Professional MBA
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Becoming Lean: theory, practice and tools. The implementation of the Lean philosophy and Six Sigma across the Automotive Engineering and Manufacturing environment – "who is who and who does what and how". The arise of the Lean Six Sigma.

A Master's Thesis submitted for the degree of
"Master of Business Administration"

supervised by

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Wien, 26th of Ferbuary 2011

Affidavit

I, **Roberto Baccaglini**, hereby declare

1. that I am the sole author of the present Master's Thesis, "Becoming Lean: theory, practice and tools. The implementation of the Lean philosophy and Six Sigma across the Automotive Engineering and Manufacturing environment – who is who and who does what and how. The rise of the Lean Six Sigma.", 96 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 26.02.2011

Signature

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Foreword

Each morning when I wake up, the series of operations I perform are part of a decision-making process aimed at optimizing movements to achieve maximum results with minimum effort. And you can bet, considering the time of day, my brain is not at all ready to develop complex algorithms that would produce precise, effective and efficient motion sequences. On the contrary, in most cases, the movements are clumsy and slow but totally automatic or, better said, natural. They are automatic as a direct result of my need to jump out of bed and they are natural because they have been made every morning every month for several years. The only thing I have achieved over the years is to become more effective in relation to my needs. An example: when I was a student, after the thrill of the alarm clock I could afford to sleep a bit more and get out from under the covers gently and relaxed, but when I started working, pressing commitments marked by the need to register my presence at the office absolutely no later than a certain time, meant that at the very moment when the alarm rung I was already standing up, indeed, I even anticipated it. What does this mean?! Is this a dissertation on my daily routine? Is it a way to inform the world about some well hidden aspects of myself? Is it a way to say I prefer routine? No, naturally, the message is much more subtle: it is about the optimization of any process, including simple natural actions we perform every day starting with the way we step out of the bed and ending with how we go back into it in the evening… everything is marked by time and movements that added together make the difference between being efficient and wasting time. At this point, a comparison with the industrial world would seem out of place, but those used to the reality of production, living the success and the frustrations connected to it, they know that what I have described so far also has a direct connection with the real world. And this is not all... Generally, there is a mistaken view that process optimization pursued through specific methods is the sole and exclusive prerogative of manufacturing companies, especially those who work in *Just In Time* (JIT) or *Just In Sequence* (JIS). But have we ever stopped to think that everything can be true and applicable equally well in the field of product development as also in accounting or business development? Basically, each department of a structured company can be more or less affected by such improvement processes. There is one single goal: show the change as necessary and natural to make the transition, and preserve the new status. How? Well, if we stop to think of ways and methods we would find thousands, maybe even millions and maybe billions, but in an age of globalization and strong transnational competition we must reckon with the need to standardize the majority of our “movements” to be more competitive in the market, eliminating waste and optimizing resources. We are constantly required to make great efforts to ensure that our customer selects us among thousands of possibilities in front of him. By a way of example, it is as if our customer opened the Yellow Pages and could spot us at a glance, the best possible response to his needs. But do we have any idea how many entries are there on a single page, in such a list? What is then that differentiates us from the competitors? A better announcement? A stylish print? Lights and glitter? Well, if it worked like that, there would be no lights and glitter available on the market any more… In fact, what makes us recognizable and appealing is the ability to show a high degree of efficiency and the continuous effort to increase the perceived satisfaction at our customers, which requires what I described above, i.e. the ‘optimization of our inner and outward “movements”. Becoming “efficient” is a must imposed by the free market, a “conditio sine qua non” our company should be concerned about, because sailing by sight in the ocean of globalization is not only difficult but also dangerous. Those are the reasons behind the birth of the LEAN philosophy and is not by chance that it happened in the country of the “Rising Sun”, a nation where ideas seem to travel twice - if not three times - as fast compared to the rest of the world. A country which has translated efficiency into its world-wide slogan. A country that despite its deeply-rooted local traditions has a remarkable ability to adapt and show flexibility, which is difficult to find in other countries. The competitive challenge Western companies (in the manufacturing industry in particular) have to face takes place on two fronts: on the one hand, growing productivity and competitiveness of emerging countries (China and India) relative to low-tech content products and, on the other hand, the continuous penetration into markets, which traditionally belong to our companies sphere of influence, by solid and renowned Japanese companies, with equal technological tools and know-how. The examples of Ford and General Motors, who were compelled to re-size their market position to the benefit of Toyota, are emblematic.

The biggest difficulties Companies meet in standing up to this challenge has to do with their scarce ability to adapt their production processes and respond more rapidly to the growing diversity of the markets, creating high-quality products at competitive cost. Since years enterprises have developed an answer, regardless their size, which is the decentralization of most production processes, mainly in countries with low labor costs. This way of doing things solved the problem only partially and only at an early stage. In fact, the raw material and labor costs did decrease, on the one hand, but on the other hand the cost of managing logistics gradually increased due to the distances and the length of the supply chain, the need to optimize transport costs, and to coordinate the various production phases spread across the globe. In several cases the savings generated by the low cost of production is almost totally offset by the increase in costs required to manage the company system and the length of production due to the transfer of goods. It can be easily observed that this course of action requires, if not a radical change of direction, at least a continuous and gradual correction towards other manufacturing options. The topic tackled in this dissertation provides a solid introduction into an alternative view of the enterprise and its way of “doing business”, a model to “integrate” (if not replace) overseas transfers with more collaboration and sharing of expertise among companies involved in the same production flow, decentralized production of large quantities of products with smaller lots produced centrally and, finally, cost reduction through production in areas with low labor cost combined with the constant effort towards elimination of waste and production without added value. Moreover, in following this philosophy, the enterprise will manage to put the Customer at the center of the production process, responding quickly to every requirement, avoiding never-ending and often inefficient inventories of supplies, whose disposal requires promotional sales, discounts, etc., thus causing continuous fluctuation of demand, affecting the reliability of sales forecasts systems on which the current production system is based. The Japanese companies experience (most importantly Toyota) and the growing interest of Western companies in these principles, are proof of the validity – not only theoretical but practical too – of the production method known as “lean”. The aim of this dissertation is to give a practical contribution to the consolidation of these theories by illustrating the introduction of a production program based on lean production in an international Company.

Hoping to be successful in my attempt, here I would now like to thank those who have always supported me in these two years of the course and I learned to know and appreciate through my participation in this Professional MBA.

First, let me say thanks to the organization team who had the patience to follow me, advised and supported me in times of difficulty. In particular, would like to thank Dr. Sihn and Prof. Lesinsky who believed in me since the beginning, and who have always shown me their unconditional support. I would like to thank Dr. Man Wook Han and Miroslav Babinsky that have provided me with valuable support to face my study commitments in the best way. I would like to thank the Automotive Cluster Vienna Region, in the person of Dr. Peter Kuen for awarding me with the scholarship that was crucial for my participation in this course. I would like to thank all the Professors and Specialists that attended in the past two years and have done their best to guide us through the various subjects, sometimes better sometimes less, but always with great dedication. Thanks to Paolo Bertone for his support, indications, and material.

Also, I would like to thank all my classmates from whom I learned a lot, especially to live in a multicultural environment, and particularly Michal Matusek, Peter Chