials.

While in theories the system would take the expected orders, calculated through the bill of materials available inventories and production times, if needed order raw materials and then suggest a production schedule. In practical it was way different, first it was never easy for a company to go from the common planning way of that period to the MRP. Then the data registered into the MRP are considered as rigid data whereas in fact data easily varies in the plant from the number of worker present the D-day to the actual manufacturing time. Several updates or new software were/are still created to match the reality of a plant at best but the common result is the lack of flexibility of the MRP and of the MRP II. This software is massively used nowadays but some workers are still needed to overdue a control and supervisor to think and decide how to plan the production to satisfy the client’s demand.

4- Toyota world leader of manufacturing

In this section rather than the history of the journey made by Toyota to create the Toyota Productive System, giving them a massive advantage over the world, I’m going to introduce the ideology imagined by Toyota and some tools that are relevant for the mission that I will apply in the second part of my master thesis.

4-1. TPS

In 1950 Toyota faced bankruptcy, the only solution seen was to radically cut the labour force, and strikes were also going on to protest over the situation in Toyota. The beginning of the Korean War has been a blessing in disguise for Toyota. Thanks to the orders coming back, the company started to be sustainable again. Taiichi Ohno, newly president of Toyota is the main reason of the Toyota Production System. He used this renew of orders to drastically change the behaviour in Toyota company and take the world by storm thanks to his new manufacturing system.

Within three years as president, Ohno changed a traditional workshop with a group of machines operated by skilled craftsmen to one worker handling a group of 5 to 10 machines arranged in sequence of operation. This revolution was based on JIT, described later, and Ohno improved the fluxes of Toyota. The logic comes from maintaining a stock inventory and reproducing only what the customer pulled out of stocks and thus created the pull system. This idea was the one of American supermarkets, where the clients can take what he wants while the company job is to refill of items. There was an unsolved problem that how to get information from the supermarket back to manufacturing. To solve this problem the *Kanban* took place.

Kanban

A Kanban as created by TPS is a card with colour coding and detailed information (lot size, name, codes…). This card is sent to the supermarket with the desire goods, then when the goods have been used the Kanban goes back to the manufactory where new goods are made and so on.

This use of Kanban has been also implemented to theirs suppliers. In fact from 1939, Toyota saw the benefits to be active in supplier development through Toyota subcontractor discussion groups. That's why Toyota also implemented pull systems using Kanban and supermarkets for his suppliers, doing so the history said that they diminished their inventory stock from two months' worth of supply to a daily delivery. Also the pull system in mass-production brought the reduction of stocks, faster reaction to the demand, better delivery performance and much more flexibility than in a push system.

As seen before, during the Second World War USA developed several system and got rid of it at the end of the war such as the process control tools leading to the Total Quality Management (TQM), and training within industry were improved and reused.

Total Quality Management

The *total* term means that everything and everybody in the organization is involved. The *Management* one means that whatever the status of the employee is, he is the manager of his own responsibilities.

TQM is used in companies to describe two slightly different but related notions. The first one is the continuous improvement and the second one is the utilization of tools and techniques to put quality improvement into action.

Another important point seen there from the TPS is the involvement of everyone in the company. This idea wasn't a new one when Toyota implemented it, Ford already tried that but the main difference was about the involvement of the workers. While workers of Ford made, in average, one improvement suggestion by person and by year, Toyota's workers made 50. Thanks to this, the continuous improvement, *kaizen*, is way easier to achieve.

Kaizen

The idea of the kaizen is to do step-by-step improvement thanks to a collection of small projects improvements, doing so it increases the confidence and builds success behaviour. Drastic intervention is not the means of change in TQM.

Also introduced at the beginning of Ohno era was the line stop. This was in fact developed by Sakichi Toyoda, predecessor of Ohno, the idea was once again to increase the involvement of the workers. Whenever a worker has a problem that he can't fix by himself, he stops the line and calls the supervisor to help him. Toyota also copied a system used by Germany during the WWII called *takt*.

Takt time

Takt time is the average time that the production needs to fit to satisfy the demand. It is defined by the time available divided by the quantity needed to be made.

Another system that set Toyota in the TPS was the *Single Minute Exchange of Die* (SMED).

SMED
The purpose of the SMED is to provide a rapid and efficient changeover. The name said that a changeover should last less than 10 minutes, single minute. To do so an analysis of the changeover should be performed leading usually to a new order of operations, suppression of orations without added value and the separation of activities.

Jidoka
Jidoka is also one typical point of the TPS, thought as a human automation to correct problems as soon as we are able to. To do so TPS focused in 4 steps, the first one is the detection of the abnormality. Followed by a stop of the process until the problem has been fixed or correct by an immediate action. Then there is a search for the root cause. And finally the installation of a countermeasure to avoid the problem to happen again.

In the 1970s, the TPS became famous and industrial's owner over the world started to implant it on their manufactories, the results weren't as good as in Toyota and we will try to find why later. By the way, in 1984, Toyota opened a factory in the United States and was able to set the same rules than in Japan with good results.

4-2. Just in Time

Just in Time is a famous expression, known from most of the people even strangers to manufacturing. It was invented by Ohno after WWII. JIT comes from the concept of ideal production, centred on the elimination of waste in the whole manufacturing process, from suppliers to shipping to clients. The idea is the following one, imaging a process without any problem thus the manufacturing time needed to do one piece is known. Thanks to this data, the beginning of the process is done at the last moment, doing so there would be no inventories which mean no dead money.

Companies doing the Just in Time (JIT), try to foresee customer demand and then planned how much goods of which type to produce, to match the defined date of delivery.

4-3. Lean Manufacturing

Lean Manufacturing is generally considered as the TPS system but not in Toyota. Well, it is true and false at the same time. Most of the principles, listed above, are the same but rather than working using the name of Toyota, companies prefer to use a common term. The general principles are:

- Elimination of waste, *7 mudas*

- Continuous improvement, *kaizen*
- Commitment, *involvement of every worker*
- Levelled production, *same quantity produced every day*
- Just in Time, *pull system*
- Quality, *over all the process*

While TPS focuses a lot on *Jidoka,* Lean Manufacturing rather focuses on the Value Stream Mapping and kaizen operations to achieve the same goal. Below you will see some of the most famous tools of the lean manufacturing, and concepts that will been used during the applied case on Valéo CDA - Santena.

PDCA

The PDCA (Plan/Do/Check/Act) is the tool usually associated to the Kaizen and usually represented as a wheel going up on a mountain. The idea is to perform the improvement action again and again and match the definition of kaizen doing little step-by-step improvement rather than a onetime drastically improvement.

- Plan: Identification of the problem (What?) and analyse of the problem (Why?)
- Do: Develop Solutions and implement them as soon as possible
- Check: Evaluate the results and demand has the desired goal been reached?
- Act: Implement the full scale solution and look other improvement opportunities to go back to plan.

Figure 3: PDCA illustration

Mudas

Recalling the TPS, Ohno was trying to lean the fluxes by diminishing the wastes. At the end of the WWII, the economic state of Japan was really different from the USA. Japan could not afford to produce as much waste as the American. Muda is any activity or process that does not add value, they are categorized in seven different types:

- Transport, any movement of the product

- Inventory, stock of material in the work in progress, finished materials waiting and raw materials hold
- Motion, physical movement from worker or machine
- Waiting, the act of waiting that another action is performed
- Overproduction, to produce more than what is required by the client
- Over-processing, conducting operations beyond those that customer requires
- Defects, product rejects and rework within your processes

All the activities of the Lean Manufacturing have for purpose to delete these mudas.

Hoshin Kanri

Hoshin Kanri is a 7-step process used to satisfy the improvements project, compare to the PDCA, the Hoshin Kanri is a long-term objective. In one Hoshin Kanri there are several kaizen projects and PDCA actions. The seven step will be shown later during the applied case.

Value Stream Mapping

VSM is a special type of flow chart that uses symbols known as "the language of Lean" to depict and improve the flow of inventory and information. Thanks to this graph, it is easier to find waste and then create an action plan to improve the process. As the Hoshin Kanri is giving a more precise purpose that a collection of several kaizen, the VSM provides a better vision and plans that connect all improvement activities together.

4-4. Six Sigma

The name six sigma comes from the ancient Greek with the letter sigma "σ" usually used in mathematics to characterize the difference. This method was inspired also from the TPS of Toyota and adapted by Motorola on what type of improvement they were looking for. This is an important point, the lean manufacturing process can have a lot of name and basically one in every company but the lean manufacturing is a concept, an ideology. Here again in Motorola the idea was to diminish the wastes.

The six sigma represents the number of defect Motorola defined as an objective, referring to the sixth decimal of the ratio difference good parts/bad parts over the number of good parts. In figure, the goal set is 0.009 defects per billion so a ratio of 99.99999900%. While the name "6 Sigma" is usually taken, the goal is difference in every company depending a lot on the product made.

4-5. The Value Chain

Michael Porter, professor of strategic management at the Harvard Business School, used for the first time the term "Value Chain" in his book "Competitive Advantage: Creating and

Sustaining superior Performance", in 1985. It is used to describe the activities performed by the companies and to link them to the organizations competitive position.

The idea is built from the fact that an organization is more than a random compilation of machinery, equipment, people and money. The correct compilation of these things brings the creation of a good for which a customer is willing to pay. Porter argues that the ability to perform particular activities and to manage the links between the activities is a source of competitive advantage. According to Porter there are two kind of activities: primary activities and support activities.

- Primary activities are directly linked with the creation/delivery of a good/service and is made of five main areas: inbound logistics, operations, outbound logistics, marketing & sales and service.
- Each of these activities is linked to support activities to improve their effectiveness or efficiency. They are also grouped in four main areas: procurement, technology development, human resource and infrastructure.

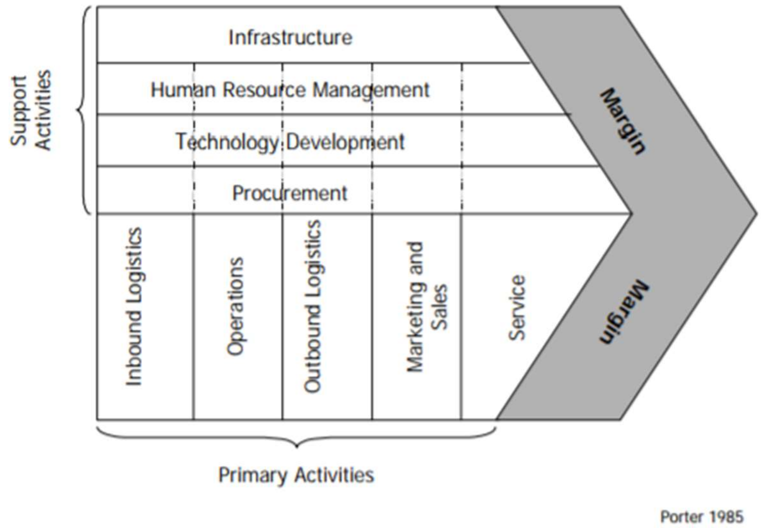


Figure 4: Porter Value Chain

The design, created by Porter to describe the idea of "Value Chain", is in form of arrow and the arrowhead corresponded to "margin". It is done in that way to show that profit depends on the ability to manage the primary and support activities. In other words, "the organization is able to deliver a product/service for which the customer is willing to pay more than the sum of the costs of all activities in the value chain"

5- Overview

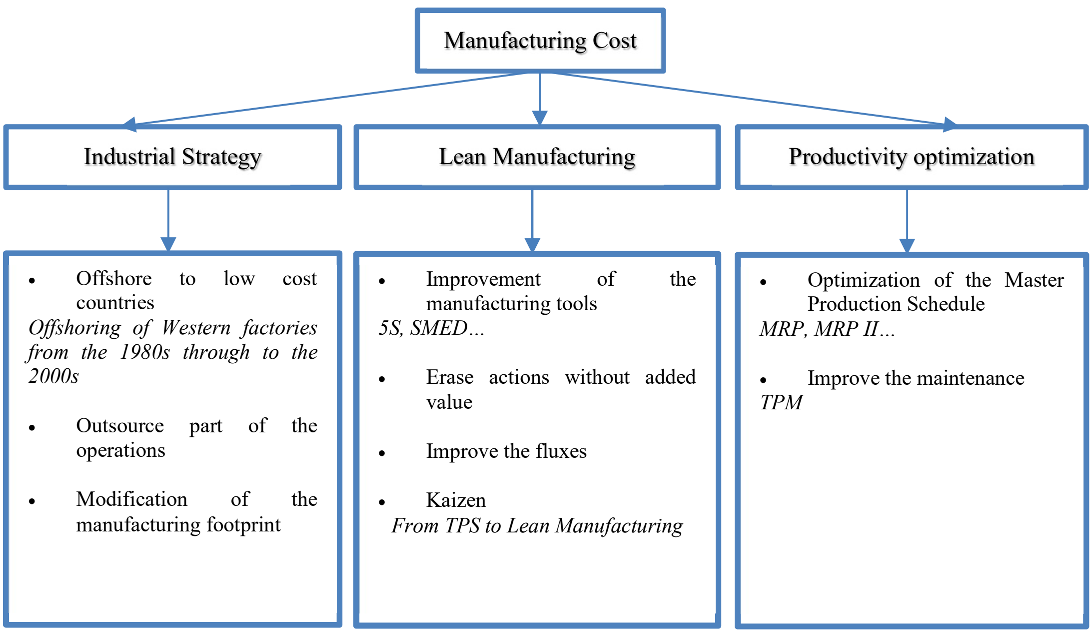
We have seen the evolution of the manufacturing field from the first industrial revolution to nowadays. From James Watt to Taiichi Ohno all the improvements were led by the increase of speed of the process and by the need to lean the processes. Moreover they were done thanks to improvement of the common thinking, led by brilliant mind but not only, also thanks to the advent of new sources of energy.

These improvements come with the advent of the civilization, the increase of use of mathematics and the adaptation to the manufacturing world, lead to the scientific management and then the TPS. We can recall that those systems have their differences, especially about the involvement of the workforce. But the main idea is the same: to optimize the production by acting on the lot size and by rethinking all the activities done.

The new sources of energy lead to an increase of the productivity. At the beginning of the history, factories were looking for water power along rivers. James Watt used the advent of steam power to increase the throughput. The emergence of electricity and the ability to stock it, thanks to Volta among others, allowed the mass production in the third industrial revolution.

Moreover the success of a factory over the competition is what we are interested in. Ford took a very large advantage over his competitors but he failed to adapt to the evolution of the market. While the demand was higher than the supply, Ford had the lead. But from the moment that the demand was outdone by the quantity of supply, customers started looking for customization and he failed to adapt. It was a blessing for General Motors which knew a skyrocket increase thanks to this understanding of the market. About manufacturing, this need of customization means flexibility. Such flexibility was brought with limitations by the MRP and MRP II software. TPS system improve the flexibility by looking for the minimum profitable lot size. Moreover TPS eliminated wastes and is worldly famous for these actions.

Summing up all these information, one can draw the chart below to find the possible way to improve the efficiency of his factory:



In the following part, we will use several process to improve the efficiency to increase the throughput of a production line at Valéo CDA Santena (Piedmont, Italy). In other, we will focus on the outsourcing of part of the operations, improvement of the fluxes, the suppression of actions without added value and the Kanban. All of that will be done using a continuous improvement mind-set.

Applied case to Valéo CDA

1- Valéo: An international Company

1-1. A world leader

Valéo is a multinational automotive supplier founded in France in 1923, in the suburbs of Paris at Saint-Ouen. Its name was at first "Société Anonyme Française de Ferodo (SAFF)". SAFF first produced brakes and clutches. In the 1960 the company decided to diversify its production, and they started producing thermal systems, electrical systems and lighting systems.

In 1980, SAFF became Valéo inspired from the Latin which means "I am well". The purpose of this shift was to federate all the companies under a same entity. It corresponds also to the acquisitions of several international companies which set the beginning of the expansion of Valéo in the world.

1-2. Valéo in the world

Figure 5: Valéo in the world

Valéo has more than 90 000 employees and possesses 155 production sites, 58 R&D expenditure and 15 distribution platforms in 32 countries.

1-3. Valéo's strategy

As a global automotive supplier and technology company, Valéo is at the heart of an industry experiencing rapid change. As the world population grows, the stakes have never been higher to tackle questions concerning mobility and assess the impact our transportation has both on the environment and our daily lives. Valéo success is due to the 5 axes. The 5 axes methodology ensures the operational excellence and customer satisfaction. This system is rigorously implemented in all their development and production sites around the world. You can find below some information concerning the company's 5 axes:

Total Quality:
To meet expectations in terms of product and service quality, everyone, employees and suppliers, must deliver total quality.

Valéo Production System (VPS):
Valéo has developed its own production system which implements a set of methods, tools and state-of-the-art production processes within a working environment that promotes quality, performance and employee motivation.

Product Development:
To develop its production and systems, Valéo's highly qualified Research and Development teams work within an optimal organizational structure that combines professional skills and product expertise with first-rate methodology and best-in-class project management tools aimed at ensuring product robustness and competitiveness.

Involvement of Personnel:
Operational excellence cannot be achieved without the ongoing commitment of all of the Group's employees. Valéo therefore implements processes aimed at creating a safe working environment that fosters employee well-being.

Supplier Integration:
In order to deliver the highest quality products and services while remaining competitive, Valéo has set up a supplier base integrating the most efficient suppliers in terms of innovation, quality, cost, delivery and risk management.

Figure 6 : Valéo 5 axes

1-4. Activities

Valéo is composed of 4 business groups, which are responsible for global growth and operating performance for their Product Groups and Product Lines. Each Business Groups is structured to reinforce cooperation and stimulate growth for all of the product groups worldwide.

- Driving Assistance Systems:

Valéo offers one of the largest range of smart sensors and features that improve vehicle safety and comfort such as automated parking systems and enhanced automated driving systems.

- Display
- Steering-wheel
- Air conditioning control system
- …

- Powertrain Systems:

Develops innovative powertrain solutions designed to reduce CO_2 emissions and fuel consumption without compromising driving pleasure.

- Stop-Start systems
- Clutch
- Electric Supercharger
- …

- Thermal Systems:

Develops and manufactures systems, modules and components to ensure the optimal thermal energy management of vehicles.

- Climate Control
- Powertrain Thermal Systems
- Climate control Compressors
- …

- Visibility Systems:

Designs and produces innovative lighting and wiper systems that improve driver comfort and safety in all weather conditions.

- Xenon lighthing
- Beanatic Premiumled
- …

And a 5th business group, dedicates to the aftermarket activity:

- Valéo Service:

Supplies automakers with original equipment spares and the independent aftermarket with replacement parts.

1-5. Valéo Santena

The plant of Santena

Valéo Santena has two main specificities, the first one is the fact that on the plant of Santena there are two business entities, CDA (Comfort and Driving Assistance) and Valéo service. The second one is about the production, Valéo usually does mass production. This is not the case of Santena, the clients make it a luxury production. Where other factories produce 2 000 parts of a product every month, we manufacture the same quantity but for a year.

Their clients are: Ferrari, Maserati, Rolls Royce, Bentley, Aston Martin, and recently Alpine Renault. For luxury cars as the Ferrari F142 or the new car of Alpine Renault the A110, for example. All of the driving assistance components that you can see on these pictures are made at Valéo Santena.

Figure 7: F142 car component

Figure 8: Alpine A110 Steering wheel

Figure 9 Alpine A110 Display

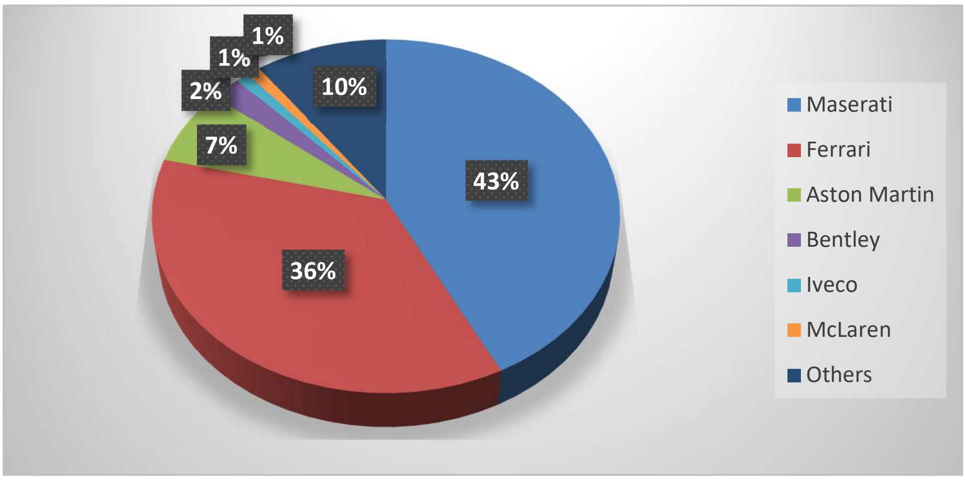


Figure 10: Clients of Valéo Santena

Our plant is divided into 34 line of production lines, two of which are clean room (I024 and I035). The surface of the plant is 4 700 m², with 112 employees in it. Valéo Santena produces more than 3000 component references.

Organization

Our workforce is composed of 50 operators, divided into two teams. A quarter of them are temporary employees. One team does the morning shift from 6 am to 2 pm. While the second one does the afternoon shift from 2 pm to 10 pm. Every week the order changes, the team doing the morning shift one week will do the afternoon shift the following week.

If necessary we can add a third squad to do a night shift. We can notice also that some operators are doing the "central" shift which means that they start their working day at 8 am, and finish it at 4:45 pm.

All of our calculation are done taking into account the time, in seconds, devoted to the operations and not the number of people in charge of the task. We are not considering the fact there is an operator on the line however there is still 24 480s which remain available, 8 hours of production.

Plant Lay-out of Valéo Santena

2- Efficiency at Valéo

2-1. DMAIC

For my project I chose to use the DMAIC method. DMAIC stands for the acronym of the 5 steps. It consists of: Define, Measure, Analyse, Improve and Control.

- Define: the problem, check the opportunity for improvement, the project goals and customer requirements.
- Measure: the process performance.
- Analyse: the process to determine root causes of variation, poor performance (defects).
- Improve: process performance by addressing and eliminating the root causes.
- Control: the improved process and future process performance.

We can add a last step, which would be Standardisation. The idea of this last step is to implement the modifications made to others areas when it can also improve the process.

2-2. How do we define the cost of the product?

As I already said before, in the automotive world one must always improve the factory to remain competitive. Some contracts done with our clients in Valéo, specify a decrease of the price of 5% every year. This means we should diminish the process time or have fewer quality problems to keep a constant margin.

The problematic is we are not able, today, to do this discount while keeping the margin constant. Consequently, if we cannot diminish our manufacturing cost while the selling price is decreasing, this means we are cutting down our profit margin. And that is not acceptable for the company, this margin is necessary to promote our products, to carry out research and development on new projects…

When a project is set in production, we define the production time that we sell. This is called "Cycle Time" (TC). It is the result of a complex study taking into account the time used by the machines and by the operator to perform the different tasks. But the workers productivity also varies during the working day. An average is calculated in this case. This complex study is not shown in this report, and is considerate an acquired data. It is to be noted that in some cases this calculation is not done when we are manufacturing a similar product for two different brand, the TC are set equal, or obviously when only the colour of a component is modified.

Valéo Santena is different of the other manufacturing factories of Valéo CDA, as I said before we are close to the luxury business. Luxury means that we are manufacturing parts with a higher level of quality expectations. Here again, some demands are too difficult to reach.

2-3. How do we measure our efficiency?

The purpose of this part is to measure the efficiency of the plant. We are carrying out this measurement thanks to document given to the operators which have all the information they need to produce and be able to check their efficiency every hour. This information is called KOSU.

KOSU is a measure of productivity. It refers to the time spent to produce one unit of a product or to complete a process. We compute it by multiplying the number of workers involved in making a product by the number of seconds used. That number is then divided by the total number of units produced during that time.

$$\boxed{Average\ time\ required\ to\ produce\ a\ part = \frac{Time\ available}{Number\ of\ good\ parts}}$$

Every hour they have to compare their KOSU with the target that was set. If it is superior to the target by 15% they have to call the Supervisor of production, and explain why they are going slower than they should. While if it is superior to the target by 25% the one called is the APU Production Manager and upper than 35% it is the plant director who should take care of this issue (accompanying by the APU and the Supervisor).

The target KOSU can't be set superior to the TC because it would mean that our target is to produce a part in more time that we are payed to do so. But the target KOSU could be inferior to the TC which means that we are able to do better that what we agreed to sell to the clients, thus an increase in our profits and also compensate with the workstations where we don't reach the TC.

As I mentioned before several products are manufactured on every line, with TC and KOSU target that have no reason to be equal. To be able to compare their efficiency we use a coefficient sets for every product. Set at 1 for the product that we are doing the most on the line, then the KOSU target of another product divided the one at coefficient one and we find the multiplier of the second product. In that way operators just need to focus on the target KOSU of the line of production and not every single KOSU.

Product	Target KOSU of the line	Coefficient	Target KOSU of the product
Code 1	X	1,00	100
Code 2		2,00	50

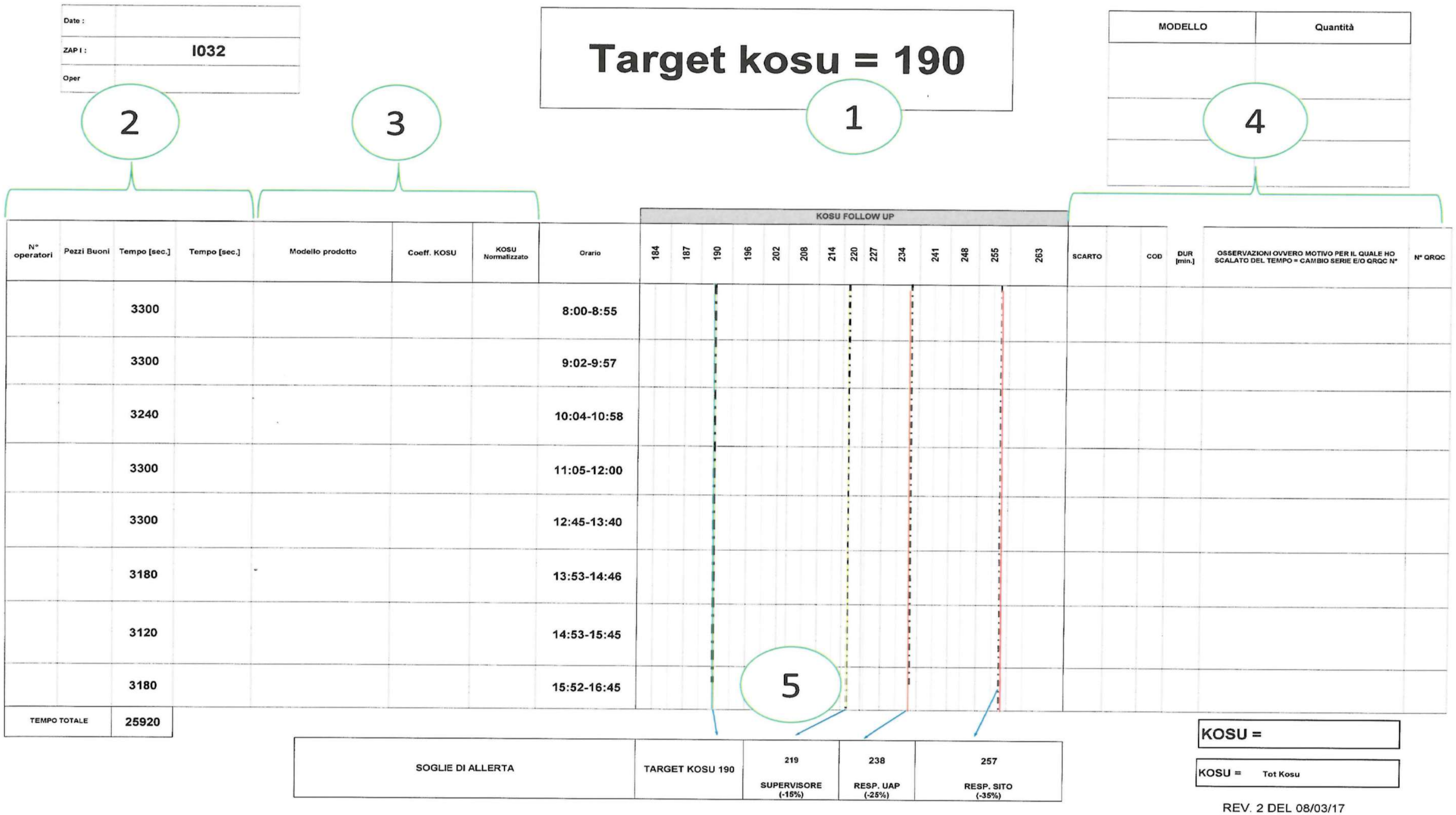
$$Coefficient(Code\ 2) = \frac{Kosu(Code\ 1) * Coeff(Code1)}{Kosu(Code\ 2)}$$

For example, in an hour of production (3600s), 72 parts should be made of the code 2 product (one every 50 s). While for the Code 1 only 36 parts should be made. To be able to compare these KOSU we should multiply the second one by the coefficient found earlier: 2.

In this document, there is a part where the operators can write down the problem that occurred during their production and the time it took them to resolve it. Particularity for the changeovers that are subtracted from the time available.

You can find in the following table, all the information needed to compile one of them. A KOSU is shown on the following pages.

N.	Observation
1	The target KOSU, which is the number they should do every hour divided by the coefficient.
2	- The number of operator working on the line during the hour - The number of good parts done during a hour - The cumulated time of the working person on the line. If the hour is made of 3300 seconds and there are two operators on the line, the cumulated time is 6600s.
3	- The code of the product done - The coefficient KOSU that we saw before - The KOSU of the line (time/number of good parts) multiply by the coefficient, and the result should be inferior or equal to the target KOSU
4	- The number of bad parts - The code of the problem (link with N°7) - Time dedicated to the issue - Observation about the issue - The number of the QRQC opened due to the issue
5	Every line corresponds to an hour of production, every hour they draw a point on the graph to see the evolution during the day. Also we have set alerts. For example if the **kosu** is overtaken of 15% they should call the Supervisor, **25%** APU Manager and **35%** Director site
6	The data box: description, code done on the line, OST (best time ever made), the coefficient, number of pieces that should be done in a hour and the KOSU target without the coefficient. The TC is also on the KOSU but we write in a way it can't be seen by the operator
7	The codes related to the basic losses of time as changeover basic or complex, opening of a QRQC, planned stop due to cleaning…



Date :	
ZAP I :	I032
Oper	

Target kosu = 190

MODELLO	Quantità

1 2 3 4 5

N° operatori	Pezzi Buoni	Tempo [sec.]	Tempo [sec.]	Modello prodotto	Coeff. KOSU	KOSU Normalizzato	Orario	KOSU FOLLOW UP 184	187	190	196	202	208	214	220	227	234	241	248	255	263	SCARTO	COD	DUR [min.]	OSSERVAZIONI OVVERO MOTIVO PER IL QUALE HO SCALATO DEL TEMPO = CAMBIO SERIE E/O QRQC N°	N° QRQC
		3300					8:00-8:55																			
		3300					9:02-9:57																			
		3240					10:04-10:58																			
		3300					11:05-12:00																			
		3300					12:45-13:40																			
		3180					13:53-14:46																			
		3120					14:53-15:45																			
		3180					15:52-16:45																			
TEMPO TOTALE		25920																								

SOGLIE DI ALLERTA	TARGET KOSU 190	219 SUPERVISORE (-15%)	238 RESP. UAP (-25%)	257 RESP. SITO (-35%)

KOSU =

KOSU = Tot Kosu

REV. 2 DEL 08/03/17

Figure 11: Recto KOSU I032

Valeo
Interior Controls

CONTROLLO PRODUZIONE

MODELLO		O.S.T. [sec.]	FATTORE MOLTIPLICATIVO	TC / SAP	Pezzi/H	KOSU
DOUBLE ROTARY M161	E1173050-E1173053	171	1,00		17	190
DOUBLE ROTARY M156MY17	E107414A-E107415A	162	1,06		18	180

6

COD.	DELLE FERMATE	T
1	Cambio serie incluso BIL o BLC	750"
2	Cambio tipo incluso BIL o BLC (es. cambio colore)	300"
3	Mancanza materiale	da specificare
4	Guasto	da specificare
5	Mancanza operatore	da specificare
6	Manutenzione 1° Livello a fine turno	300"
7	Altro : precisare	da specificare
8	QRQC (x Operatore)	300"

7

...pi per "cause delle fermate" non vanno ...nel calcolo del kosu, ma sono solo il ...vo da inserire nel campo "Osservazioni" Tranne per ...MBIO SERIE , BIL e BLC" e manutenzione 1° Livello

Il KOSU

1 - Definizioni

Tempo necessario alla linea per produrre unpezzo buono

2 - Formula di calcolo :

KOSU Normalizzato= $\dfrac{\text{Numero operatori} \times \text{Tempo (Secondi lavorati)}}{\text{Numero pezzi buoni}}$ **x fattore moltiplicativo**

KOSU Cambio Tipo= $\dfrac{\text{(Numero operatori} \times \text{Tempo Secondi lavorati) - Secondi Cambio Serie}}{\text{Numero pezzi buoni}}$ **x Fattore moltiplicativo**

I032

Target kosu = 190

Figure 12: Verso KOSU I032

- AGV

The assets gross value is a productivity metric that measures the contribution to an economy, producer, sector or region. AGV provides a Euro value for the amount of goods and services that have been produced, less the cost of all inputs and raw materials that are directly attributable to that production.

At the company level, this metric could be calculated to represent the assets gross value by a particular product or service the company currently produces or provides. In other world, the AGV number reveals how much money the product or service contributed towards meeting the company's fixed costs and potentially creating a bottom-line profit. Once the consumption of fixed capital and the effects of depreciation are subtracted, the company knows how much net value the operation adds to its bottom line

It's set for every line of production.

- TRP

The TRP comes from the French "Taux de Rendement de la Production" which means Production rate of return. It is the means we use to calculate the efficiency of our plant. It is calculated by the Useful Working time divided by the Scheduled Time.

The useful working time is the number of good parts per the unitary cycle time, while the scheduled time is the time during which equipment is scheduled to produce by Supply Chain.

Every day we calculate also the site TRP (sTRP); which is the average TRP weighted by the gross value and scheduled time of the equipment involved in the site TRP calculation for the considered period.

$$Site\ TRP = \frac{\sum(Assets\ Gross\ Value * Scheduled\ Time * TRP)}{\sum(Assets\ Gross\ Value * Scheduled\ Time)}$$

The sTRP characterizes the wellbeing of the production. Be cautious the TRP only take into account people working directly on the manufacturing. While we also calculate the DLE (Direct Labour Efficiency) which is the efficiency of the plant taking into account all people involved in the manufacturing, directly and indirectly. We may mention in the case of indirect labour that the team leaders, the operators selecting the good parts, operators on the super control, members of the quality squad acting like quality supervisor,…

The TRP is affected by the losses made on the production. One can see in the three following parts the losses:

- Machine Stops
  - Changeover

Each manufacturing process has periods of time where equipment is unavailable due to material changes, part changes or any other changes to production that must be performed while equipment is stopped. Collectively, these events are referred to as “changeovers”. Most of them are done by the maintenance team. Changeovers usually weigh more or less on the operator’s daily loss.

  - Breakdowns

Breakdowns are stops due to an issue related to equipment/tooling (mechanical, electrical, software...) equal or higher than a few cycle times. Any stop of that kind of more than 5’ has to be considered as a breakdown.

  - Micro-stoppages & technical slowdowns (including self-maintenance)

Stops due to an issue related to the equipment lower than a few cycle times. Self-repair time of less than site breakdown time definition: typically restarted by line driver without external help (for instance from maintenance or methods/process engineering department). Due to cycle time higher than nominal one, for technical reasons. And finally, this loss time % is usually subtracted as follows: 100-TRP-Sum (other TRP losses).

- Organization Malfunctions

In this section of losses, we can name the following: lunch and legal breaks. In the case of Valéo Santena, those already take 15% of our efficiency. On 8 hours worked every day, 1,2 hour are lost between break (7 minutes every hour) and lunch (30 minutes one time a day). But also 5’ meetings, monthly meetings, line QRQC (whatever issue type), lack of personal, raw material/component (shortage or handling/transportation issue), lack of energy, lack of packaging or production order and also training, line stopped for training and slowdown due to formation.

- Non Quality

The last one concerns quality, it is characterized by the number of faulty parts multiplied by cycle time and any line stop due to quality issue.

- Other Losses

These three losses are the ones that impact on the TRP. There are other losses that are only interesting for the TRS, which comes from the French “Taux de Rendement Synthétique” and means Synthetic rate of return. We have:

  - No Load

Is the difference between “Switch-on time = 24h a day, 7 days a week” and time opened to work. Time opened to work is open time decided by Logistic to meet customer demand.

- Planned stop

Line stops for planned preventive maintenance and equipment inspections on the line. Time devoted to trials for new products or lines modifications. And time devoted to cleaning the line of production at the end of their shift.

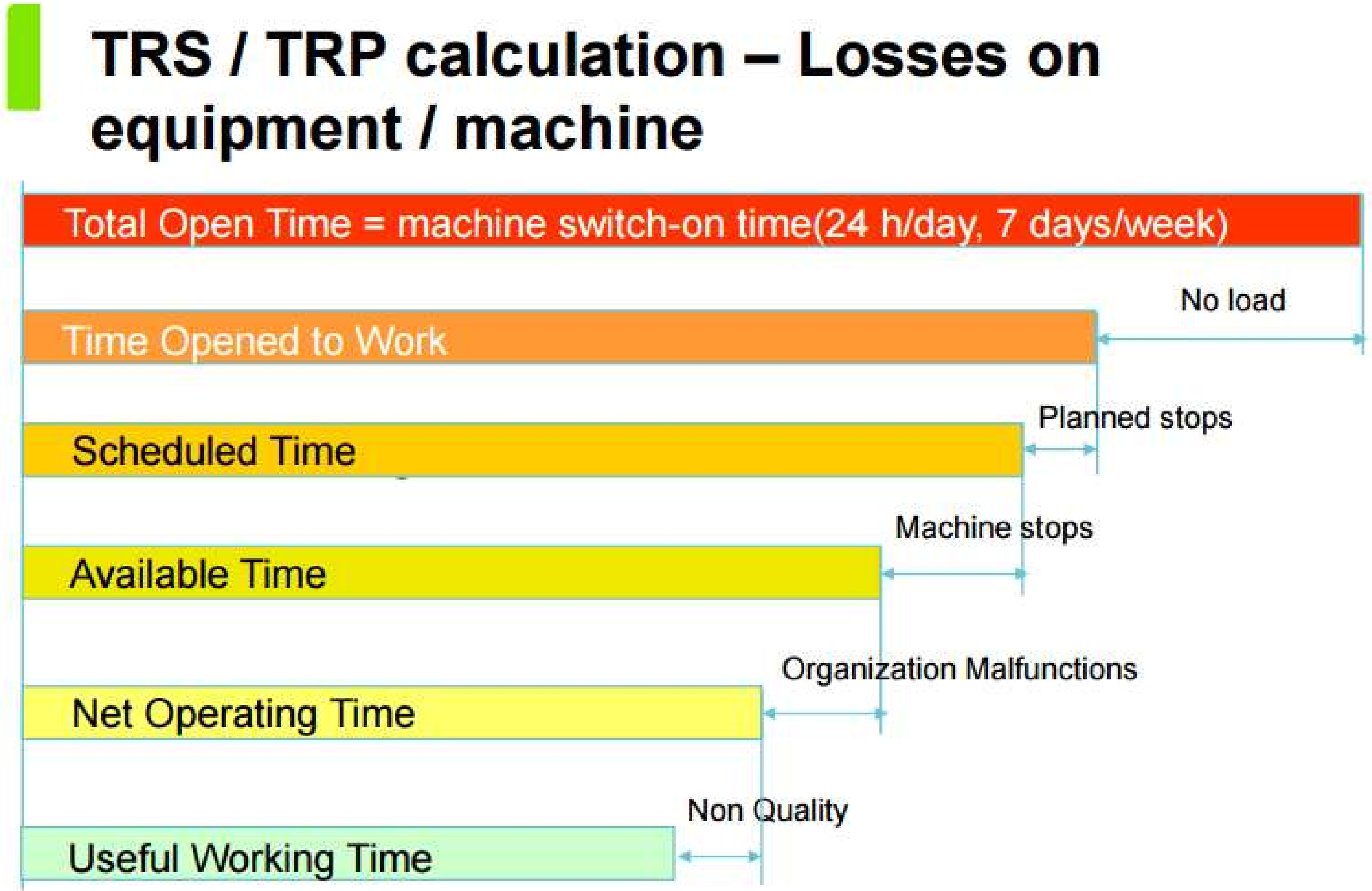


Figure 13: From Time available to Useful Working Time

- Master Data

When I arrived, Valéo was already using a file called "Master Data", which was edited every day its purpose is to collect all the data coming from the KOSU of the lines. This file is a numerical data base. We wrote it in the product code, the man time of production, the date, the quantity produced, and the time spent for every type of loss.

I reedited this file making it easier to use, but also more productive. The losses are now arranged by types. This file also calculates the efficiency for every day, every week and every month… As a consequence, we are able to follow the productivity of the plant on a daily basis.

At the beginning of each day, I collected all the KOSU of the previous day. Then I entered it in the Master data, starting with the code produced, after which the line, the TC and the target KOSU are automatically informed. Then we insert the working time, the quantity produced, the time dedicated to the changeover, the malfunctioning of the organization, breakdown & micro stoppage, breaks, training, and finally planned stops. Thanks to all the data inserted the production KOSU is calculated and the TRP of the code produced.

When this work is completed, you have the sTRP of the day. We talked about this information every day during the 5 minutes production meeting. On the board of the production, I also exposed the time devoted to the losses and the reasons why. And finally the 3 worst TRPs of the day.

You can see the sTRP of week 13 below and on the following page you can find a sample of the Master Data of March.

Étiquettes de lignes	sTRP
27/03/2017	77,16%
28/03/2017	77,84%
29/03/2017	73,13%
30/03/2017	66,23%
31/03/2017	73,96%
TRP of the week 13	73,54%

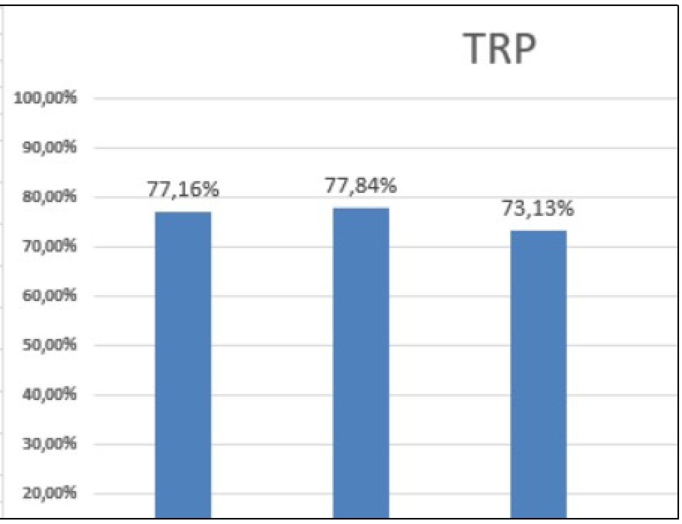


Figure 14: TRP of the week 13

I compiled it during the first month, after I trained another intern to compile it. I therefore had more time to analyse the data and make improvement in the plant.

Linea	Codice	Kosu Target	TC(SAP)	Giorno	Prod	Working Time	Cambi	Breakdowns & Microstoppage	No Qual.	Org. Malf.	Formazione	Planned Stop	Kosu Reale	TRP
I008	E1151149	1102	1102	09/03/2017	16	18 780	300	-	-	-	-	-	1155	93,88%
I039	E1171718	750	990	02/03/2017	10	10560	300					420	984	93,75%
I033	E1167732	72	72	01/03/2017	301	23160	1050		72			420	72	93,58%
I032	E1173050	190	210	08/03/2017	101	22680	1050		270	600		420	210	93,52%
I024	E1174431	239	239	06/03/2017	90	23040	750					420	243	93,38%
I008	E1151149	1102	1102	06/03/2017	15	17712	600			300			1141	93,33%
I005	E1175430	110	110	28/02/2017	30	3535	300						108	93,18%
I001	5145063	105	122	28/02/2017	72	9423	750						120	92,98%
I033	E1113272	180	180	27/02/2017	75	14520	2400						162	92,98%
I008	E1153894	1102	1102	06/03/2017	14	16608	300			600			1165	92,89%
I039	E1149868	512	591	28/02/2017	3	1920	300						540	92,42%
I032	E1173050	190	210	07/03/2017	208	47460	1450		1200			720	218	92,03%
I001	E1086547	225	261	27/02/2017	32	9090							284	91,88%
I025	5086310	72	85	02/03/2017	125	11580	1500					420	77	91,32%
I005	E1174364	120	120	07/03/2017	231	30560	1050					840	124	90,71%
I024	E1139076	547	720	28/02/2017	4	3180	300						720	90,57%
I039	E1155008	512	990	01/03/2017	24	26280	300				12684		1083	90,41%
I009	E1147072	140	240	02/03/2017	48	12760	600				4560		253	90,29%
I005	E1175430	110	110	09/03/2017	30	3650	300						112	90,25%
I020	E1177277	435	505	01/03/2017	159	89100	900				20265		555	90,07%
I005	E1175429	110	110	06/03/2017	60	7330	750						110	89,88%
I032	E107414A	250	148	28/02/2017	244	40140	1350		534			420	157	89,72%
I005	E1174364	120	120	01/03/2017	72	9660	72						133	89,44%
I005	E1174365	90	90	08/03/2017	120	12100	300						98	89,26%
I028	E1174611	144	144	08/03/2017	30	4860	750						137	88,89%
I008	E1161206	1102	1102	07/03/2017	6	7500	750						1125	88,16%
I032	E1173050	190	210	27/02/2017	144	34320	3480		270	300		300	212	88,11%
I019	5144930	20	20	27/02/2017	144	3240							23	88,00%
I008	E1151149	1102	1102	02/03/2017	35	43875	600			600		420	1224	87,91%
I039	E1155009	512	990	02/03/2017	23	25920	300			13414			1114	87,85%
I032	E1173053	190	210	09/03/2017	14	3400	300					420	191	86,47%
I001	E1162570	374	374	28/02/2017	8	3470	750						340	86,15%

Figure 15: Sample Master Data March

2-4. How do we quantify our losses?

I created a file entitled the Master Losses, which is connected to the Master data. This gives us the information on the quantity of operators that we have "lost" as far as efficiency is concerned. I chose to create this file because we cannot only take the worst TRP to know where improvement actions should take place first.

The TRP doesn't take into account the time used to produce. In fact you can produce during a day's work, 8 hours, and produce only half the parts that you should have done. The TRP would be 50%. While if you manufacture another code with the same TC, during 30 minutes and produce only half of the quantity you should have done. You would have also a TRP equal to 50%.

The fact that both of the TRP are equal is not a good news for us. Because we have been losing more money for the first one (4 hours) than for the second (15 minutes).

Knowing that our production is more or less regular, the quantity of every product manufacture during month m is quite the same of the quantity needed to be done for the following month m+1. Considering this hypothesis I envisaged two solutions that could help me select witch product/line of production, I should work on.

- The first one was to count the number of "productivity heads" lost on each product during the month of March. Let us call it the "productivity head method" (PHM).
- The second one was to compare the denominator and the nominator of the TRP, let's call it the Comparison Method

Productivity head method

I calculated the difference between the working time and the quantity produced multiplied by the unit cycle time. We find out the quantity of second lost in production, then divided by the number of day worked and by the number of hour worked in a day. The result is the number of productivity head lost in the month for the manufacturing of these products. One can see in the following table, the results for the 10 worst codes.

	Line	Code	Description	Head lost in the month	Head lost in a day	Money Lost
1	I034	E1154962	87263400 CPL NIT GRIGIO BRUNITO T.F142M	35,74	0,23	1 585,78 €
2	I028	E1162944	670064671 ASCM GSX M161	35,39	0,23	1 570,04 €
3	I028	E1165642	319573 MOSTRINA NIT F151M	34,49	0,22	1 530,30 €
4	I032	E107414A	670110723 DOUBLE ROTARY GSX M156MY17	28,72	0,18	1 274,47 €
5	I028	E1175142	331197 MOSTRINA NIT GR.NART F151M	26,73	0,17	1 186,16 €
6	I028	E118162A	87291200 PLANCETTA CLIMA F151M	24,29	0,16	1 077,82 €
7	I008	E1151149	314910 NVO CARBONIO F142M	23,43	0,15	1 039,64 €
8	I034	E1155435	87263500 MODE DISP GRIGIO BRUNITO F142M	19,54	0,12	867,19 €
9	I001	E1154828	87379100 CLE DRL.GRIGIO BRUNITO F142M	16,71	0,11	741,62 €
10	I005	E1154880	319063 SPECCHI OPT C/ABBAT.GRIG.BR.F142M	15,26	0,10	677,05 €

Figure 16: Losses PHM

Drawback: this method is really effective, if we consider all the AGVs equal (set to 1, to simplify). In other words, that all the products have the same value for us, making the same profit and costing us time and money in workforce and raw materials the same price. It gives us an important information: the time lost. In fact the sum of “head lost in a day” of these 10 codes is 1,66 while we manufactured 199 different products for a total of 5 heads lost every day in the plant (33%).

Moreover this method was applied to find out the money lost on the workstations’ efficiency, and did not take into account the money lost through not working efficiently as selecting parts coming from the provider or the super control done on some products.

Comparison Method

I also tried to find also another way to characterize these losses which would take into account the fact that all products don't have the same weight over our profit and the wellbeing of our plant.

First of all, I chose to take into account the AGV and not the price of the product to quantify the losses. I made that choice because when a piece is not manufactured in the time it should, it has no effect over the price of the product. We set a price for this and it should be our limit. It is not flexible, our manufacturing system has to evolve to reach this limit or do better. Also when a product is declared as scrap, the part is not sent to the trash but could be reused or reworked. Another idea was to integrate the price of the workforce, but that corresponded to the PHM. In fact I did it and you can find some value in the table above, these results are find by multiplying the time lost by the hour cost of a single operator for the company. The most coherent monetary value to use is, in my opinion and in our case, the AGV.

I was seeking a calculating method which would take into account the quantity produced, the time used, the AGV and the losses.

My solution was to modify the sTRP and TRP formula. The computation of the sTRP is made up of all these elements. As I said before the problem with the computation of the TRP is that it doesn't show the weight of the production time, but let's go back to the definition of each of them. The TRP gives us the efficiency of our product while the sTRP gives us the efficiency of the plant using the TRP of all products. So using the formula of the sTRP over each code for itself only we get a percentage that is equal to the TRP. Normal, we have been multiplying the numerator and denominator by the same value (AGV*Scheduled Time). But now the calculus also takes into consideration the AGV.

The Denominator of this calculus is the target we should reach and is equal to the AGV x Scheduled Time x 1 (100%), while the Numerator is what we are doing: AGV x Scheduled Time x TRP. Unlikely the sTRP, my idea is to do the difference between the denominator and the numerator, let's call this number "Perte":

$$Perte = (AGV * ST) - (AGV * ST * TRP)$$

$$Perte = AGV * ST * (1 - TRP)$$

Perte is a numerical value that is the multiplication between €/year*seconds. Using the same unity for time we find:

$$Perte = \frac{AGV * ST * (1 - TRP)}{31536000}$$

This number corresponds to the sum of money we lost by not reaching a TRP equal to 100%. It takes into account the AGV, the time of production and the efficiency.

You can find in the following table, the money lost for the 10 worst codes for the month of March.

Line	Code	Description	Mone
I032	E1173050	670087463 DOUBLE ROTARY GSX M161	
I008	E1151149	314910 NVO CARBONIO F142M	
I032	E107414A	670110723 DOUBLE ROTARY GSX M156MY17	
I028	E1162944	670064671 ASCM GSX M161	
I034	E1155435	87263500 MODE DISP GRIGIO BRUNITO F142M	
I034	E1154962	87263400 CPL NIT GRIGIO BRUNITO T.F142M	
I028	E1165642	319573 MOSTRINA NIT F151M	
I028	E118162A	87291200 PLANCETTA CLIMA F151M	

Figure 17: Losses Comparison method

Decision

Comparing the two methods and the 10 worst cases, one can see that the same codes usually come back in the 10 worst cases.

While the first one doesn't take into account the AGV or the price of the component. The second one would be more effective if we were producing always the same product on the same single line, mass production. We are not looking for producing the maximum quantity of a code but when an order is completed, we produce another one, this calculus is giving information that we may not need.

After a discussion with Andrea Massone, the production APU, the decision was made to focus on the first one, which characterized the losses on the workforce. To justify this choice we take also into account that the line of production I034, I028, I032 and I008 have more or less the same AGV (90 000€), which are the line of production with the higher AGV. So it would not affect the classification, and we can focus only on the losses in the workforce.

During my time at Valéo Santena, we improved projects on I028, I032 and I034. The other problem we faced in Valéo Santena was caused by the fact that we are not able to manufacture 100% of the clients' demands. It doesn't come from breakdown or quality issue but usually from the fact that we miss some qualified operators. To solve this problem I analysed how many hours were usually spent on the different codes.

You can see the result below for the month of March:

	Codice	Descrizione	Working Tine (ore)
1	E1177277	670089095 CAMBIO A VOLANTE M161	524
2	E1173050	670087463 DOUBLE ROTARY GSX M161	207
3	E1151149	314910 NVO CARBONIO F142M	156
4	E1130966	E0201222 COMANDO SEAT MEMORY LHD M157	104
5	E1178653	670096828 MOSTRINA ASBM G/SX M161	93
6	E107414A	670110723 DOUBLE ROTARY GSX M156MY17	86
7	E1162944	670064671 ASCM GSX M161	71
8	E1155435	87263500 MODE DISP GRIGIO BRUNITO F142M	71
9	E1154859	87263200 CLIMA CELSIUS GRIGIO BRUN.F142M	64
10	E1154962	87263400 CPL NIT GRIGIO BRUNITO T.F142M	64

36% of manufacturing time

So the sum of the working time of the 10 codes that you can find above in the table corresponds to 36% of the sum of all working time spent in the month of March. Moreover, the code E1177277 which is the paddle shift of Maserati weights as much as 13% of all working time.

This document was presented to APU Production, Andrea Massone and Production Supervisor, Lucio Milione during a meeting. After the meeting, we chose to open a new improvement yard project on the code E1177277, project of which I would be the pilot. The purpose of this project was to diminish the weight of the working time of this code over the overall plant.

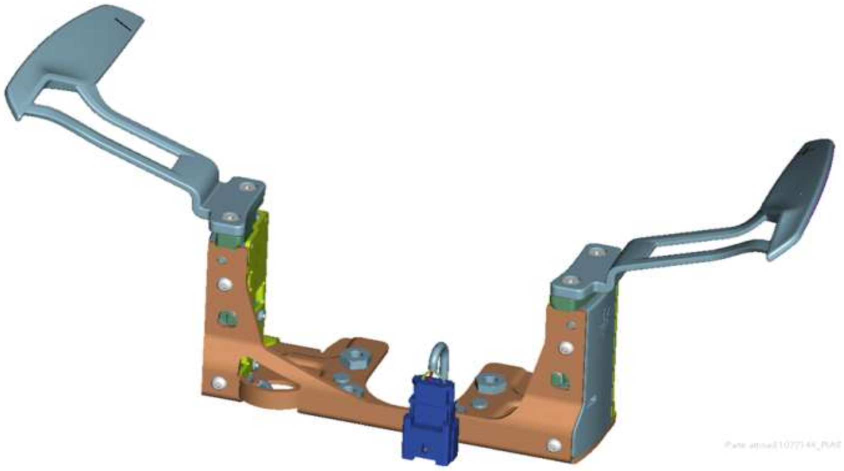


Figure 18: F1 gear paddle shift

3- Maserati Paddle shift

I took part in several projects and managed to find where we were losing efficiency. You will find below the last improvement project that I have been part of, it the one about the Maserati gear paddle shift, code E1177277.

We produce on the line I020 the paddle shift in aluminium or in carbon for Maserati. This paddle shift that you can see above is used in the Ghibli and Levante Maserati models. Approximately 800 parts are produced per week, 750 of them in aluminium and the 50 others are in carbon. To be able to produce this quantity we have 2 workers working in 2 shifts. Each team produces more or less 85 units. We need 2 workers working on the I020 to equal the demand but we are not able to have 100% of adherence throughout the plant. To have only one operator working on that line would mean that another operator could help on another line. The

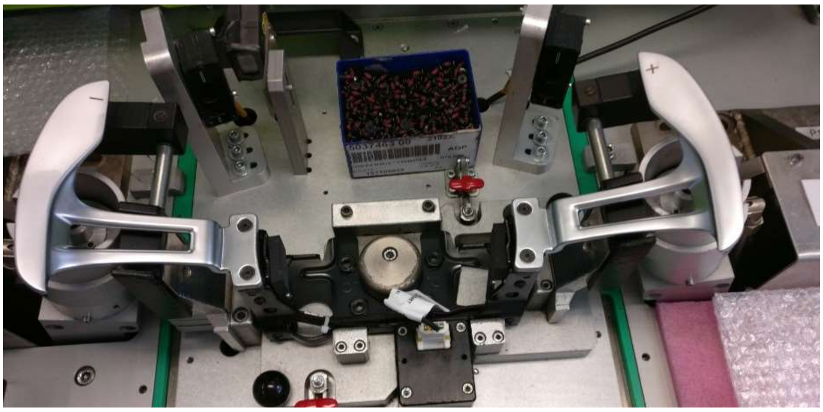


Figure 19: Paddle Shift finished on the I020

AGV of line I020 is 120 k€ and is the highest one with the I039 which produces the paddle shift for Ferrari.

First, I am going to describe the state of line I020 at the beginning of the project on the 13th of June 2017. It was composed of three work stations (10, 20 and 30).

Figure 20: Line I020

On the first station (10) the part made is called "bracci", there is a left and a right one. These bracci are the components that activate the commutation up and down of the paddle shift.

On the second station (20) we add all the components to the bracci except the paddles.

On the third one (30) we screw the paddles and do the global check of the paddle shift. The global check is a software control made by the computer, which controls the different angle of the paddles but also the range of commutation, the force to shift the left and right and make the difference between the left (down) and right (up) paddle.

When the control is completed, and the machine has certified the quality of the part, the operator puts two plastics bags over the paddles to protect them and a protection over the entire paddle shift. It is then put into a big box of 32 paddle shifts and is then sent to Maserati.

Two workers are working together on that line, to do so an operator is operating the station 20 and the other one is operating 10 + 30 + packaging.

In the following part I will give a description of the initial state and the objectives that were set.

Hoshin Kanri

Valéo standards use the Hoshin Kanri method to carry out its improvement projects. I will then go on to present the different steps:

- The first step is to define the improvement objective. The objective is to be able to satisfy the client's demand with only one operator on the line, thus diminishing the manufacturing time of the paddle shift.
- The second step is to map the process and look for waste while producing the item. This operation was carried out by Valéo CDA Production's Director, you can find a non-exhaustive list of the different types of waste that were found during the tour we did with the director:
    - The manufacturing time of our product should be at maximum in a range of 2-3 minutes
    - Several stops of the manufacturing process are performed due to layout not being sufficiently wide to contain enough components hence there is a need to perform the supply
    - Packaging issues of the paddles
- The third step is the measure of the manufacturing time of the process and the OST (One Single Time), which describes the best manufacturing time in which we can perform the manufacturing process.

  Ti = initial Time, time at the beginning of the workstation

  Tf = final Time, time at the end of the workstation

  Tf-Ti = final time of st10, is same as the time at the beginning of st20

  Tci = the initial checking time performed by the computer on st30, equal to the starting of the next part

  Ii = beginning of the packaging

  If = end of the packaging

St10	St20		St30			Imballo		Uscita tra pezzi	TC(pezzo)	T(in attesa)
Ti	Tf-Ti	Tf	Ti	Tci	TCf	Ii	If			
0	107	275		324	350	594	621	621	621	244
324	424	594	621	659	683	934	963	342	639	278
659	758	934	963	1001	1023	1326	1353	390	694	332
1001	1146	1326	1353	1396	1463	1703	1734	381	733	267
1396	1516	1703	1734	1778	1800	2056	2090	356	694	287
1778	1882	2056	2090	2132	2156	2398	2425	335	647	276
2132	2224	2398	2425	2471	2493	2740	2767	342	635	274
2471	2565	2740	2767	2807	2829	3085	3117	350	646	283
2807	2895	3085	3117	3157	3179	3422	3451	334	644	275
3157	3247	3422	3451	3491	3513	3823	3850	399	693	0

OST =	334

Figure 21: First measure of OST

The OST of the line is set at 334 s (5 minutes and 34 seconds). There is a waiting time for each part which corresponds to the time during which the product is waiting to be packed. The OST doesn't take into account this time because it is the minimum time between two properly manufactured parts. When we are working with only one operator, the cycle is as follows:

i. St10 to manufacture the "*bracci*"
ii. St20 to complete the paddle shift
iii. St30 to screw the paddles on it.
iv. The operator starts the automatic control performed by the computer on st30.
v. The operator starts the next paddle shift. So the first one is waiting until the st20 of the next one is done.
vi. When the operator comes back to the first one, he sticks the label which certifies the proper working of the paddle shift and inserts plastic bubble bags around the paddles and the paddle shift.
vii. Then the second paddle shift is set on st30 and so on

- The 4th step is to measure the manufacturing time wasted during a shift. I spent one shift with the operators to measure the wasted time, one can see the results below:

Supply Time

		Quantità	N di cambio/g	Tempo impiegato/g
Piccola su Linea	E1077134	50	2	30
	E1077133	50	2	30
	Braccio SX	79	2	30
	Braccio DX	79	2	30
	E1077104	30	3	45
	E1077501	40	2	30
	E1165260	12	7	105
	Palette SX	15	6	90
	Palette DX	15	6	90
	Somma per giorno :			480

		Quantità	N di cambio/g	Tempo impiegato/g
Media su Rack	E1077134			
	E1077133			
	Braccio SX			
	Braccio DX			
	E1077104			
	E1077501			
	E1165260	30	3	90
	Palette SX			
	Palette DX			
	Somma per giorno :			90

Remove the tape over the circuits

	Quantità	N	Tempo impiegato/g
E1077104	5	16	240
Somma per giorno :			240

Change the box full

	Qtà/ode	N	Tempo impiegato/g
Finito	32	2	60
Somma per giorno :			60

Bar code problem

	Tempo perso	N	Tempo impiegato/g
St10	2	80	160
St20	5	80	400
St30	0	80	0
Somma per giorno :			560

Time wasted	1430	3,4	E1177277 lost by shift

Figure 22: First measure of losses

The box containing the paddle shift is made of 4 floors with 8 levits on each one. So it contains 32 paddle shifts.

Every 5 circuits there is a sticking tape that the operator needs to remove.

On the st20 and st30, the computer has to read the products' barcode, which can sometimes cause problems.

- The next step was to write the Action Plan located in the Appendix.
- The following one was to study the time balance over the workstations, if we are working on several workstations with several operators we don't want to have a bottleneck situation which would slow down the line, so thanks to this step we should balance the activities between the stations. But the purpose of our project is to work with only one operator so we didn't take into account this task.
- In the final part we are going to define the Takt Time, which describes the manufacturing time that we have to reach to be able to satisfy the demand of Maserati with only one operator.

Takt Time: $TT = \frac{Production\ TIme}{Quantity\ Required} = \frac{10\ \ shifts\ by\ week\ \left((8\ hours-(break,cleaniong,\ldots))*10\right)}{Quantity\ Required\ (MPS)}$

Linea	Codice	Descrizione	W19	W20	W21
I020	E1177277	670089095 CAMBIO A VOLANTE M161	800	864	800

$$TT = \frac{(24480 - 720) * 10}{864} = 275\ seconds$$

First, the target was set to 275 seconds which was the Takt time, but during the improvement project we were informed that the demand made by Maserati was going to increase. That is why we calculated a new Takt time:

Linea	Codice	Descrizione	W35	W36	W37
I020	E1177277	670089095 CAMBIO A VOLANTE M161	960	960	960

$$TT = \frac{(24480 - 720) * 10}{960} = 247{,}5\ seconds$$

Thus the new Takt time is 247 seconds. After carrying out study on the previous months and after a meeting with the operators, I noticed that this line was not the one which corresponded to machine stops losses. The losses were due to Organization Malfunction and quality issues with the paddles. So in order to obtain a security range, we set the objective of a manufacturing time of 223 seconds, which is equivalent to all the production in 9 shifts and not 10 per week. With a KOSU of 223 seconds we would produce a little more than 100 paddle shifts per shift.

Last but not least part of the beginning of the project was to define the team working on the project, in which I was the pilot:

- Lucio Milione, Production Supervisor and my tutor
- Paolo, computer maintenance
- Gianni, maintenance
- Andrea, maintenance
- Tiziana, operator
- Alessia, operator
- Gaetano, operator

Then there were also 2 members of the quality team that were not in the team at the beginning but helped us during entire project and diminish the risk that we usually face during a modification of a process:

- Adriano, Quality process
- Usman, Quality Supervisor

The Master Data of the month of March shows the manufacturing state of the code E1177277. Pay attention to the fact that the Working Time = 24 480s means 1 operator.

Linea	Codice	Kosu Target	TC (SAP)	Giorno	Prod	Working Time	Cambi	Breakdowns & Microstoppage	No Qual.	Pausa	Org. Malf.	Formazione	Planned Stop	Kosu Produzione	TRP
I020	E1177277	435	505	24/03/2017	154	103 440	900		73 080	17 280			840	660	64,84%
I020	E1177277	435	505	30/03/2017	169	96 180	900		7 035	17 280	300		840	559	75,74%
I020	E1177277	435	505	23/03/2017	77	48 960	300		22 200	8 640	300		420	626	67,97%
I020	E1177277	435	505	29/03/2017	89	48 960	600		3 480	8 640			420	539	78,56%
I020	E1177277	435	505	23/03/2017	59	33 840	600		3 025	6 960			420	556	73,75%
I020	E1177277	435	505	29/03/2017	97	52 380	300		435	6 967			420	533	83,08%
I020	E1177277	435	505	01/03/2017	159	89100	900					20 265		555	90,07%
I020	E1177277	435	505	28/03/2017	95	48 960	300		870	8 640	300		420	508	83,86%
I020	E1177277	435	505	27/03/2017	160	73 440	900		4 338	12 960	300		840	448	94,38%
I020	E1177277	435	505	31/03/2017	88	43 680	900		1 305	5 700			420	481	90,72%
I020	E1177277	435	505	08/03/2017	116	61605	600				2700		840	519	96,35%
I020	E1177277	435	505	03/03/2017	173	89700	900		5280		300		840	508	98,26%
I020	E1177277	435	505	22/03/2017	66	32 400	600		471	2 100				482	96,56%
I020	E1177277	435	505	02/03/2017	174	89100	1200				300		840	500	99,50%
I020	E1177277	435	505	21/03/2017	56	24 480	300			4 320			420	424	99,59%
I020	E1177277	435	505	20/03/2017	145	73 440	600				600		720	497	100,64%
I020	E1177277	435	505	09/03/2017	99	48 960	600	2 010					420	464	102,94%
I020	E1177277	435	505	10/03/2017	147	73 440	600	1 800					840	478	102,20%
I020	E1177277	435	505	06/03/2017	184	91680	900				600		840	489	102,23%
I020	E1177277	435	505	15/03/2017	180	85 560	600				1 380		840	467	107,24%
I020	E1177277	435	505	27/02/2017	247	118632	900				1200		840	473	105,84%
I020	E1177277	435	505	28/02/2017	181	84120	1200		507				840	453	109,70%
I020	E1177277	435	505	16/03/2017	162	73 440	900		1 170				840	443	112,62%
I020	E1177277	435	505	07/03/2017	151	67030	900						840	432	115,14%
I020	E1177277	435	505	17/03/2017	161	71 940	900		435		600		840	436	114,29%
I020	E1177277	435	505	13/03/2017	164	73 440	600	1 200					840	432	114,01%
I020	E1177277	435	505	14/03/2017	144	69 930	600		870				840	476	105,20%
I020	E1177277	435	505	28/03/2017	93	48 960	300		870	4 320	300		420	519	88,80%

TRP del codice:	96,40%
Kosu Reale:	494
KOSU per carico:	501
Ore lavorate	78

Figure 23: Master data of March 2017

We know that we can manufacture a paddle shift every 334 seconds. Therefore, for a single operator on the line, this means approximately 70 paddle shifts per shift (24 480s-cleaning-BIL) hence 700 paddle shifts every week (10 shifts), which are still fewer than what is asked by Maserati. Moreover, when I looked at the KOSU of March we saw that there was a difference of almost 160s with the OST. This means that we are losing time on other operations which weigh a lot at the end of the day on the KOSU and on our line efficiency and our productivity.

3-1. Subgroup from supplier

Define

During the two first weeks, the main activity was to present the Hoshin Kanri to the different departments and the director. Then we began to check the opportunity for improvement to satisfy our objective. The first idea was that we had too many operations which bring added value. We therefore can't do without them.

Valéo CDA's manager said that we are assembly plant with an expensive workforce. Our business relies on the final quality of our pieces.

One product is made at the very best every 334 seconds, with half of the manufacturing time on workstation 20. The time spend on workstation 10, workstation 30 plus the packaging is equivalent to the other half. Moreover, we decided to take the average KOSU of the last months as a starting point, with one operator on the line, it was therefore set at 456s.

Measure

One can see the measure of the OST below:

St10	St20		St30			Imballo		Uscita tra pezzi	TC(pezzo)	T(in attesa)
Ti	Tf-Ti	Tf	Ti	Tci	TCf	Ii	If			
0	107	275		324	350	594	621	621	621	244
324	424	594	621	659	683	934	963	342	639	278
659	758	934	963	1001	1023	1326	1353	390	694	332
1001	1146	1326	1353	1396	1463	1703	1734	381	733	267
1396	1516	1703	1734	1778	1800	2056	2090	356	694	287
1778	1882	2056	2090	2132	2156	2398	2425	335	647	276
2132	2224	2398	2425	2471	2493	2740	2767	342	635	274
2471	2565	2740	2767	2807	2829	3085	3117	350	646	283
2807	2895	3085	3117	3157	3179	3422	3451	334	644	275
3157	3247	3422	3451	3491	3513	3823	3850	399	693	0

OST =	334
KOSU =	385

Figure 24: Second OST measure

Then this is the time spent on every station and for the station 30, the time spent on every operation:

st10	st20	st30 (Paddles)	st30(Check)	st30(Imballo)
107	168	49	26	27
100	170	38	24	29
99	176	38	22	27
145	180	43	67	31
120	187	44	22	34
104	174	42	24	27
92	174	46	22	27
94	175	40	22	32
88	190	40	22	29

Figure 25: Time spent on each stage

Analyse

To reduce the manufacturing time our idea was to ask a supplier with a workforce, which was less expensive than ours, to manufacture part of the component which is produced on the line on workstation 10, which doesn't need qualified operators.

You can see below a picture of the *bracci* made on station 10:

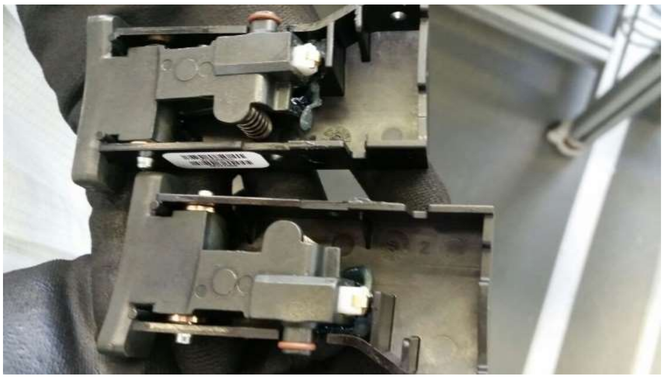


Figure 26: Bracci

Moreover, in order to reduce the risk of manufacturing faulty parts, we decided to send all of them to workstation 10 with our software. So that the result would be less costly in terms of workforce as this part would be made using the processes used in our factory. The Board of Directors agreed with this solution.

The purchase team could then start finding offers from our suppliers.

Improve

We removed workstation 10 from the line and placed it on another line of the plant. This action was meant to act as if the station were already at the supplier's. We then defined a barcode for the right *bracci* and the left one with a packaging that abode with Valéo's norms quality standards. We then started to organize the way in which we would create a small supply stock.

We received an offer from Compatech, which is one of our main suppliers, that suited us, and we decided to accept it. We will discuss later the savings this choice enabled us to make.

Figure 27: Box full of bracci

We had to create a small stock, in fact we told Compatech that as soon a workstation 10 would be at their plant they would have 2 weeks to supply us with *bracci*. Therefore, we had to make a 2-week stock in our own plant. This decision implied that we needed almost 2000 pairs of *bracci*, keeping in mind that during this period we were still producing on the I020. Thus, I created a chart and defined a workstation with the logistics department to stock the *bracci*. The plan would enable us to reach a full stock within 6 weeks. One can see below the totem used to see the daily advancement of the stock:

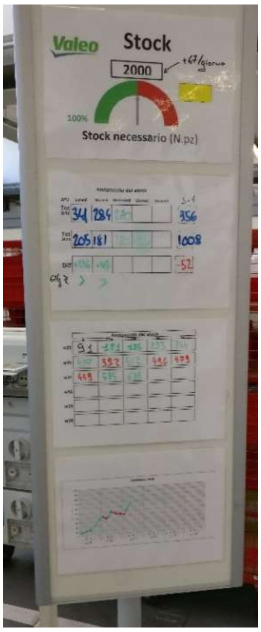


Figure 28: Table workstation 10

Figure 29: Workstation 10

When the stock was completed, we sent workstation 10 to Compatech, the day after Lucio Milione, our Production Supervisor, went to their plant to show their operators how the machine should be used and assisted them during half a day to see that everything was working alright.

Control

First, I controlled the new manufacturing time, on the line. One can see below the measures made on the 28th of June.

St10	St20		St30			Imballo		Uscita tra pezzi
Ti	Tf-Ti	Tf	Ti	Tci	TCf	Ii	If	
0	0	174		203	228	375	403	403
203	203	375	403	445	467	617	647	244
445	445	617	647	688	711	873	902	255
688	688	873	902	933	976	1128	1159	257
933	933	1128	1159	1204	1236	1376	1404	245
1204	1204	1376	1404	1448	1473	1620	1645	241
1448	1448	1620	1645	1685	1707	1854	1889	244
1685	1685	1854	1889	1928	1972	2122	2157	268
1928	1928	2122	2157	2199	2221	2377	2404	247
2199	2199	2377	2404	2447	2477	2787	2815	411

OST =	241
KOSU =	282

Figure 30: Third measure of OST

When I measured the KOSU on the line I found a KOSU of 282s, presenting no particular problem. Then I checked the average KOSU for this period and I found it corresponded to 300s. We are now producing around 80 paddle shifts per shift.

The second control concerned the quality of the subpart we received from the supplier, when our Supervisor was at their plant to train their operators. They manufactured during a couple of hours and produced approximately 50 pairs of *bracci*. The supervisor came back with a sample, to check that everything was working properly.

Figure 31: Station 10

The 50 pairs of *bracci* he brought back were first used to test their quality. A first control was carried out by the quality team for the packaging to be sure it worked then we used them to manufacture Levit. All the samples passed the control tests and the Quality department gave its OK.

With this improvement we diminished the medium manufacturing time to approximately 150s. One can see below the document from the finance department showing the savings on the industrial margin calculated according to this improvement. Recalling the first part of the master thesis, in this part we have shown the possibility to outsource a part of the operations to increase the efficiency and the productivity of the production line.

3-2. Layout Modification

Define

As one can see from the control of the part's manufacturing process there is a difference

Bracci		
Quantity for a year		36 000
KOSU before improvement (sec)		456
KOSU after improvement (sec)		300
Cost for each one from Compatech	€	4,56
KOSU beginning x pz. Year		16 416 000
KOSU end x pz. Year		10 800 000
Saving in sec.		5 616 000
Saving in hours		1 560
Saving MOD	€	74 287,20
Saving MOI	€	121 633,20
Saving in euro MOD + MOI	€	195 920,40
Price material per yearly quantity		164 160
Time on CA		505
Time on CA x pz. Year		18 180 000
Saving in ore CA		2 050
Totale saving. In euro / CA MOD	€	97 621,00
Totale saving. In euro / CA MOI	€	159 838,50
Tot sav. In euro / CA MOD + MOI	**€**	**257 459,50**
Totale saving. In euro compare to the beginning		**€ 31 760,40**

Figure 32: Saving from the improvement of the bracci

between the KOSU that I measured on the line from the measurement on the operator's document. At the end of the day there was a difference of 20 seconds. This difference may be a consequence of the process we have seen in the 4th step of the Hoshin Kanri. The fact that the operator has to go to the rack to supply his workstation at least twice every hour, and he sometimes has to change the final box when it is full. These operations have an impact on the manufacturing time.

Moreover, the I020 was made for 2 operators on the line, the fact that we now want to work only with one, an ergonomic improvement could be done.

Measure

It corresponds to the 4th step of the Hoshin Kanri. One can see below that the analysis has been completed.

During a meeting with the operators, we talked about ergonomics and theirs feelings about the line. Even if they were generally happy about the operations on the line, they told me that in their opinion workstation 20 was too tiring. In fact, when we were working with two operators on the line, the operator who operated this workstation changed every hour. Now that we are working with one operator this is not possible anymore.

Another problem concerned the barcode printer on workstation 30. It did not have a defined position on workstation 20. On workstation 20 a heavy component is needed which is the base of the paddle shift. Even if one box weighs less than 20 kg, which is the maximum weight according to ergonomics norms, the operators felt tired handling this component and preferred to handle only 5/10 of it, and bring it to the line. This meant that they actually needed to leave the line and go to the rack between 8 and 15 times per shift.

Supply Time

		Quantità	N° di cambio/g	Tempo impiegato/g
Piccola su Linea	E1077134	50	2	30
	E1077133	50	2	30
	Braccio SX	50	2	30
	Braccio DX	50	2	30
	E1077104	30	3	45
	E1077501	40	2	30
	E1165260	12	7	105
	Palette SX	15	6	90
	Palette DX	15	6	90
		Somma per giorno :		480

		Quantità	N° di cambio/g	Tempo impiegato/g
Media su Rack	E1077134			
	E1077133			
	Braccio SX			
	Braccio DX			
	E1077104			
	E1077501			
	E1165260	30	3	90
	Palette SX			
	Palette DX			
		Somma per giorno :		90

Remove the tape over the circuits

	Quantità/g	N°	Tempo impiegato/g
E1077104	5	16	240
	Somma per giorno :		240

Change the box full

	Qtà/odette	N°	Tempo impiegato/g
Finito	32	2	60
	Somma per giorno :		60

Bar code problem

	Tempo perso	N°	Tempo impiegato/g
St10			0
St20	5	80	400
St30	1	80	80
	Somma per giorno :		480

Time wasted	1350	4,8	E1177277 lost by shift

Figure 33: Second measure of losses

Analyse

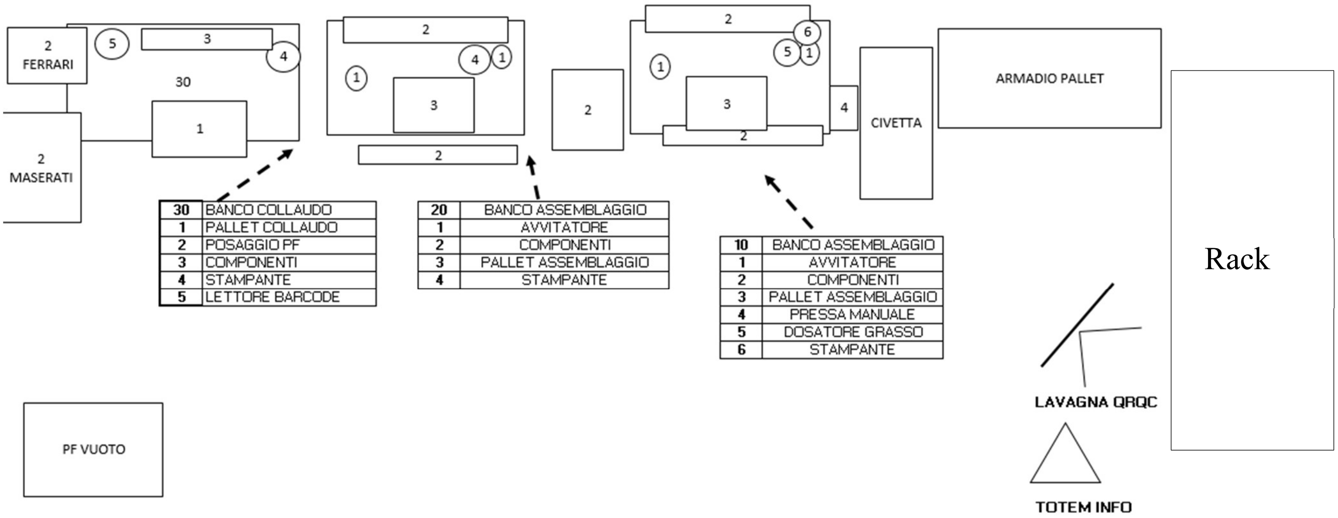


Figure 34: Lay-out before any modification

One can see above the lay-out before any modification on the line was implemented. Since we were sending the st10 to Compatech, we have a free zone between station 20 and the “armadio pallet”. This figure represents the field of production on the line.

The lay-out modification is usually a part of every manufacturing project. As a matter of fact it shows the workers what we are going to improve on the line. That is one of the reasons why we decided after sending workstation 10 to Compatech, we modified the lay-out. The idea was to improve the general ergonomics and reduce the number of walks during a manufacturing hour, and fit everything needed in the worker’s golden zone.

The solution was planned thanks to discussions with the operators according to their needs, taking into account ergonomic norms, and imagining a way to carry more components onto the line than they were actually carrying.

To do so we had to create a system which would allow them to carry at least 100 items of each component.

Improve

The first improvement we completed was to set the line in a L-shape with 90 degrees between the two remaining stations. The I-shape is usually the one providing the best solution, with a worker manufacturing in front of the workstation and the component arriving on one side and leaving by the other. We chose here to use an L-shape, because we needed two workstations. Due to their dimensions, having two workstations next to each other would mean that the operator would have to walk a distance that would have to walk 2 m distance twice for each part.

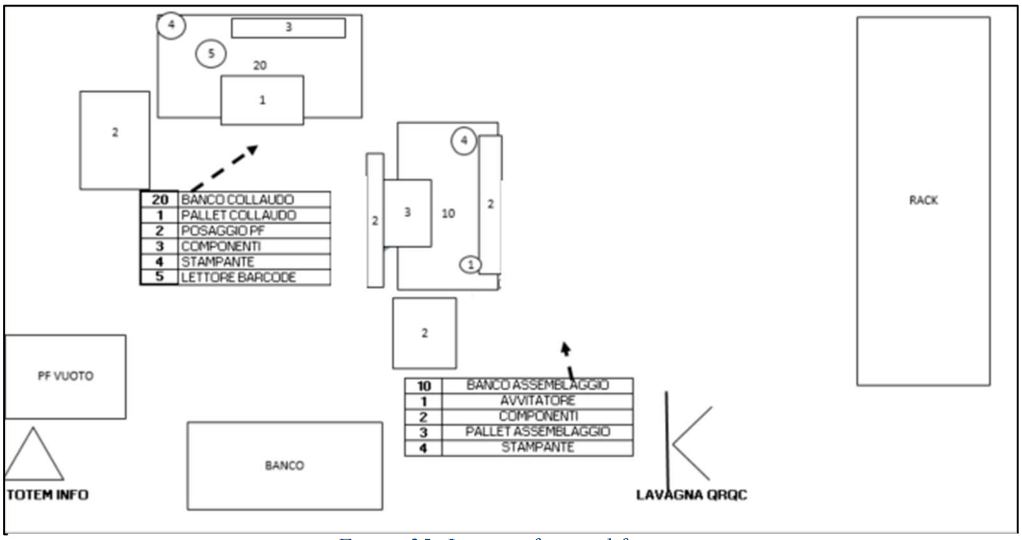


Figure 35: Layout after modification

I took advantage of the situation to modify the space used to set the components, therefore increasing the space available in such a way that the displacement from the rack to the station may not occur.

For workstation 20 shown below, the first thing was to move the computer screen which was taking up a lot of space at the centre of the station. This space could be used to supply components. Moreover, on the workstation table, the place to put the components was not defined.

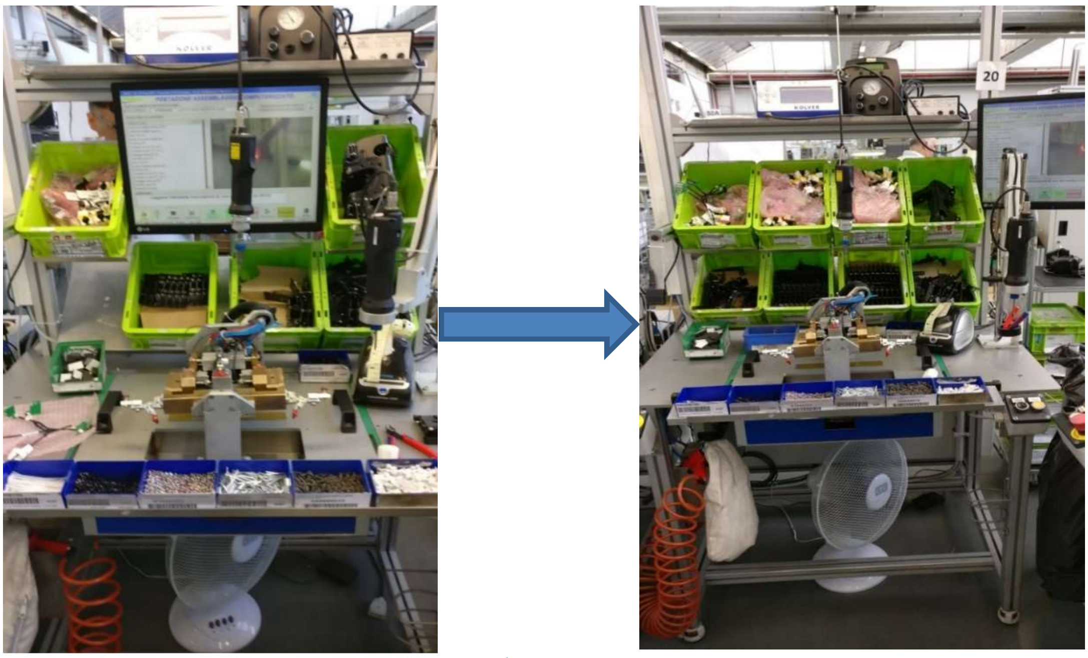


Figure 36: Workstation 20 improvement

Another major issue concerned the screwier. Each levit implies 14 screwing operations. The operators are now working 8 hours straight on the workstations and they say it is really tiring. As soon as we got that information, we tried to solve the problem as quickly as possible that is why we got a new screwing tool the following week.

Figure 37: Workstation 20 with the new screwer

The new one is a semi-automatic screwdriver. The operator just needs to take it and place it above the screw. When he pushes the button, the screwdriver goes down by itself and performs the operations. When it registers the torque limit, thanks to a pressure valve placed under the screwdriver, the tool returns to its initial position and so on until each screwing operation has been performed.

I carried out the same study on workstation 30. The problem was that the operator usually took one box from the right paddle and one from the left one. First, the boxes were placed on the workstation but there was no place to do so and they usually had to change these boxes several times a day. The solution we found with the maintenance team was to use a rail on which it would be possible to carry all the paddles needed during a production shift. We also created a place to set the printer and we defined a position for the box of screws.

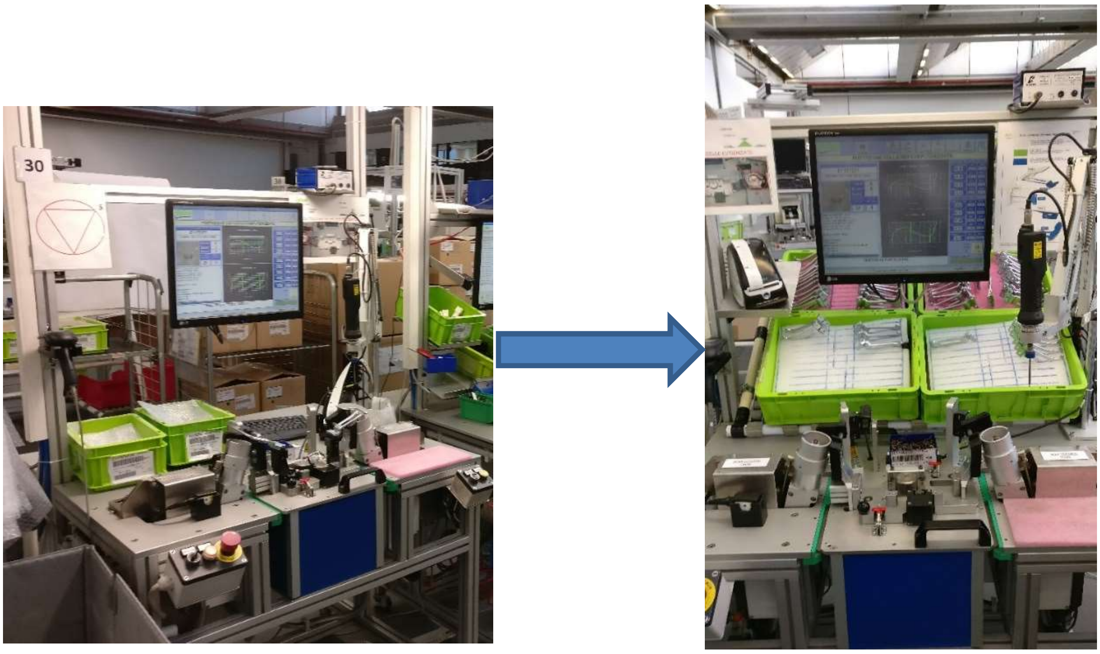


Figure 38: Workstation 30 improvement

As for the issue concerning the heavy components on workstation 20, we created a roller at the same level as the post-station and a rack where the heavy components are placed, thanks to that it is now possible to move boxes containing 30 parts without carrying them. The operator just needs to carry this roller to the rack, slide it onto the rack from the two boxes and then pull the roller to the station.

Figure 39: Roller for heavy component

The zoning of the post stations also took place at the same time in order to respect the 5S and the Valéo norms.

Control

The control over the lay-out relies more on the operator's feelings so after a couple of weeks, I asked them what they liked and what they wanted to change. The result was that we changed some things again such as the position of the touchscreen on the workstation.

The place that we freed with our modifications enables us to have the components of one shift directly placed on the line.

Figure 40: Workstation 20 with the roller on its right

According to the KOSU several days after the modifications were made, we improved the number of paddles manufactured by shift by 2-3. For an average KOSU reducing from 300s to a bit more 280s. The finance file for this improvement is the following one. This improvement increase the industrial margin of 21 350€, and the direct savings of 8 095€ by year. Recalling the first part, we use a leaning of the fluxes to improve the efficiency and the productivity of this line of production.

Lay out		
Produzione anno		36000
TC inizio cantiere (sec)		300
TC fine cantiere (sec)		283
Tempo iniz. cantiere x pz. Anno		10 800 000,00
Tempo fine. cantiere x pz. Anno		10 188 000,00
Saving in sec.		612000
Saving in ore		170
Saving MOD	€	8 095,40
Saving MOI	€	13 254,90
Saving in euro MOD + MOI	€	21 350,30
Tempo a CA	€	505,00
Tempo CAA x pz. Anno	€	18 180 000,00
Saving in ore CAA	€	2 220,00
Totale saving. In euro rispetto CAA MOD	€	105 716,40
Totale saving. In euro rispetto CAA MOI	€	173 093,40
Totale saving. In euro rispetto CAA MOD + MOI	**€**	**278 809,80**
Totale saving. In euro rispetto inizio cantiere	**€**	**21 350,30**

Figure 41: Saving from the lay out modification

3-3. Paddles

Define

On SAP, "Systems, Applications and Products for data processing", the software we use to manage the plant we noticed that most of the cycle times of the products manufactured with the laser were wrong. We therefore started a Hoshin Kanri on that line too, in order to redefine all the time cycles.

Meanwhile, I was spending time on the two lines, and I noticed an issue related to the marking operations concerning the paddles that are then sent to the lines I020 and I039 (paddles for Aston Martin and Ferrari).

The problem was due to the fact that during the marking operation on the paddles, the operator has nothing much to during such a long operation.

Then when the paddles arrive from the supplier they are in a cardboard box. There are 20 paddles in each one and every paddle is covered in a plastic bag to avoid direct contact between them. When the marking operations are completed, each one of them is put back in its plastic security bag and by boxes of 15 they are sent to the lines I020 or I039 where they are screwed. The operator takes it out of the bag, carries out a quality control check then screws them. When the control is done they put the plastic bag back on the paddles and so on.

First, we have an issue concerning actions without any added value. We also have a packaging issue and the third problem is the lay-out of the laser, where we have a big ergonomic issue.

Measure

The laps of time lost while removing the paddle from the plastic bag is 2 seconds, and the time to perform the quality check of the paddle is 5 seconds, if the paddle is perfect. If there is the slightest problem, we will lose quite a lot of time. It can last for 5 minutes for example.

At the end of the day there are at least 14 seconds lost on each paddle shift. For operations without added value the time lost can escalate quickly. Moreover, every time we throw away a paddle we also lose the marking time on the laser.

At the beginning of the laser Hoshin Kanri on the laser line, I directly noticed important ergonomic issue. The operator needed to go between two tables separated by only 40cm. When the laser line was made the idea was to allow the operator to work on both lasers placed on the line at the same time. The results were not really conclusive and we ended up dealing with an ergonomic issue.

The Rofin and the Data Logic are the names of the two lasers machines, the paddles are marked on the Data Logic.

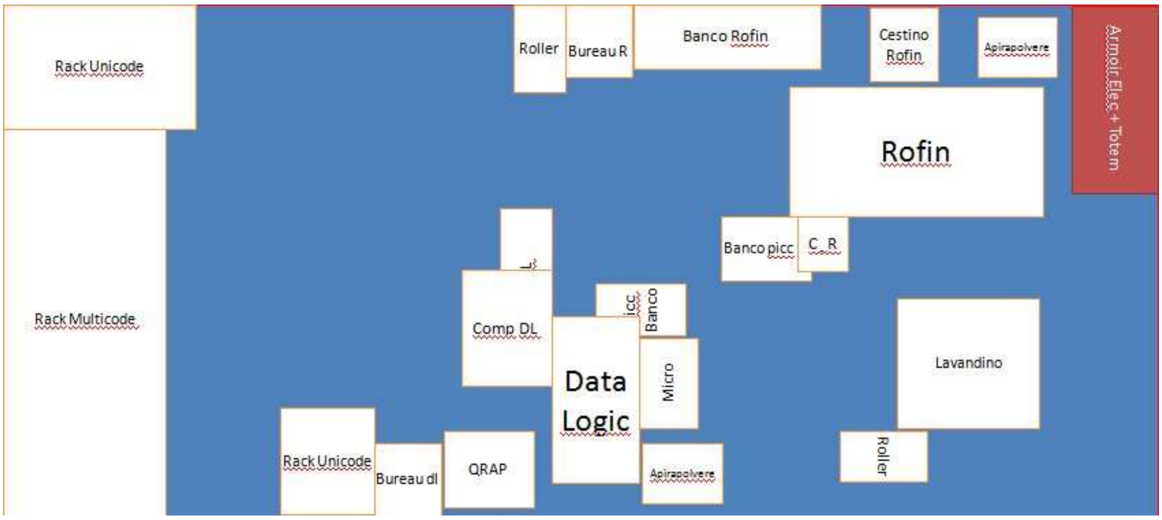


Figure 42: Lay-out of the laser before modification

On the Laser the idea is that we should never have stock. It creates a bottleneck in most manufacturing processes using different lines. To solve the problem we generally have two operators on the line.

The idea of one worker operating on both lasers was an attempt to manage all the components with only one person thus moving the other worker onto another line. We quickly understood that it was not possible and we began to have bottlenecks. We went back to the two operators on the line. But the zone had become too small and they felt oppressed working on this line.

I also measured the time spent doing a marking operation which took 180s, instead of 15s informed on SAP. We are producing the two paddles (right and left) at the same time. It means that for 3 minutes the operator has “nothing” to do/ is waiting. Of course, they use this time to put the paddles back into the bag or to work on the supply if needed or help other workers on the other laser.

Figure 43: Laser before modification

Analyse

The first piece of information is that we have to go back to having two workers on the line. We defined the space needed for each laser and the necessary ergonomic distance. A 5S should also be implemented because of the number of boxes and old set up systems present on the line. A check-up will be carried out by the logistics team in order to have a clearly defined flux of products.

One can see in above figure the paddle example. The logistics train that comes from the supplier will be put on the racks. The operator will then take it and bring it to the laser once he finishes marking it. After that he will bring it to a new rack, the exit rack, where the train is going to take it and bring it to the line.

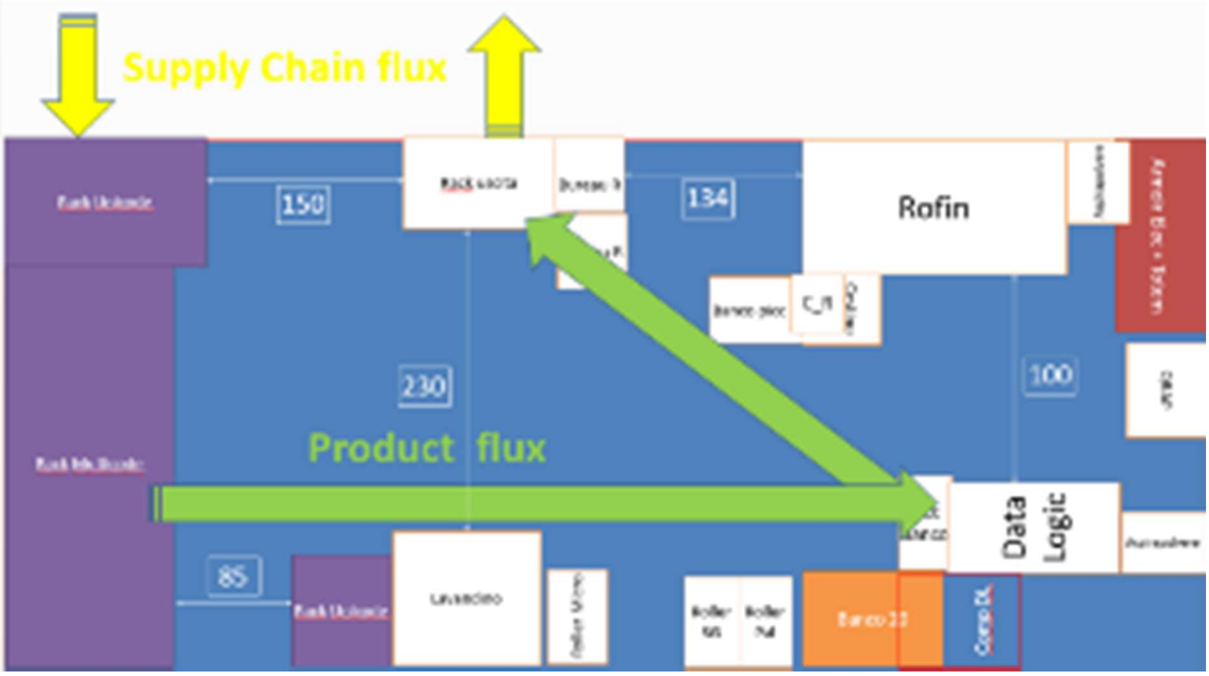


Figure 44: Flux on the laser

As we manipulated fewer boxes, we decided to change the dimensions of the boxes used. The idea was to be able to put only four of them on the line, two for the right paddle and two for the left paddle. This gave us the first dimension. We then wanted to use the entire space created thanks to the rail which had been made by the maintenance team we had the second range of dimension. For the height, the last dimension we needed, we wanted to stock them in a rack with different stages of boxes but we didn’t want the paddles to be in contact with anything, so we needed boxes we can superpose without contact this give us our last dimension.

We found boxes that fit with our needs in our Mantuan shop: Boxes with a capacity of 15L, 400x300x170. When we had the boxes, I searched for a way to stock the maximum of paddles in each one (production’s demand) and also a packaging that would not be a risk for the quality (quality’s demand).

The solution that I found would avoid contact with the esthetical aspect of the paddle. It is as follows:

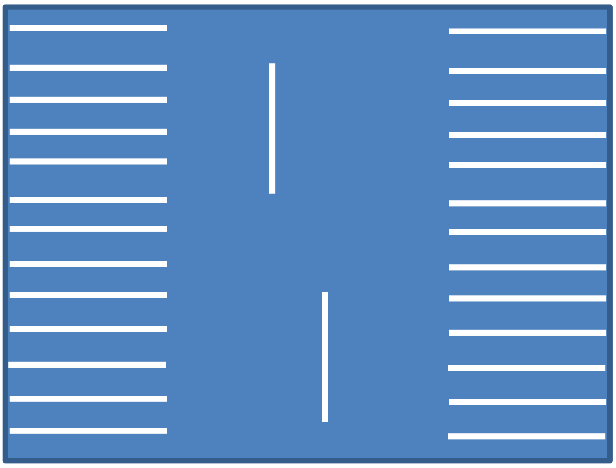


Figure 45: Design of paddles box

We are now able to put 28 paddles into one box, so we are able to supply station 30 with 56 paddle shifts.

This model was accepted by the Quality and Production. A demand made by Production APU was to have at steady state the equivalent of three paddle shift shifts. So while our objective was to produce more than 100 paddle shifts per shift. Thanks to this information we knew how many boxes we needed.

Then the question concerned the marking operation with the laser. At the laser we implement a new rule: each code must not be made several times per shift. It means that you can't manufacture paddles one hours then switch to another code then come back to paddles. This new rule will help us avoid losses and waste less time. To be able to know when we have to mark paddles we decided to create a roller that would have the space necessary for 8 boxes (2*4 boxes of each side). When an operator has finished one box, he puts it on the roller. When the roller is full, he puts the roller next to the logistic train, which will bring it to the laser. Then on the laser, we gave a new rule that from the moment this roller arrived on their line, it has to be the next thing to mark. When the laser operation is completed they push the roller to the exit rack and the train will bring it back to the paddle shift line.

We created 3 rollers to be able to meet different production situation. The worst being one roller is empty so in the direction of the laser, another one is finishing to be fill at the laser (more or less 6 hours to full fill one) and the last one on the I020 where the operator needs it to put the box empty. To do so we created a zone on the lay out and also on the line to put the roller.

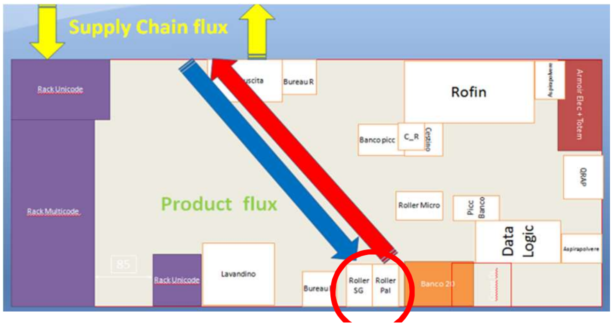


Figure 46: Flux for paddles

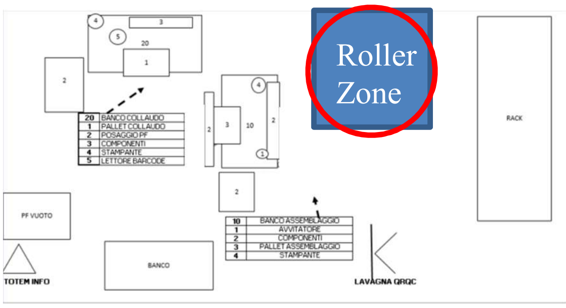


Figure 47: Zone of the rollers on the I020

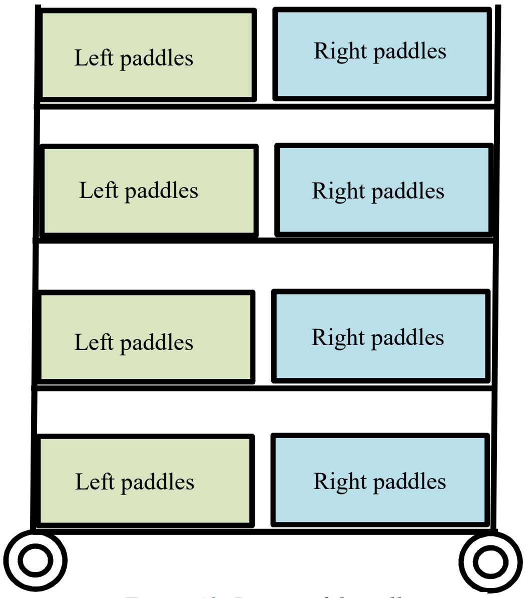


Figure 48: Design of the roller

One can see on the following page the pace that the rollers should have.To diminish time on station 30. This operation should be performed before the marking operation we should not perform any more paddle control checks but of course before the marking operations. So the operators on the laser had to be trained.

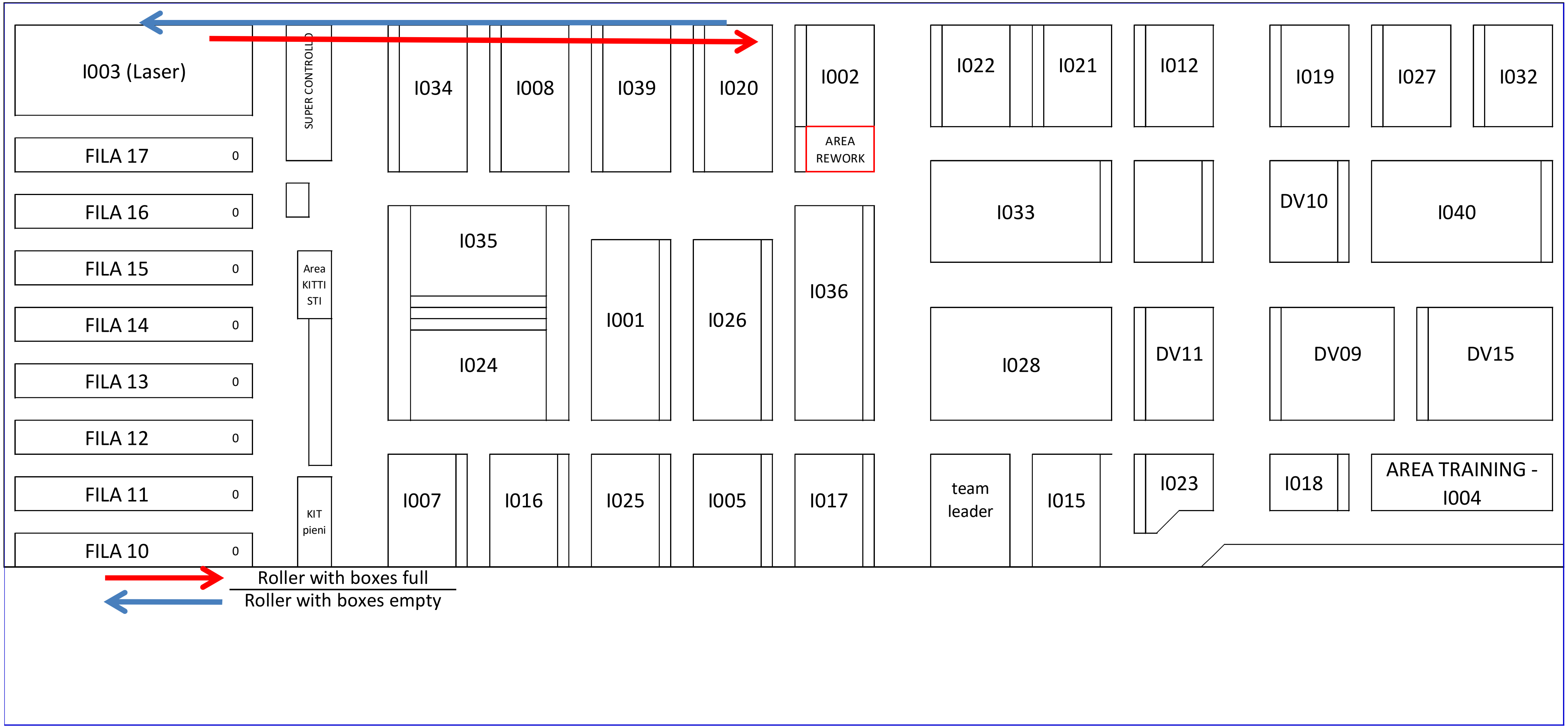


Figure 49: Lay out of the plant

Improve

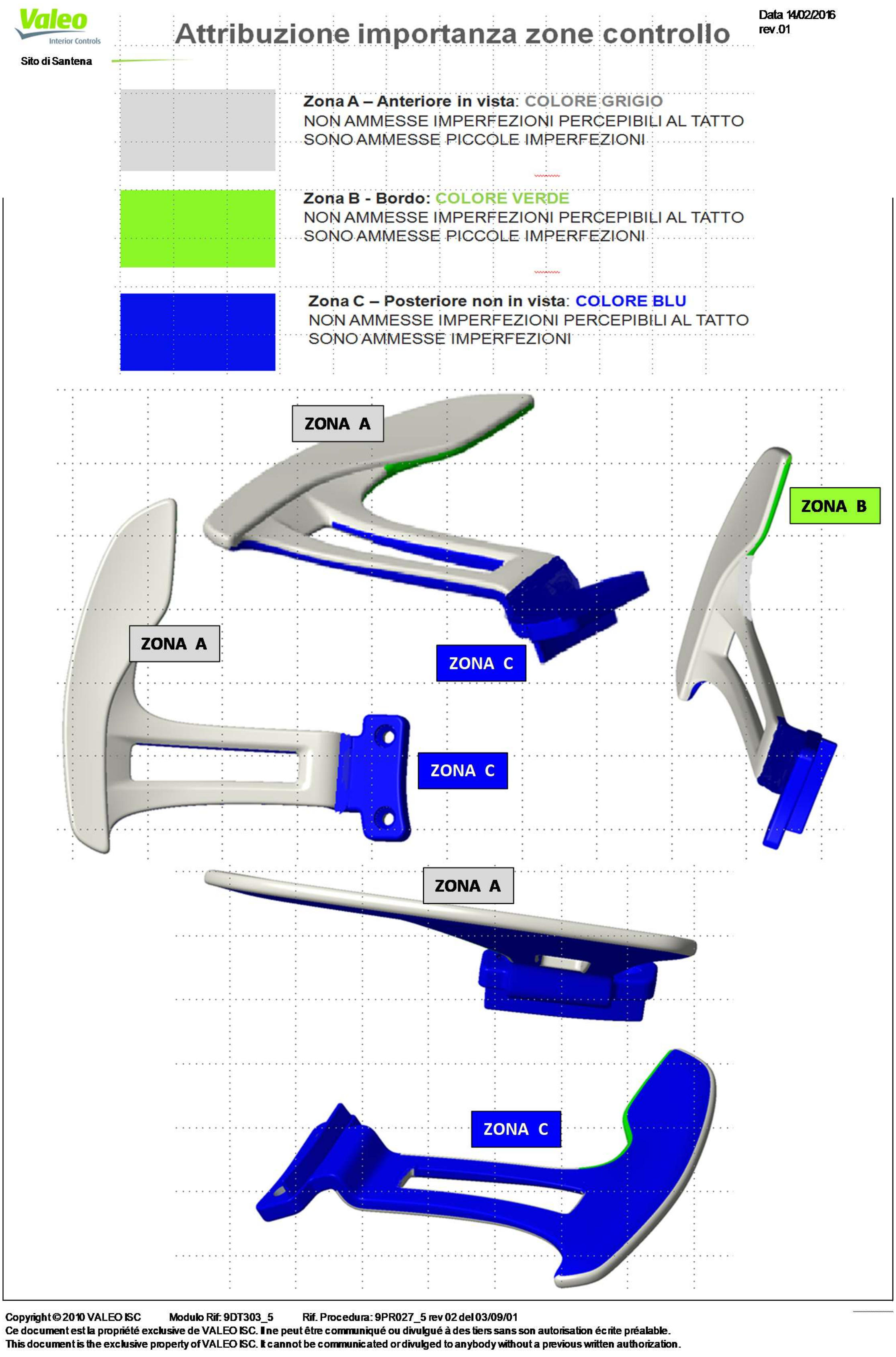


Figure 50: Control zone of the paddles

I began with the training of the operators, thanks to the files that the Quality Department provided me with. This is a document given to us by Maserati, describing the different zones.

- Zone A: the most important one, no visual defect or sensitive defects are admissible.
- Zone B: Same as zone A even if small visual defects can be accepted.
- Zone C: Visual defects are accepted, only sensitive defects are not accepted.

The beginning of the improvement process took place after the layout was modified, I did the packaging for all the boxes and set them in place.

Figure 51: Paddles on workstation 30

We still needed to put the plastic bag over the finished paddle shift for safety reasons.

Figure 52: Station 30

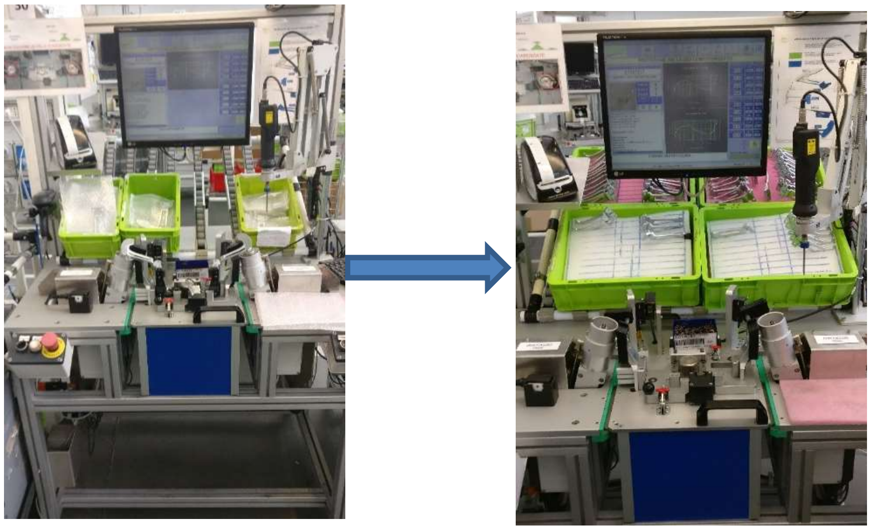


Figure 54: Station 30 improvement

Figure 53: Roller in their zones

We modified the layout of the laser station. There are no more ergonomics problems. We also create space that allows the workers to feel better as they work on the line.

After we implemented the 5S, we reduced the number of boxes on the lines and added a bench with some spaces under the workstation to organize the boxes. This is the Data Logic:

Figure 55: Data Logic

One can see the space between the lasers:

Figure 56: New lay out laser

According to the ergonomic norms, we set as a minimum space to create a corridor of 80 cm when the operator has nothing to carry and a corridor of 1m20 when he has something to carry.

Figure 57: New lay out laser (2)

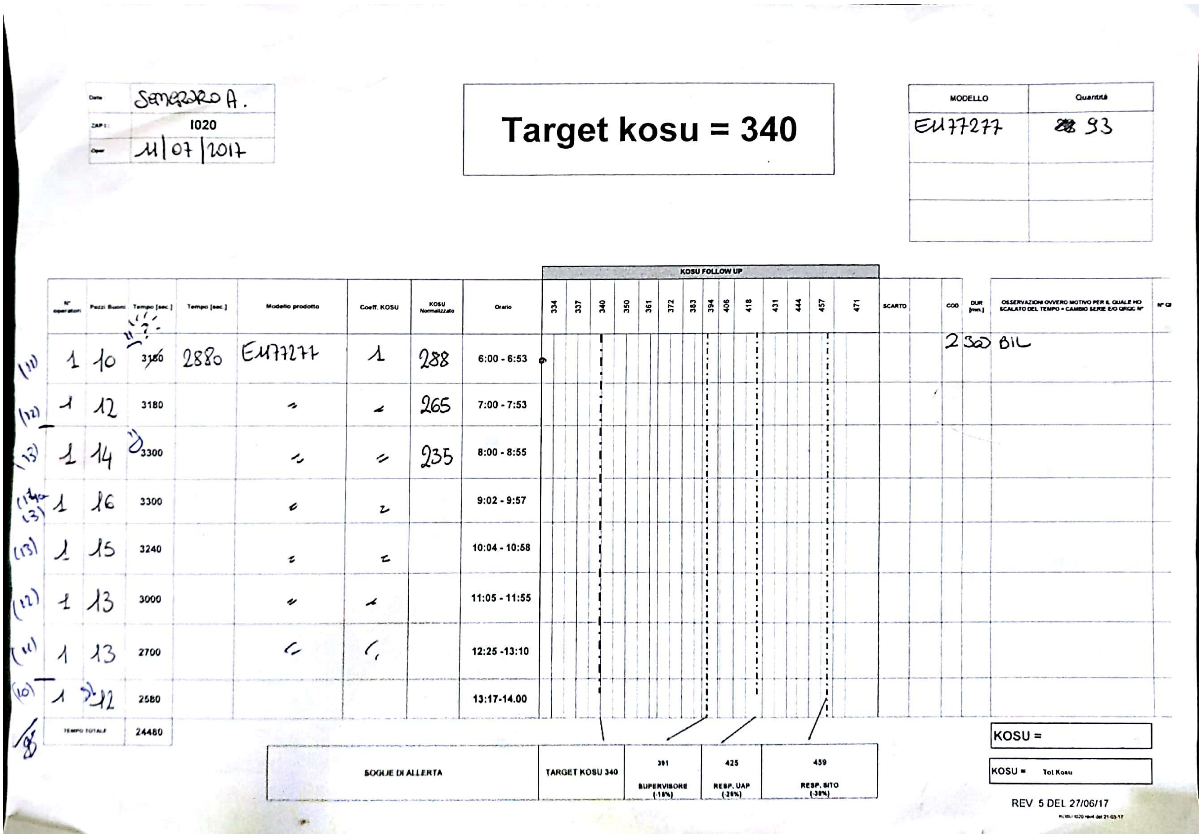
On the previous picture one can see the exit rack on the right. It is from this rack that the logistic train is going to take the marked parts and bring them onto the appropriate line.

Control

The first control was made at the end of the production line with a supervisor from the quality team (Usman). He was looking at the paddle shifts exiting from the line while making sure that the new packaging procedure for the paddles would not create a quality issue. Of course the packaging was already defined with another member of the quality team as it is the most important quality element on the Levit. We therefore decided to perform a second control check over this part in steady condition, just to confirm that the process works.

The second control check concerned the KOSU and we now produced a little more than 90 paddle shifts per day, with a KOSU of approximately 255s. We can see here that we reduced the manufacturing time by more than the 15 seconds expected. This was probably thanks to the training undergone on the laser. The operators noticed that the number of parts with defects on the line I020 had strongly diminished. But they still found some. Thus, every time we find one on the line, the quality supervisor brings it to the laser to improve their training on dealing with defects. Therefore, the operators are still checking the paddles.

One can see below a KOSU of line I020 several days after the layout was completede:


Semeraro A.
I020
11/07/2017

Target kosu = 340

MODELLO	Quantità
EU77277	93

	N° operatori	Pezzi Buoni	Tempo [sec.]	Tempo [sec.]	Modello prodotto	Coeff. KOSU	KOSU Normalizzato	Orario	COD	DUR [min.]	OSSERVAZIONI OVVERO MOTIVO PER IL QUALE HO SCALATO DEL TEMPO = CAMBIO SERIE E/O QRQC N°
(11)	1	10	3180	2880	EU77277	1	288	6:00 - 6:53	2	300	BIL
(12)	1	12	3180		=	=	265	7:00 - 7:53			
(13)	1	14	3300		=	=	235	8:00 - 8:55			
(14) (13)	1	16	3300		=	=		9:02 - 9:57			
(13)	1	15	3240		=	=		10:04 - 10:58			
(12)	1	13	3000		=	=		11:05 - 11:55			
(11)	1	13	2700		=	=		12:25 -13:10			
(10)	1	12	2580					13:17-14.00			
93	TEMPO TOTALE		24480								

KOSU FOLLOW UP: 334, 337, 340, 350, 361, 372, 383, 394, 406, 418, 431, 444, 457, 471 | SCARTO

SOGLIE DI ALLERTA	TARGET KOSU 340	391 SUPERVISORE (15%)	425 RESP. UAP (25%)	459 RESP. SITO (35%)

KOSU =
KOSU = Tot Kosu
REV 5 DEL 27/06/17

Figure 58: KOSU of the 11/07/2017

The document from the finance department gives an idea of the industrial marginal increase induced thanks to this improvement. We should normally take into account that this improvement also increases the checking time on the laser. But, as we saw in the analytical part there is a little less than 3 minutes of available time during the paddles marking operation. It would therefore not have any effect on the industrial margin. Recalling the first part, we use

Paddles		
Produzione anno		36 000
TC inizio cantiere (sec)		283
TC fine cantiere (sec)		256
Tempo iniz. cantiere x pz. Anno		10 188 000
Tempo fine. cantiere x pz. Anno		9 216 000
Saving in sec.		972 000
Saving in ore		270
Saving MOD	€	12 857,40
Saving MOI	€	21 051,90
Saving in euro MOD + MOI	€	33 909,30
Tempo a CA	€	505,00
Tempo CAA x pz. Anno	€	18 180 000,00
Saving in ore CAA	€	2 490,00
Totale saving. In euro rispetto CAA MOD	€	118 573,80
Totale saving. In euro rispetto CAA MOI	€	194 145,30
Totale saving. In euro rispetto CAA MOD + MOI	**€**	**312 719,10**
Totale saving. In euro rispetto inizio cantiere	**€**	**33 909,30**

Figure 59: Saving from paddle improvement

the mind-set of continuous improvement, the suppression of actions without added value and improvement of the fluxes to bring an improvement to the efficiency and productivity of the line.

3-4. Subgroup

Define

We now have a KOSU running around 255 seconds which is still above what we set as objective. The operators were therefore complaining about station 20 that was still too tiring. Moreover, they were satisfied with the new screwier. However, the problem concerning the screwing of four screws on the circuits performed by another screwier that wasn't ergonomic remained a problem. Consequently, we still have a process where we are spending too much time whereas on the laser, we still have available time.

The purpose of this improvement is to check the feasibility of performing a group of operations on the laser and bring it on I020 as we did for the paddles.

Measure

First, during the marking operation I timed on the laser how long the operations performed by the worker lasted and then the time which was still available. In the worst case the operator has to do the following things

- Supply the laser with two others boxes of paddles
- Check the marking which had been done on the previous paddles
- Put them in the defined packages
- Check the state of the paddles that will be marked

In this case we still have a little more than 1 minute and 45 seconds available.

Then I timed and noted all operations carried out on station I020:

st20	1°	Step by Step 1
Inizio		
Lettura traciabilita modulo OP10	4	4
Lettura tracciabilità supporto	11	7
Rotazione verticale	14	3
Inserire Gomino spellicolato	18	4
Inserire piastra SX	21	3
Inserire circuito	28	7
Awitatura circuito SX	34	6
Inserire Molla	36	2
Inserire commutatore	38	2
Inserire barra metalica	44	6
Inserire braccio SX	48	4
Rotazione verticale 180°	50	2
Inserire Gomino spellicolato	54	4
Inserire piastra DX	57	3
Inserire circuito	63	6
Awitatura circuito DX	73	10
Inserire molla	75	2
Inserire commutatore	78	3
Inserire barra metalica	81	3
Inserire braccio DX	85	4
Rotazione orizzontale	87	2
Inserire la piastra primaria	97	10
Centrarla con attrezzo	102	5
Rotazione 180° orizzontale	104	2
Awitatura x6 vite	122	18
Rotazione orizzontale	124	2
Awitatura x4 vite	144	20
Montaggio connettore e fascietta	154	10
Prelevamento pezzo	156	2

Figure 60: Operations of the I020

Analyse

We want to bring some operations carried out on station 20 to the laser, the subgroup should be as follows:

- Have a manufacturing time inferior to 1 minute 30 seconds.
- Easily transportable
- Basic operations

We will now focus on the Levit. When the part arrived at the end of station 20, the levit was almost done and we just had to add the paddles. Then the levit was made of one plate on which everything was fixed. So on the plate there were two other plates (left & right) on which the circuit will be screwed, 2 screws for each side, with the spring, the commutator, and the pin which holds the whole commutation system together. Then, on each side of the first plate and above the circuit the two bracci assembled by the supplier.

10 screws are used to fix the whole system together. The connector that allows the paddle shift to work is then attached to the primary plate and the band is used to fix the cables.

st20	1°	Step by Step 1
Inizio		
Lettura traciabilita modulo OP10	4	4
Lettura tracciabilità supporto	11	7
Rotazione verticale	14	3
Inserire Gomino spellicolato	18	4
Inserire piastra SX	21	3
Inserire circuito	28	7
Avvitatura circuito SX	34	6
Inserire Molla	36	2
Inserire commutatore	38	2
Inserire barra metalica	44	6
Inserire braccio SX	48	4
Rotazione verticale 180°	50	2
Inserire Gomino spellicolato	54	4
Inserire piastra DX	57	3
Inserire circuito	63	6
Avvitatura circuito DX	73	10
Inserire molla	75	2
Inserire commutatore	78	3
Inserire barra metalica	81	3
Inserire braccio DX	85	4
Rotazione orizzontale	87	2
Inserire la piastra primaria	97	10
Centrarla con attrezzo	102	5
Rotazione 180° orizzontale	104	2
Avvitatura x6 vite	122	18
Rotazione orizzontale	124	2
Avvitatura x4 vite	144	20
Montaggio connettore e fascietta	154	10
Prelevamento pezzo	156	2

Time removed :

43

Between all these operations we thought of the ones which didn't need to be controlled. And so possible to carry on another line that doesn't have any system. The results are the two secondary plates with the anti-vibrations stickers with the two circuits screwed on them.

Once these operations will be completed on the laser, we should be able to remove 43 seconds from the manufacturing time. This would allow us to have a KOSU medium beneath the objective also 48s is less than the 90s that we set as maximum to do on the laser.

So the idea was to create a group of components made up of the secondary plates, the stickers, the circuits. Moreover this system allowed us to diminish by four the number of screwing operations on the line.

As a consequence, the maintenance team had to create a post-station that we would be suitable for the bank. While with the computer maintenance, we were modifying the software to prepare the system to the new manufacturing process.

During this analysis we also improved the software. The operators used to press the "ok/start" button to allow the system to continue. Now that we removed as many press buttons as possible action and do instead control over the sensors. Instead of putting the bracci and push ok you now set the bracci then the sensors feel its presence and the correct position and the system by itself lets you go forward.

When we were carrying out this analysis we were also doing the control phase of the previous improvement, seeing that the new system with the roller was working really well we decided to do the same with the subgroup. In fact we are going to use one pair of paddles with one subgroup. Thus, instead of one roller we will be working with two rollers.

I designed a packaging that would fit with the subgroup. As for the paddles, the idea was to carry the maximum of them in one box and that the quality department would agree with this packaging system. The only demand from the quality team was that the circuits must not be in contact with anything else because the risk was that it could be damaged and not perform its function anymore.

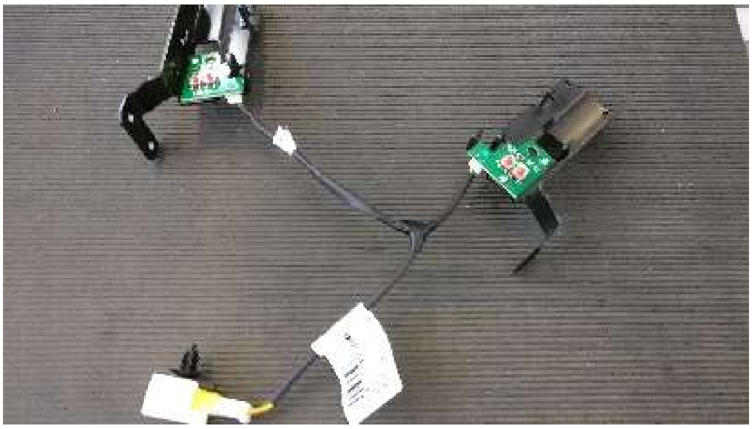


Figure 61: Subgroup

I carried out several tests to find the best solution. As one can see below here are the two solutions that the quality team agreed with.

Figure 63: Packaging design 1

Figure 63: Packaging design 2

As far as capacity is concerned the best one is the one on the right, but I wanted also the operators' point of view. They also preferred the one on the right because it was possible to take it with one hand without any problem. This configuration enabled us to make boxes for 20 components, which means that we would need to have 5 or 6 boxes per shift. We created rollers similar to the ones we used for the paddles.

Thanks to that we would be able to free space on the line and carry more components onto the line and diminish the time the operator needs to go to the rack.

Improve

The maintenance team created a basic post-station which works like a poka-yoke. There is one position for each component which perfectly fit. One can see an example below with the anti-vibration stickers in it.

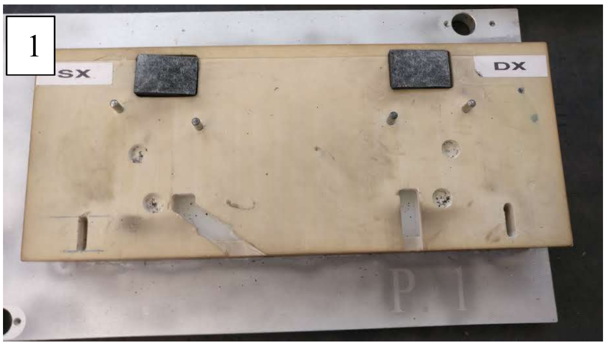
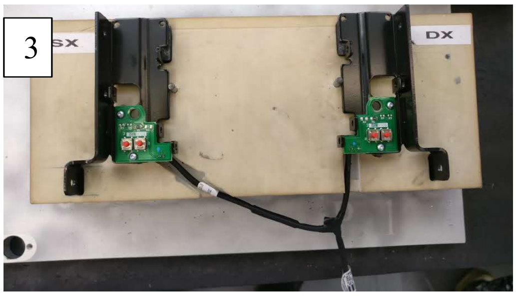
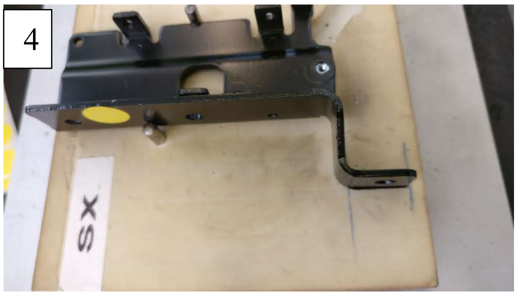


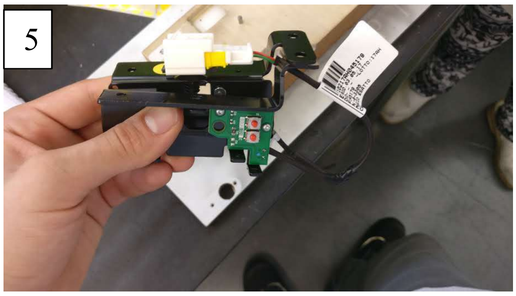
Figure 64: Post-station

It has been set on a plate that we can set on the bench near the laser. It will not move as it is blocked with two pins. The different operations are as follow:

- Put the 2 stickers and remove the film
- Insert both left and right secondary plates
- Screw the circuit on both plates
- Glue a sticker on the left plate







The yellow sticker is an observation made by the operator on the line, when we were implementing the process. The barcode will be glued above the yellow sticker on the I020. The whole traceability of the Levit relies on the barcode printed on station 20. It is made in a way that the person reading the barcode is looking at the bar code on a zone located on the left secondary plate. During the first trials the operator needed to find which one was the left one to glue the barcode in the proper place. So we decided to add this information. Now when the operator takes one subgroup he directly notices where the barcode needs to be glued.

On the picture with the number 5 you can see the way the subgroup is going to be packaged with the two circuits in opposite direction which assure that the circuits will not be in contact with something else.

All subgroups are then put in the same way, to facilitate the exit by the operator, in the package defined before.

The system has been implemented at first on the laser, to create a bit of stock. The laser was the only line where we didn't set a KOSU, because for all codes but paddles, the marking operation is quick so calculating the KOSU would make no sense. But in the case of the paddles and the subgroup the supervisor asked to have one now, to be able to check when they have been done by who and to set a rhythm of production. We implant the st20 on the line I020, in a new way:

Figure 65: First trial for the subgroup design

Figure 66: Work station of the subgroup

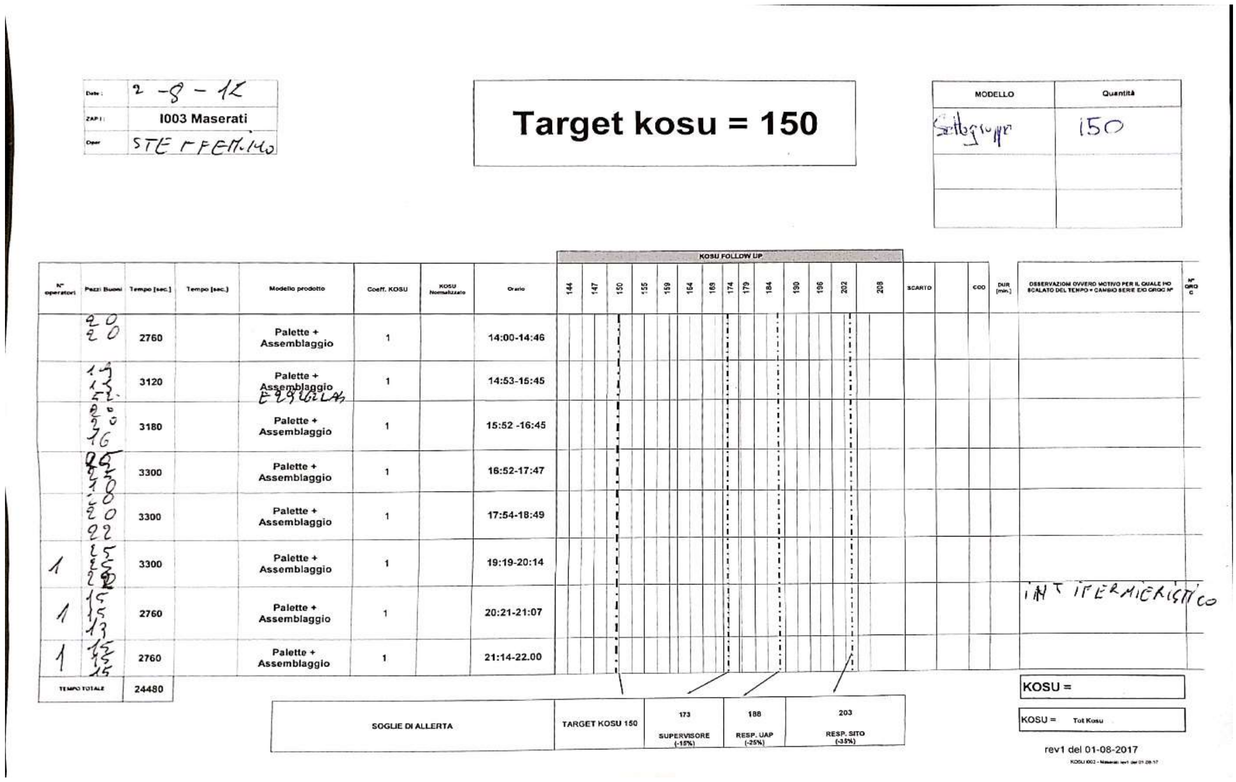
We now only need bracci coming from the supplier and the subgroup from the laser. So we have two floors on the station, one is dedicated only to subgroup and the other one to bracci.

Control

The first control concerned quality. We noticed that there was a problem after the first week. One of the circuits had only one red button instead of two as one can see on the pictures. There are two push buttons to make sure that the paddles will work in case one of the buttons is not working. But our system on the st30 control that both buttons work when we send them.

The mistake was found on station 20 by the operator who notified me about it. I finished the assembly of the Levit to see if the st30 and the software were able to find it and it did.

The process was then checked. And moreover the system with the rollers, actually it is the same process than the paddles one. We only added a couple of rollers and increase the two different zones created before allowing to park more roller than before. You can see below the new KOSU added on the laser:


Date:	2 - 8 - 17
ZAP I:	I003 Maserati
Oper	STE FFEM.MO

Target kosu = 150

MODELLO	Quantità
Seitbgruppr	150

N° operatori	Pezzi Buoni	Tempo [sec.]	Tempo [sec.]	Modello prodotto	Coeff. KOSU	KOSU Normalizzato	Orario
	20 20	2760		Palette + Assemblaggio	1		14:00-14:46
	[illegible]	3120		Palette + Assemblaggio	1		14:53-15:45
	[illegible]	3180		Palette + Assemblaggio	1		15:52 -16:45
	[illegible]	3300		Palette + Assemblaggio	1		16:52-17:47
	[illegible]	3300		Palette + Assemblaggio	1		17:54-18:49
1	[illegible]	3300		Palette + Assemblaggio	1		19:19-20:14
1	15 15 13	2760		Palette + Assemblaggio	1		20:21-21:07
1	[illegible]	2760		Palette + Assemblaggio	1		21:14-22.00
TEMPO TOTALE		24480					

KOSU FOLLOW UP: 144 147 150 155 159 164 169 174 179 184 190 196 202 208

SCARTO | COO | DIR (min.) | OSSERVAZIONI OVVERO MOTIVO PER IL QUALE HO SCALATO DEL TEMPO + CAMBIO SERIE EXO GROC N° | N° GRO C

INT INFERMIERISTICO

SOGLIE DI ALLERTA	TARGET KOSU 150	173 SUPERVISORE (-15%)	188 RESP. UAP (-25%)	203 RESP. SITO (-35%)

KOSU =

KOSU = Tot Kosu

rev1 del 01-08-2017

Figure 67: Laser KOSU on the 02/08/2017

The last one we checked was the new manufacturing time:

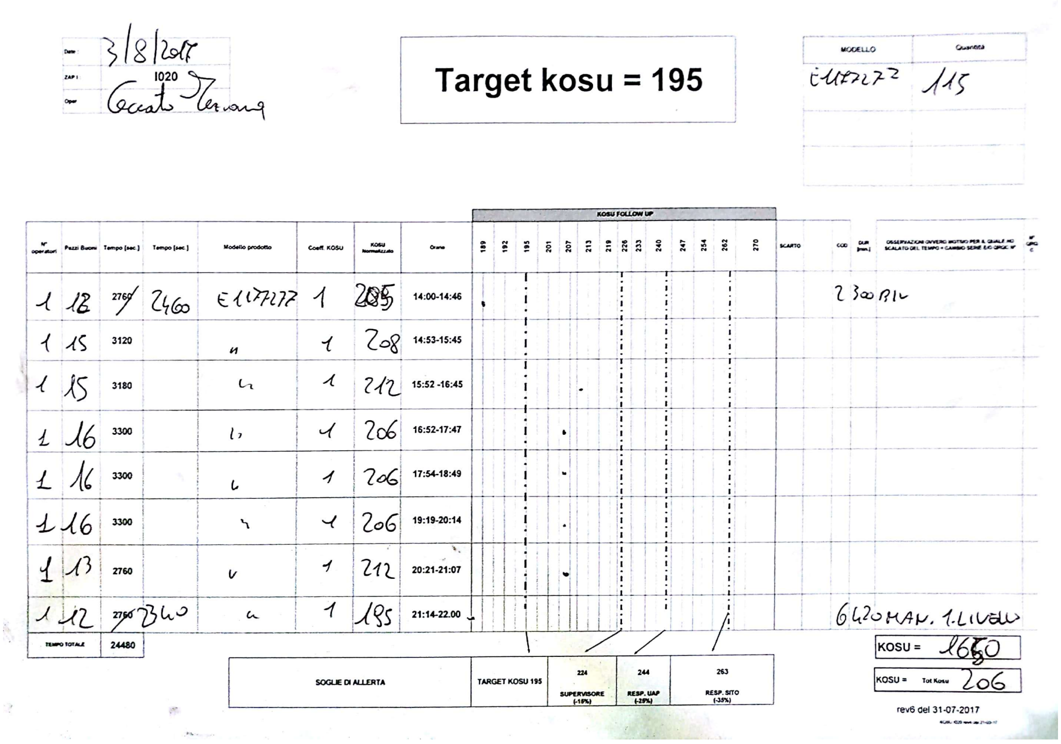


Figure 68: E1177277 KOSU on the 03/08/2017

The average KOSU is approximately 210s and we produce about 110 paddle shifts per shift.

Codice	Kosu Target	TC (SAP)	Giorno	Settimana	Mese	Prod	Working Time	Cambi	Breakdowns & Microstoppage	No Qual.	Pausa	Org. Malf.	Formazione	Planned Stop	Kosu Produzione	TRP
E1177277	435	585	01/09/2017	35	9	116	24 480	380			4 320			426	285	205,33%
E1177277	435	585	01/09/2017	35	9	269	24480	300			4 320			420	141	303,59%
E1177277	435	585	05/09/2017	36	9	73	22 680	380	600		4 320	300		426	381	138,62%
E1177277	435	585	08/09/2017	36	9	115	24 480	380			4 320			426	287	204,52%
E1177277	435	585	08/09/2017	36	9	99	24 480	380	1 620		4 320			426	240	175,07%
E1177277	435	585	11/09/2017	37	9	31	4860	300			420			426	197	213,09%
E1177277	435	585	12/09/2017	37	9	115	24 480	380			4 320			426	287	204,52%
E1177277	435	585	12/09/2017	37	9	83	20040	300			3900			420	233	178,11%
E1177277	435	585	13/09/2017	37	9	133	24480	300			4320			420	236	255,68%
E1177277	435	585	13/09/2017	37	9	88	24 480	380			4 320			5 730	230	192,27%
E1177277	435	585	14/09/2017	37	9	113	24 480	380			4 320			426	230	203,59%
E1177277	435	585	14/09/2017	37	9	113	24480	300			4 320			426	230	203,59%
E1177277	435	585	15/09/2017	37	9	63	18120	300			3480			420	290	142,58%
E1177277	435	585	15/09/2017	37	9	116	24480	300			4320			426	287	204,52%
E1177277	435	585	18/09/2017	38	9	115	24 480	380			4 320			426	287	204,52%
E1177277	435	585	19/09/2017	38	9	115	24 480	380			4 320			426	287	204,52%
E1177277	435	585	20/09/2017	38	9	34	18360	600	2 324		1 680			420	294	190,18%
E1177277	435	585	22/09/2017	38	9	101	24 480	380			4 320			4 026	280	205,72%
E1177277	435	585	22/09/2017	38	9	103	24 213	380			4 320			426	228	184,54%
E1177277	435	585	25/09/2017	39	9	115	24 480	380			4 320			426	287	204,52%
E1177277	435	585	25/09/2017	39	9	104	24 480	380	900		4 320			426	228	184,59%
E1177277	435	585	26/09/2017	39	9	17	4 448	680			420				226	175,19%
E1177277	435	585	26/09/2017	39	9	54	21300	300			3900			420	225	251,48%
E1177277	435	585	27/09/2017	39	9	88	21300	300	400		3900			420	234	173,24%
E1177277	435	585	27/09/2017	39	9	158	24 480	380			4 320	300		426	141	303,59%
E1177277	435	585	28/09/2017	39	9	102	24 480	380		900	4 320			426	233	181,40%
E1177277	435	585	28/09/2017	39	9	108	24480	300		435	4320			420	220	252,07%
E1177277	435	585	29/09/2017	39	9	109	24480	300			4320			420	258	259,85%
E1177277	435	585	29/09/2017	39	9	118	24 480	380			4 320			426	226	155,69%

TRP del codice:	199,57%
Kosu Reale:	209
KOSU per carico:	214
Ore lavorate	26

Figure 69: Master data of September

At the beginning of September I did another OST to see how we had improved.

St10	St20		St30			Imballo		Uscita tra pezzi
Ti	Tf-Ti	Tf	Ti	Tci	TCf	Ii	If	
0	0	95		114	137	201	216	216
114	114	201	216	237	260	330	344	128
237	237	330	344	368	390	491	509	165
368	368	491	509	531	563	671	685	176
531	531	671	685	709	733	844	860	175
709	709	844	860	885	907	1017	1031	171
885	885	1017	1031	1057	1081	1185	1200	169
1057	1057	1185	1200	1227	1249	1369	1382	182
1227	1227	1369	1382	1407	1429	1533	1547	165
1407	1407	1533	1547	1569	1592	1718	1733	186

OST =	128
KOSU =	198

With the time spent on every step:

st10	st20	st30 (Paddles)	st30(Check)	st30(Imballo)
	95	19	23	15
	87	21	23	14
	93	24	22	18
	123	22	32	14
	140	24	24	16
	135	25	22	14
	132	26	24	15
	128	27	22	13
	142	25	22	14
	126	22	23	15

During the first 3 trials I asked the operator to do things as quickly as possible in order to see which time could be the lowest one. Giving us an OST of 128 is too high a rhythm for an operator. An operator cannot work at this speed all day long. Without taking into account this result, we have an OST of 169s, with a KOSU of 198s.

The difference between the average KOSU and the OST is due to the fact that our lines are carried for almost half a shift and not a whole shift. 3 or 4 times during any shift we need to change the Maserati box (contains 32 paddle shifts). We are still doing the quality control of the paddles on the st30 because we still have faulty paddles arriving on the line. Recalling the first part, the improvement made are similar to the one done on the paddles. With an idea to internally outsource some process and the instauration of Kanban system customized in our own way.

Sottogruppo circuiti st20	
Produzione anno	36000
TC inizio cantiere (sec)	256
TC fine cantiere (sec)	206
Fatto al laser // laseratura palette (2 min dispo)	0
Tempo iniz. cantiere x pz. Anno	9202064,516
Tempo fine. cantiere x pz. Anno	7 416 000,00
Saving in sec.	1786064,516
Saving in ore	496,1290323
Saving MOD	€ 23 625,66
Saving MOI	€ 38 683,18
Saving in euro MOD + MOI	€ 62 308,85
Tempo a CA	505
Tempo CAA x pz. Anno	18 180 000,00
Saving in ore CAA	2990
Totale saving. In euro rispetto CAA MOD	€ 142 383,80
Totale saving. In euro rispetto CAA MOI	€ 233 130,30
Totale saving. In euro rispetto CAA MOD + MOI	**€ 375 514,10**
Totale saving. In euro rispetto inizio cantiere	**€ 62 308,85**

The last point is that following a meeting with my two superiors we decided to set the KOSU target at 195s. Choosing 195s means that the first alert on the KOSU is set at 225s which is the objective that we set before.

Modifica	Pz/turno	KOSU	Information	Data	Industrial Margin
1	54	456	Stato Initiale	16-juin	/
2	82	300	Bracci fatto dal fornitore	28-juin	€ 31 760,40
3	84	283	Modifica Lay out	03-juil	€ 21 350,30
5	93	256	Cambio Imballo Palette	11-juil	€ 33 909,30
6	115	206	Sottogruppo st20	03-août	€ 62 308,85
OST	147	168	One Single Time	01-sept	110 033,05

Ind. Margin	€ 149 328,85
Ind. Margin OST	€ 197 053,05

On the 15th of September, Maserati came to our plant and controlled the new manufacturing process of the paddle shift, and they agree to use it, which completed the project.

The future of manufacturing

Recalling the first part of the master thesis, the Lean Manufacturing is one of the current way used to do manufacturing improvements in the factories, with productivity optimization and industrial strategy. We will focus on the Lean movement, it is the consequence to the emergence of Toyota Production System of Ohno. The main reason that the movement is called Lean Manufacturing is it would have been a terribly bad marketing move to call the improvement tools from another name company. The 5 axes from Valéo described at the beginning of the second part is a continuous improvement tool. As shown in the second part a lot of tools used in Valéo come from the Lean Manufacturing and also the TPS. The strength of Valéo is that they were able to custom the movement to their environment and creates their own movement that is now worldwide famous and is an inspiration for other companies.

The 5-axes system works, as shown by Valéo expansion over the past years but a lot of improvement processes aren't working as well and we are going to try to find reasons why. In this part we are going to discuss first about Lean Manufacturing, then the success of a factory over its competitors and in a last stage we will examine the others ways of improvement and the Big Data emergence.

1- Lean Manufacturing

The Lean manufacturing field has created a lot of jobs in the past decades and most of the time in the developed countries. Indeed this movement appeared during period of recession. Toyota created the TPS following the end of the WWII, while the company was facing bankruptcy. Whereas the USA and the Western countries are aiming to lean theirs factories following the offshoring to emerging countries such as the BRICS (Brazil, Russia, India, China and South Africa) with a low-cost labour. Developed countries are trying to improve their attractiveness thanks to manufacturing cost reduction and by offering a better productivity and efficiency to counter the fact that the labour cost may be against them.

1-1. Cleaning and improving process

When the world discovered the TPS, it was a real evolution. Ohno used a lot of system coming from the USA and the WWII, the Fordism and the American supermarkets as a source of inspiration. The results for the Toyota Company was a record breaker.

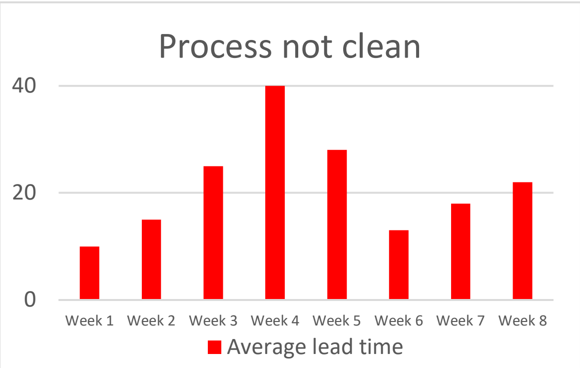
To do so Ohno leaned the flux by cleaning the process, eliminate defects and deviation throughput. Then he increased the speed of the manufacturing process by first of all diminishing the number or the time spent on non-value added operations.

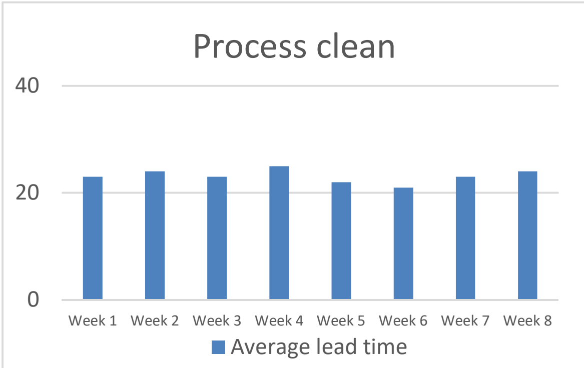
Seeing the renew of the company, competitors all over the world tried to use the TPS tool and implement it in their own company, without a lot of success at first. Such a thing can be explain by the fact that Ohno wrote in Japanese a book called "*Toyota Production System: Beyond Large-Scale Production*" explaining the whole improvement made, of which a lot of translations were made. However they weren't able to translate the Japanese image language with its authenticity so the description of the processes weren't as good as the Ohno wrote it in Japanese.

Nowadays, 40 years after the publication of his book, the processes are known and understood worldwide by most of the companies. A golden rule of Ohno is that improvement should be performed on the non-value added operation (NVA) to improve the flux of the product, which takes usually more or less 90% of a process. Action to improve NVA have been performed all along the improvement process described in the applied case, for example at the beginning we were looking for movements without VA which resulted in the lay-out modification.

So while the TPS is worldwide understood, its application is a bit different. In fact as Christophe Roser described it in *"Faster, Better, Cheaper" in the History of Manufacturing*, there is no other company in the world where the TPS/Lean Manufacturing brings such results than in Toyota.

We are going to anyhow describe what the benefit brought by the Lean Manufacturing is and why its actions may sometime limited. Before any analyse to be performed the flux has to be cleaned. We need to have a clean flow throughput with a low standard deviation on the lead time.





Indeed on the left bar chart, a productivity improvement shouldn't be performed because the average lead time is not regular. Thus an analysis performed on this dataset would mean to analyse high standard deviation throughput. Hence would not bring accurate results. First of all actions that would smooth the average lead time should be performed such as 6-

sigma, then when the lead time is regular with a low standard deviation, productivity improvement actions should take place.

At Valéo CDA we didn't have a high deviation problem so we were able to directly focus on productivity improvement process. A correlation could be made with quality issue about the paddles coming from the laser line. We diminished the deviation by increasing the trainings at the laser line. We increased also continuous improvement process: when a Not OK part is found at the I020, the information is sent back to the laser and a QRQC, as a Jidoka system, is performed to avoid the issue to happen again.

1-2. Negative connotation

Lean Manufacturing has for purpose to increase the attractiveness of a company but it may have a negative connotation for part of the workforce, indeed labour forces assimilate too often lean actions to suppression of jobs.

Toyota and Ohno created the TPS to save jobs and the Toyota brand. Remembering the first part we have seen that improvement actions even in Toyota have never been welcomed in factories. Also the scientific management of Taylor was called "the tyranny of the clock" and the Fordism was strongly criticized, even Chaplin made the famous *Modern Times to caricature it*. The difference is that while the Taylorism and the Fordism were criticized for the dehumanization of the work, the TPS/Lean Manufacturing is seen by the operators as a way for the companies to diminish the overall labour cost in the firm.

It is worth remembering that as Ohno described in its book all the actions performed were made to improve the fluxes because he didn't see the point on trying to diminish the labour cost, Ford acted in a same way by paying higher wages than others brands (and also because he was really hard on his employees asking for total commitment).

Ohno didn't wanted neither to negotiate more than necessary the cost of the raw materials. This come from the fact that he was looking for sustainable business partner. This is now part of the lean manufacturing process, the factories work together with the suppliers and with its clients to improve constantly the fluxes. So why the operators usually think that lean manufacturing means suppression of jobs?

This feeling comes from the fact that factories and managers themselves did not always understand well the purpose of the lean manufacturing and act in a way that lean manufacturing actions can be used to diminish the labour cost without changing the throughput of the factory. Doing so is a mistake and while the lean manufacturing actually should improve the involvement of every worker, claiming the self-improvement by the operators of the process.

It usually brings a situation like Taylor with the operators doing soldiering, operators trying by any means to show the management that improvement is not possible.

To sum up using lean manufacturing to diminish the number of operators and thus the labour cost could at best work once but would impede future improvements actions. So now the question is how to act in a way that the operators would want to be part of the improvement movement?

- First of all an explanation of the reason why the company needs this improvement process should be made. In the applied case described in the second part of the master thesis, when the team was created the purpose was directly set: we should be able to provide our clients with 100% of theirs demands and hence there would not be job cut
- Then we also informed that a new line would be added to the factory in the coming months corresponding to the beginning of the production of the Alpine A110 and then a new Ferrari model. Showing that the company is reliable.
- The last action which takes place to increase the involvement of the members of the team is the gratification. Once the project is done a picture is taken of the team and is shown with the results of the project (this photo was removed for the master thesis for privacy reasons). The project is then presented to the director committee and during the monthly meeting managed by the director, the team is congratulated.

It is worth remembering that Toyota during the period of low production still employed its workforce, permanent and non-permanent workers, and use these laps of low productivity to do trainings or to open new improvement processes. They show the sustainability of all the continuous improvement movement.

The involvement of the operators in regard to the lean manufacturing is what we may call an indirect drawback, because it is the use made of it that may have a negative connotation.

1-3. The limitation

Let's start again from the fact that the lean manufacturing is the movement following the creation of the TPS. Ohno worked during more than 20 years to bring a system as efficient as it is in Japan. All the principles created correspond to the environment in which they were working and even the others factories of Toyota as in the USA don't have the efficiency of the ones in Japan.

Companies using Lean Manufacturing are in fact trying to generalize a process that was extremely efficient because it was customized to the Japanese firm. Applying directly the Lean Manufacturing tools without thinking through would actually bring "buzzwords". And without real improvements, the progress would not last and that's one of the reason why some companies are more and more reluctant to invest in lean manufacturing. Companies see in the Lean an idyllic world and may perform foolish actions to have a system that would look leaner. It is an example from the book *"Faster, Better, Cheaper" in the History of Manufacturing*, the one of a company to perform the zero stock and the Just in Times at its best bought a store where the suppliers would bring the raw materials and when it will be needed in the factory it will be supplied from the store. So the results seems to be as lean as possible with no stock until it is needed but the company didn't diminish its lot sizes so they still have the same amount of opportunity cost and even more because they actually need to rent another store now.

Even Ohno in his book describes the system as an ideal one, no stock is not possible and diminish the lot size to one product is also a flux that could bring other losses and would not be the best one. Ohno wanted to diminish the lot size to be the more flexible hence he moved against the emergence of all the MRP (Material Requirement Planning) software which would try to find the best economic lot size. He wanted to achieve first of all flexibility.

Every environment is different and to force the use of lean manufacturing when it doesn't fit the environment is counterproductive. Obviously analysis of the environment to improve efficiently the fluxes take a lot of time, for Ohno it lasted 20 years at least. The process is maybe slow but a total understanding of the environment is needed and when understood, really effective.

Several process coming from the Lean Manufactory has shown their efficiency such as the Kanban and the 5S in all environments without a lot of analyse of the environment, but in some case a better understanding would bring even more results.

To sum up every factory has nowadays usually its own department lean manufacturing. Or have continuous improvements missions related to one or several departments as production in Valéo CDA, quality or supply chain, according to the subject of the improvement. There are few companies that provide their own customize system of lean manufacturing and Valéo is one of them with the 5 axes. Talking about the 5 axes, an audit is done every one or two years depending on the state of the factory. The purpose of these audits is to help the factory to constantly improve itself and a big part is about questioning the fluxes and always improve them.

Lean Manufacturing take time and bring results, but it is not just tools it is first of all a spirit that the entire company should have.

2- Success of a factory

In *The Goal*, Goldratt, the originator of Optimized Production technique, gives the obvious definition of the success of a factory: making money. To achieve this a factory needs productiveness and effectiveness. He also provides a definition to describe a factory that would perfectly work and his definition comes from the first factories at the beginning of the nineteenth century. Where in a single factory one could find several tasks performed when in the past there were several artisans in their own building. These first factories were functioning with the best "efficiency" because the same quantity of resource were consecrated to every task. Doing so if one quantity was superior to another, the surplus wasn't used and work in progress product could not be created.

But first of all the real difference was about the demand. At that time the demand was fixed and way more stable that it is nowadays, with a really little variety of product and each machine was usually made to manufacture one specific product. Then a lot of stocks could be made at that time, due to the little variation of product there was only a small risk of obsolescence. Now on the market the kind of demand constantly change and so does the number of products demanded. The "perfect" equilibrium of the first factories doesn't exist anymore but thanks to continuous improvement, factories are still running after it or a so called pseudo-equilibrium where the production is adapted to search an equilibrium.

This equilibrium is hard to find and there are many reasons why, we have already seen that variety of the demand is one of them and we are going to discuss about the bottlenecks, then thanks to an interview with Lucio Milione, Supervisor at Valéo CDA Santena, we would discuss about how factories are trying to reach this equilibrium. Then we will talk about stability and flexibility helping the achievement of equilibrium/quasi-equilibrium.

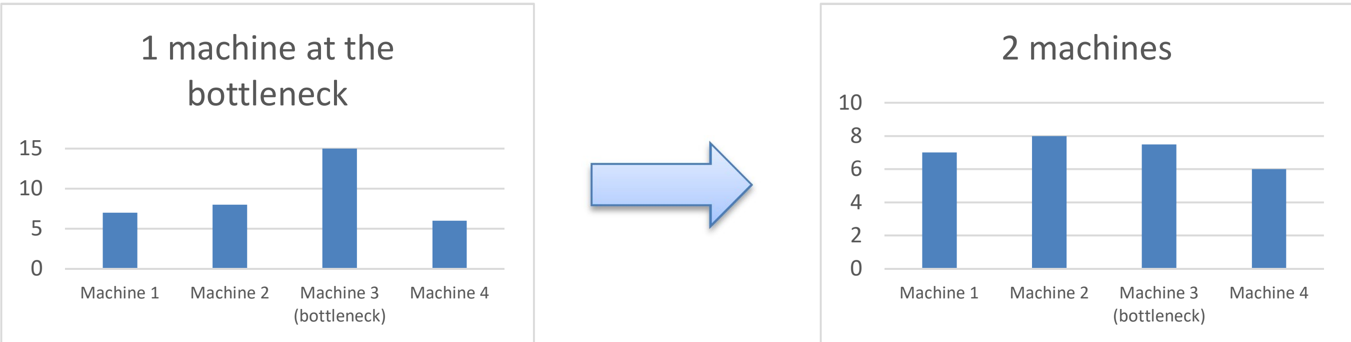
2-1. Where is the bottleneck?

Goldratt give the following definition of a bottleneck: it is "any resources whose capacity is equal to or less than the demand placed upon it". In a lot of continuous improvement project, the goal is to find this bottleneck. Once find several changes can be done depending on what is looking the firm.

The Goal provides the following example to explain the value of the bottleneck: In the middle of a manufacturing process, there is one workstation that is slower than the rest. Then because we can't go faster than the slowest machine, the entire production is limited through it speed. That machine may be functioning without problem and an efficiency of 100% providing even a low cost per unity. But the effect of this bottleneck over the overall efficiency is that other machines of the process are "waiting" and thus a loss over the overall efficiency.

To improve the productivity of this process, one may think to add another machine that would double the productivity at the bottleneck, but also increase the cost per unit. It would multiply by two the productivity of the bottleneck and thus of the overall process. Such improvement usually gives rise to a diminution of the local efficiency at the bottleneck. In fact it is from such reasoning that Ford and Ohno also implemented the idea to forget about the common thinking of local efficiency of each part of the process to actually look for the overall process efficiency improvement.

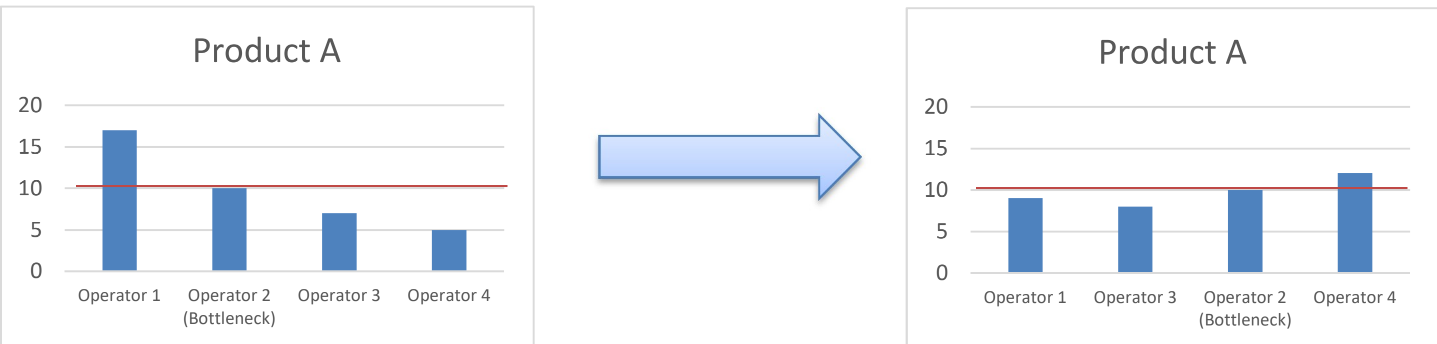
"*An hour lost at a bottleneck is an hour lost for the entire system*" - Goldratt



Such improvement, in our example, could at best double the production. In the example we move from one product every 15s to one product every 8s.

Another frequent improvement about the bottleneck in a process involving several operators is in the same way of the gold age described above: attach the same amount of work to every operator equal to the bottleneck:

(This is a fictive example with several hypothesis as the task performed by the operator 1 can be divided in two equal tasks and no modification can be done on the bottleneck "Operator 2")



The improvement done here is to equally manage the load of work between the workers. In a way like the one extol by Goldratt. Also one could see that the lead time has been improved from a piece product every 17 seconds to every 12 seconds. The improvements described above are for an obvious bottleneck that can be improved or can't modified, but as Goldratt described in *The Goal*, bottlenecks are not always so easy to find and even worse nowadays factories face flying bottleneck.

Indeed the factories are subjects to the demand, and the latter is nowadays not always regular and can have its own rhythm. A flying bottleneck is a bottleneck that appears due to a change in the usual manufacturing routine and usually an increased in the demand. To avoid them the MRP software are usually famous, with the limitation that it makes all the calculus for the information given to the data base, in fact MRP software tried to smooth as possible to avoid the apparition of bottlenecks. Problems have been that the software manages an ideal system but factory actually needs a supervisor to manage the real system, providing solutions to daily basis issues.

2-2. Interview with Lucio Milione

Lucio Milione was my company tutor and supervisor of the Valéo CDA Santena factory and also an ex-WCM (World Class Manufacturing).

On a weekly basis the logistic team sends the result of the Master Production Schedule analysis for the following week and thanks to it L.Milione plans the real plan of production using his knowledges of the products, of the lines, of the workforce available and their own capacity (the previously called real system). All those information make that the plan production made by the software is usually adjusted. In fact as said Lucio issue usually come from the line that are loaded at their maximum, where we are looking for a perfect local efficiency on the line and where any delay on the line would have direct consequences on the throughput and the adherence. It is equivalent at what Goldratt wrote that too often some lines of production or machines are overloaded which creates a big productivity risk if any issue should occurred.

Moreover Lucio is constantly in contact with the Logistic team and particularly the Customer Service members and the Supply Chain Scheduler, to have constantly news about our suppliers and prevent any missing components and also manage any change in the client demand. As we already said before the demand from the client can vary and nowadays a supplier as Valéo should be able to answer these variations of demands to keep its clients happy and stay competitive.

Also production can be affected by quality issues at the client factory. Lucio faced once this problem during my thesis internship and had to find a way that it would not stop the production line of the client and hence avoid to pay for it. Do the production plan had to be modified.

Talking about the Quality, Lucio has to be also in permanent contact with the quality team enhancing to avoid any problem such as the one described above. In fact as Lucio told me, his problem should be about the throughput, in Valéo also managing maintenance issues, while Quality should guaranty that all parts made are good parts. Unfortunately when quality issues are found, his help is also needed and thus also affect even more the wellbeing of the production.

We talked also about the effect of the improvement site over the operators and their reaction, as already discuss in the 1.2 part. Lucio among others things noticed me of the direct improvement of the I020 line when the team was formed and the purpose of this site explained to them. The explanation of this improvement is that people appreciate the changes when they truly understand how it could improve their situation but also that their opinion would be taken into account. Actually it is a remark also made by Ohno in *Toyota Production System*, the involvement of the operators (and the team in a more common way) is a master piece of the success of an improvement site.

On a more global discussion and thanks to his past as WCM, Lucio was able to discuss a courant issue found in the literature about improvement process: firm usually sees it as a magic wand that would enable the factory to reach a golden stage with a total efficiency and would mean an increasing margin, it is not necessarily the case. Recalling that Ohno implementation in Toyota was the result of a study which lasted for 20 years. The overall is that in every action made in the 1960s, when Toyota made its comeback, was thought. From the order at the supplier to the delivery to the client. Worth remembering that TPM (Total Productive Management) which is one of the tool of lean manufacturing that actually work for every firm that implemented it, needs more or less five years to be effective.

We can find here a reason why in *Standing on the Shoulders of Giants*, Goldratt wrote that in Japan less than 20% of the factories implemented it. It is not about the fact that they do not believe in this improvement but more about the fact that they understood that Ohno created this system not in an abstract way but according to its environment and thus implementation of Lean Manufacturing must precede of an environment study.

2-3. Stability and Flexibility

The stability is as we have seen before a must in any improvement process, in *The Goal* three kind of instability that can affect a firm are described: the first one is about the period of life of a product, the second is about the demand over time and the third is about the global load.

If the life of a product is small, there is a huge risk of obsolescence and thus a monetary loss coming from a too big amount of work in progress. Having product with a small life cycle should also mean to have quick response on the production field. Taking the example of a product with a life of six months, if the factory needs two months there will be losses not because there is not demand but because the reaction of the factory was too slow. This kind of instability can usually be found in automotive industry on the model year car of each brand. The solution should be flexibility. It means that to diminish the number of component of the factory by trying to use as often as possible same parts for different model. In fact Ford was the first to implement this system, Ohno improved it by adapting it to a larger range of application.

The second instability is about sporadic demand. A factory that is subject to high variation of the demand for a wide range of products over time usually tried to solve this problem by increasing its stocks of finished products and by answering demand thanks to the stocks. The issue is the following one this situation usually brings a lot of work in progress, risk of obsolescence over time and a high opportunity cost. Studies about the flux would actually increase a lot the efficiency and the margin of factories undergoing this kind of instability.

The third instability found in factories is regarding to the client deliveries, factory undergoes variation on the demand that leads to delay on delivery. The answer usually provides to this issue is an increase in the supply capacity but also of the workforce. It is said in *Standing on the Shoulders of Giants* that experiments have shown that once factories with this instability succeed to improve theirs fluxes, they then succeed to deliver 90 to 100% of the demand client with a reduction until 50% of capacity.

The latter is the one that seems to take place in Valéo CDA on the I020 and is coherent with the result that we have. We have seen that continuous improvement is too often only assimilated to buzzword that would seem to bring results but without improvements momentums and real studies over the environment in which the improvement takes place, it would lead to its own degradation over time, until the situation turned to be the same as before.

However over the manufacturing history we have seen emergence of new systems that revolutionize their own period, so how did they do to improve their efficiency?

Taylor, Ford and Ohno improve the efficiency of theirs factories by analysing the flux:

- Taylor brought the Taylorism and the Scientific Management, which was one of the first analysis of the flux and the study of the lot sizes, the rhythm of work… The results were the ones shown in the first part and the increase by four times the load carried by the worker in one day.
- Ford brought the Fordism and the assembly line. He improved his factories to what were the pinnacles at this period and the beginning of mass production. The result was the success of the famous Model T and moreover the fact that his model became for years the way to manufacture worldwide.
- Ohno brought the TPS which brings Toyota to a new top of efficiency and of production without losses. The result was that between 2003 and 2005, Toyota recorded a net profit 70% than the average of factories. By the way, at the same moment GM was losing money.

They all have in common that the focus was made on the fluxes and not on the fixed costs that are the cost of the workforce and raw materials. Smoothing the fluxes has for result a lower unit cost.

To do so, several principles that seems to act against the common thinking were created such as the suppression of the local efficiency. Ohno and Ford creates systems allowing the regulation of the production. Ford used assembly line that would describe the flux but moreover would allow a quick observation of any problem. If the process is stopped due to any problem, the fact that the assembly line is mostly shaped as a straight line. When an issue occurred the supervisor was able to see the problem as soon it happened and may manage a way to limit the impact and not have accumulation of work in progress before the workstation that is stopped.

Figure 70: Model T assembly line

While Ohno let only available on the factory space for a limited amount of product thanks to the Kanban. In fact Kanban is usually seen as the impulsion to start the production but it is by consequence also the element showing that production should not be performed. Toyota started to diminish the space available and the lot size of the Kanban, they weren't trying to find an economic size but what would be the minimum to increase as its most the flexibility.

Figure 71: Assembly line at Toyota warehouse

Those examples are given in the automotive world because it is the pioneer field. Valéo is also part of the automotive industry but we have to recall as explained before that improvement is more about the environment. An obvious observation is that Ford was able to manufacture a car from iron to client in 81 hours of work while at Valéo CDA Santena, we need less than 3 minutes to manufacture our product. That's why work should be performed on fluxes rather than applying a copy of what is done in other environments where it is working.

It should not be forgotten that the Toyota Supplier Support Centre, TSSC, spent at least six to nine months on a single line to each improvement site of production line. Again in comparison, the site described in part 2 took more or less 2-3 months of real studies then a period to control and correct issues. The difference is that we doing a comparison between a car production line and a paddle shift production line, showing again that the environment should be taken into account.

2-4. Shorten the Value Chain

ZARA, the fast fashion retailer, called by the New York Times *"mind-spinningly supersonic"* is a good example of another way to answer the manufacturing issues in the developed world. Of course ZARA have a part of its factories in emerging countries and countries with low labour cost but moreover are able to conserve massive factories in Western Europe by improving its supply chain, and so the fluxes.

- First ZARA improves its flux from design to catwalk in a way that they are able to do it in two weeks while the average time on the market is about 66 days (more than two months). One could noticed that it may correspond to the first kind of instability described previously. Thanks to this, ZARA, is more flexible as ever and manage to follow more accurately than any other brand the fashion trends.
- Then, ZARA relies heavily on factories near its headquarters in Spain. The wages of these European workers are higher than those in developing countries but ZARA benefits from a miraculous turnaround and an easy and fast supply time to the shops in Western Europe.

The results of the ZARA's way is getting 85% of the full price on its clothes against an industry average between 60 and 70%. Also unsold items weights less than 10% of the stock while the average industry is about 17 to 20%. About the goods ZARA is able to deliver them to every European store within 24 hours and 40 hours for American and Asian ones.

Improving to excellence its Supply Chain is also what have done Amazon but it is not the only answer, another promising one is the smart factories (described in the next part).

3- The future of manufacturing

During the past decades we have seen factories relocated to emerging countries or at least countries where the workforce had a lower cost. Firms were looking for reducing the fixed costs whether acting on the fluxes. The difference of cost was stunning at this period and manufactory sourcing strategy showed the benefits to offshore to these countries. But nowadays that these countries are becoming richer and richer, the labour cost is constantly increasing and would reach the one of developed countries and due to the delivery cost, developed countries will not see any more emerging countries as attractive countries. So what is going to happen? How factories are going to sustain? Are firms going to still looking to diminish the fixed cost or going to work more on smoothing the fluxes?

3-1. Industry 4.0

It is at Hanover in Germany, in 2011, that we heard for the first time about the fourth industrial revolution. And it is between 2013 and 2015 that studies started to be presented. It is characterized by the increasing digitalization and interconnection in the world. As most revolution it appeared first in the automotive sector. Several consulting firms think that it will have transform the manufacturing sector by 2025.

The steam engine powered factories during the first revolution, then electricity led to mass production, following the WWI automation took place for what is called the third industrial revolution. During the last 40 to 70 years the advancement made are only considered as incremental. But the period that we are living in is a critical one for the industry. It is said that factories that will not be able to enter in the industry 4.0 within 5 to 10 years will lose big from it.

The industrial internet, other name used to describe the industry 4.0, promotes the transformation of processes. This revolution has not only an impact on the manufacturing techniques and its implementation but overall the business and also over the portfolios of products manufactured.

Thanks to this new system, manufacturing will be transformed from a single automated cell to a full integrated. Automated manufactory that will be able to communicate with others increasing flexibility, speed, productivity and quality.

Studies show that the companies that are now implementing the industry 4.0 in their manufactory are expecting a higher productivity of at least 18% over the five next year (number coming from PowerWaterHouse's study over German industry), while BCG (The Boston

Consulting group) declared that, in the coming years, production systems would be 30% faster and 25% more efficient.

The fourth industrial revolution plays an important role in making long-term manufacturing efficiency possible, it will increased production, energy and resource efficiency. The main improvements that may results from the digitization are to try to focus on core areas in the individual value chain. The reduction of redundancies in processes, minimising quality losses and to be able to make processes more flexible. In others words a gain in transparency will improve the factory, for example optimizing the lot size. Then the increase connectivity between the different sectors will lead to a better rationality and a gain in productivity, and the use of data will diminish the rejection rate in production.

3-2. Nine Pillars of Technological Advancement

Industry 4.0 is made of nine advances in technology, many of them are already pillars of the manufacturing that followed the automation system and moreover the TPS/Lean Manufacturing. Let's introduce the nine pillars that form this revolution:

Big Data and Analytics

Big data refers to the use of huge quantities of data coming from different providers. Some of the data will be relevant whereas others won't. Theirs analyses will help and become standard tool to support real-time decision making for every matter of the manufactory (Quality, Supply Chain, save energy…).

Autonomous Robots

Robots are already used in many sectors of the industry, generally in the zone that are too hazardous for human being or complex assignments. Industry 4.0 will have a greater utility, they will interact with one another and work safely side by the side with humans.

Simulation

As autonomous robots, simulation is already a common thing for engineering and prototyping, thanks to CAO software for example. But it will be extend to 3-D simulation. A lot of applications could be imagined such as to predict the first piece setting after a changeover. Doing so it would delete the waste of materials, of time and increase the efficiency and productivity.

Horizontal and vertical system integration

This is often considered as a real problem of nowadays manufactories, the different departments of the companies are not linked as they should be. Thus there is a waste of time and a loss of information in the company (fluxes). It is usually even worse with the suppliers and the providers. In the future this lack of integration will be solved, companies, departments, functions and capabilities will become much more cohesive and will lead to a truly automated value chain.

The industrial internet of things

This is an upgrade of sensors and machines that are usually connect in a vertical automation pyramid. It means that sensors and field devices are built with a limited intelligence and it is the automation controllers that feed the overall manufacturing process. With the internet of things, there will be more device that will enrich the embedded computing system which will be able to interact together. Doing so it decentralizes decision making point, enabling real-time responses of the system.

Cybersecurity

When the manufactories will be made of management and production systems that are connected between each other. These connections will reveal a risk about the security of these systems, in fact some people with bad intentions could enter in the system and may be able to modify as they want the system. It would be also possible that to be done by an employee by mistake and it can have the same consequences.

Nowadays manufactories are using cobots, robots which work alongside human, if someone would be able to modify theirs parameters that could be a disaster.

The cloud

The cloud is already part of the companies and the manufactories. To use cloud-based software and analytics applications, the improvement will be that the data shared will be increased inside and outside the company boundaries. The cloud is able to achieve a reaction time of just several milliseconds, enabling more data-driven services for production systems.

Additive manufacturing

3-D printing is the most famous additive manufacturing systems used nowadays, most of the time only for prototyping. It is a great benefit to be able to print a prototype and to be able to perform several tests that needed way more time in the previous prototyping systems. But nowadays additive manufacturing is going always further, and more and more materials can be used.

A company that would be able to supply all its components thanks to additive manufacturing would mean almost zero inventories, reduce transport distance…

Augmented reality

The last pillar is augmented-reality-based systems that will support a wide quantity of services, the selection of parts, and the send of repair instruction to mobile devices, to provide workers with real-time information to improve decision making and work procedures and virtual training.

3-3. Smart factories

Smart factories seems to be the future of the manufacturing and is seen as a good news for Western Europe factories and firms. They are made of the emergence of the Big Data.

All the elements described previously would lead to smoother fluxes, in the case of a supplier issue such as the one raised in the previous section. The supervisor would not need to be in constant contact with the Supply Service, who are in constant contact with the suppliers, the horizontal and vertical system integration would foresee this kind of issue and thanks to the human order try to avoid it. Actually it would be an improvement of MRP system that should be able to already perform it but the smart factory would go further thanks to data analyse of its own factory but also from the data coming from the supplier factory. The human contact role between the factory and the supplier would be deleted or at least the load of work would be diminished. And in the case of a missing part, the simulation system and the data science would be able to give an accurate approximation of the delivery time of the missing part. Having the good information would thus able the company to make the decision to stop the line until the part is supplied or rather manufacture another product. All of this thanks to calculus that would be performed by the cloud computing system instantaneously, diminishing losses due to uncertainty.

Actually this is one of the reason why it is called a smart factory because it is able to take a decision according to its environment and the data instantaneously received. It would perform the job of the Supervisor but would not need the experience on the factory to “feel” the processes and would be able to take a decision which would not take into account guessing.

Thanks to the data science, the smart factory would be able to identify pattern leading to issues. During my thesis application at Valéo CDA, we lost between 30 minutes and 1 hour of production during one day of the summer. Due to the increasing temperature in the factory control system on most of our production line started to declare way more than usually not ok part. Maintenance team when they heard about it, noticed that it may be because of the temperature rising in the factory, actually they were giving this information because in the other factory around Turin, this issue happened some years ago. We had to cool down the workstation and find a way to keep them cool and it started working as usual. Thanks to the smart factory and captors, we would been able to have the information of the temperature rising and that we may go over the working range temperature of hardware and thus provide a solution even before the issue occurs. One may noticed that it would be as the TPM of lean manufacturing in a more generalist way and of course thanks to study of the system used and the degradation of hardware and parts the TPM would be more accurate than the one currently performed in the factories.

Data would be provided constantly in a huge amount to the system and would able studies such as lean manufacturing or industrialization more accurate than before. The efficiency would computed directly with data received from the line of production. We began to implement this kind of system in one of the line at Valéo CDA. The system is computing by itself the takt time, the average lead time and the different losses. The information given by the operators thanks to the KOSU would be provided directly by the computer and would be objective value. I noticed this issue during the first site improvement, when I checked the process and timed every operation, I noticed that the operator wasn't writing every loss because it could not be possible, they would spend all of their time writing down that the printer stamped with a delay or not in way that would not allow the process to continue. The system implemented on the new line would be able to calculus the time lost for other actions and we may ask the operator what didn't go well.

Also new manufacturing are taking place as additive manufacturing which already exists for plastic for a while but is now created for other materials such as metals. Improving the prototype process and also would lead to an even better scale customization.

The experiences that would provide the industry 4.0 are not covered in this document, only examples that suit the previous descriptions have been made to show what would be the impact over the factories efficiency.

3-4. The possible results of the industry 4.0

As the previous industrial revolution it would be primary for firms to not miss this evolution and not to take up late this movement because the efficiency improvement and the benefit that it would provide the company that does adapt to this system will be consequent. According to a study made by the Boston Consulting Group (BCG), "connectivity and interaction among parts, machines and humans will make production system as much as 30 percent faster and 25 percent more efficient and elevate mass customization to new levels" (Industry 4.0, *The Future of Productivity and Growth in Manufacturing Industries*, p.4). Thus providing an important benefit to the ones that do enter in the industry 4.0.

From the previous part, one may say that it would diminish the number of jobs. We have seen how cloud computing would allow to make decision without a supervisor, how the job of the supply team would be eased and would seem to request less employees or even the increase from 8 to 25% the number of automated actions performed by advanced robots in factories now until 2025.

As every manufacturing revolution the condition of the population does actually evolved but it is worth noticed that automated actions usually are the ones that are made of hazardous operations or repetitive ones. Operations that provide added value would still be performed by operators while the robots would work along on the non-value added operations that have anyway need to be done. Then this revolution would bring an increase in the skills of the workers. New trainings should take place for every level in the industry.

The increase of flexibility about scale customization would actually push factories to have the best fluxes being close to its suppliers but also its clients, shortening the chain value. From this we can easily imagine factories coming back to developed countries. Western Europe is still one of the biggest market and so does the United States of America. The reshoring will also mostly depend on the kind of industries. It is first of all high end product that will come back to the developed countries while low end product from American brand with a market mostly in Asia would stay in China rather than going back to America for example. Some low cost products may be manufactured by new low cost countries such as Vietnam or Mexico, it has already begun but no country in the world would have enough workforce to totally replace China.

To encourage the reshoring to Europe, governments are massively using generous financial incentives. Our economy is moving from complex value chains to a shorter value chain that would bring production jobs to be located in the same area than the market, mostly thanks to new technologies.

Increasing jobs and demands in these countries leading to a new area of GDP growth. This would have been provided thanks to the improvement over the flexibility and efficiency of the factories. Anyway the workforce that will be looked for in Europe would not be the same as the one century ago, it would be workforce with high skills. Jobs that “left” our developed countries decades ago would for most of them not come back because due to the improvements of technologies that we have seen all along this master thesis, this jobs do not exist anymore.

Conclusion

Manufacturing has always shown the state of development of every civilization and the one who succeed to evolve faster than the others have always made huge benefits from it. The last evolution on the manufacturing field was the Toyota Production System that has been adapted worldwide under the name of Lean Manufacturing, mostly without the success expecting but had brought stability and flexibility to factories. At the end of the day Ohno has done the same as Taylor, Ford at their own period. Analyses the environment and leans the fluxes to increase their flexibility and aptitude to answer an always faster moving market. Leading to a better productivity and efficiency.

To increase the margin of an industrial company, we have seen that a company may have three major possibilities: act on its industrial strategy by offshoring, looking for a lower labour cost. Such strategy corresponds actually to savings money and delay the issue, not bringing a real solution. Another would be to act on the productivity optimization. In coming years, thanks to the Industry 4.0, such optimization will highly increase. The last one is to act on the manufacturing process and it is the one that has been performed during the applied case of this master thesis, with the Maserati paddle shift. We diminish the lead time, increase the efficiency and bring stability to throughput thanks mostly to Lean Manufacturing tools and reengineering.

Recalling the words of Jon Womack, “another Toyota” is not possible and the improvements that we have done in Valéo CDA Santena are not as good as were the ones implemented by Ohno. To improve its efficiency, factories should nowadays focus mostly on the big data era. It would have as effect to bring manufacturing at a new level which may come back to developed countries. High-cost countries have to take advantage of the new technological opportunities that is currently reshaping the usual value chains. Governments, companies and sectors have a big role to play in this new era of the globalisation that may shaped the future of the world.

In February 2018, Elon Musk, co-founder, CEO and product architect of Tesla Inc. said that his company would soon be able to be more efficient than Toyota and produce over 1 million of car every year in its American factory, thanks to digitalization thus the Big Data.

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Appendix Summary

Appendix 1: Action Plan Follow Up

ZAP	ACTION PLAN FOLLOW UP					LINEA:	I020	
Data	**N°**	**Problema/Necessità**	**Causa**	**Contomisura/Solution**	**Pilota**	**Data Prevista**	**Data Realizzata**	**A P C D**
19/06	1	Riorganizzazione della st10 dopo l'arrivo dei sottogruppi	Arrivo dei sottogruppi. Meno componenti	Trovare un posto per i sottogruppi. Modificare l'ordine.	M. Fieurgant	29/06	28/06	
//	2	Zoning delle viti	/	Zoning da fare	M. Fieurgant	29/06	23/06	
//	3	Lavoro in linea "I"	/	Provare nuovo layout L o L (45°);	M. Fieurgant	29/06	26/06	
//	4	Zoning Armadio (palette) Definire Posti per palette	/	Zoning Armadio (palette) Armadio con roller (JOB)	A. Techeira	29/06	26/06	
//	5	Posizione dei avvitatori	Non è corredo. Tornano al posto iniziale quando le lasciano.	Fare in modo che non muovie quando lo lasciano	G. Pasquino	13/07	14/07	
//	6	"INGOMBRO st30"	Manca spazio per le buste plast. delle palette.	Definizione d'un posto "buste plast. palette"	M. Fieurgant	13/07	14/07	
//	7	Tempo carico sulla st30	Non spazio per mettere le palette di un turno	Sistema di passaggio componenti per 1 turno	A. TECHEIRA	3/07	3/07	
//	8	Dimensione delle odette	Manca spazio, difficile da manipolare.	Provare odette piccole e medie. (Roller)	M. Fieurgant	21/07	11/07	
//	9	Senza identificazione per le palette.	/	Fare identificazione (label) per le palette.	M. Fieurgant	3/07	30/06	
//	10	Manca zoning pezzi st10 → st20	/	La [illegible] in 1 pc contiene 2 p. [illegible] nella 20	(1 pezzo) M. Fieurgant	3/07	30/06	
//	11	Avvicinare e piegare componenti st10	/	Avvicinare e piegare componenti st10 (+ altre?)	A. Techeira.	29/06	26/06	
//	12	(Avvitatore automatico) tempo di avvitatura lungo. ERGONOMIA	/	Avvitatore automatico	L. Milrone.	ottobre	14/07	

P plan: descrivere il problema, le cause (5 perché), la soluzione

D: Da realizzare

A act: Assicurarsi che sia una soluzione stabile e generalizzata

C Check: Verificare il risultato

ZAP		ACTION PLAN FOLLOW UP				LINEA: I020		
Data	**N°**	**Problema/Necessità**	**Causa**	**Contomisura/Solution**	**Pilota**	**Data Prevista**	**Data Realizzata**	A P C D
27/06	13	Tempo carico/scarico odette finito	No spazio per tutti i ~~ecc~~ componenti ~~di~~ un torno	Aggiungere spazio sulle st10/20	G. Pasquino	3/07	29/06	
"	14	Tempo scarico odette vuota (rack)	Non c'è un posto per buttare odette vuote	Aggiungere un posto (Layout + Posto)	M. Freregat	19/07		
"	15	Imballo circuiti st 20	5 circuiti attaccati con nastro (15 s)	Cambiare l'imballo.	M. Freregant	Settembre	14/07	
"	16	Cambio odette finito	Il cambio non è "Lean" (30 s)	Modificare il layout	M. Freregat	9/07		
"	17	Etichette non si legge bene	lettura Barcode (Macchina)	Cambiare le macchine se c'è un guadagno	L. Milione.	Gennaio 2018		
	18	~~Roller per~~ carico st20 delle prese	Pesante i carico tutte i 5/10 pezzi	Roller che si porta dal rack alla st 20 con pezzi per linea	M. Freregat	9/07	11/07	
6/07	19	Odette vite vuote bisogna chiamare logistica	~~Per carico~~ Non c'è il prodotto (vite/molle) su i racks della linea	Posto per mettere il cambio con odette già pronte	M. Freregat	9/07		
"	20	St10 pesa troppo	Tempo di lavorazione lungo e non rentabile	Fare i bracci dal fornitore	L. Milione	11/07	11/07	
"	21	Imballo Palette	Perdita di tempo	Cambiarlo	~~G. Pasquino~~ M. Freregant	10/07	11/07	
11/07	22	Tempo lavoro st20	Molto alto comparante alla 30	Sottogruppo delle prese + circuito	M. Freregant	21/07	12/07	
	23							

Appendix 2: KOSU I020 after modification

Valeo
Interior Controls

CONTROLLO PRODUZIONE

MODELLO		O.S.T. [sec.]	FATTORE MOLTIPLICATIVO	TC / SAP	Pezzi/H	KOSU
CAMBIO A VOLANTE M161-CAMBIO VOLANTE CARBONIO M156MY	E1177277-E1178171	186	1,00		16	206

COD.	DELLE FERMATE	T F
1	Cambio serie incluso BIL o BLC	750"
2	Cambio tipo incluso BIL o BLC (es. cambio colore)	300"
3	Mancanza materiale	da specificare
4	Guasto	da specificare
5	Mancanza operatore	da specificare
6	Manutenzione 1° Livello a fine turno	300"
7	Altro : precisare	da specificare
8	QRQC (x Operatore)	300"

Note: I tempi per "cause delle fermate" non vanno scalati nel calcolo del kosu, ma sono solo il giustificativo da inserire nel campo "Osservazioni" -
Tranne per " CAMBIO SERIE , BIL e BLC" e manutenzione 1° Livello

Il KOSU

1 - Definizioni

Tempo necessario alla linea per produrre unpezzo buono

2 - Formula di calcolo :

$$\text{KOSU Normalizzato} = \frac{\text{Numero operatori} \times \text{Tempo (Secondi lavorati)}}{\text{Numero pezzi buoni}} \times \text{fattore moltiplicativo}$$

$$\text{KOSU Cambio Tipo} = \frac{\text{(Numero operatori} \times \text{Tempo Secondi lavorati) - Secondi Cambio Serie}}{\text{Numero pezzi buoni}} \times \text{Fattore moltiplicativo}$$

I020

Target kosu = 206

Date :	
ZAP I :	I020
Oper	

Target kosu = 206

MODELLO	Quantità

N° operatori	Pezzi Buoni	Tempo [sec.]	Tempo [sec.]	Modello prodotto	Coeff. KOSU	KOSU Normalizzato	Orario	KOSU FOLLOW UP 200	203	206	212	219	225	232	239	246	253	261	269	277	285	SCARTO		COD	DUR [min.]	OSSERVAZIONI OVVERO MOTIVO PER IL QUALE HO SCALATO DEL TEMPO = CAMBIO SERIE E/O QRQC N°	N° QRQC
		3180					6:00 - 6:53																				
		3180					7:00 - 7:53																				
		3300					8:00 - 8:55																				
		3300					9:02 - 9:57																				
		3240					10:04 - 10:58																				
		3000					11:05 - 11:55																				
		2700					12:25 -13:10																				
		2580					13:17-14.00																				
TEMPO TOTALE		24480																									

SOGLIE DI ALLERTA	TARGET KOSU 206	237 SUPERVISORE (-15%)	258 RESP. UAP (-25%)	278 RESP. SITO (-35%)

KOSU =

KOSU = Tot Kosu

rev6 del 31-07-2017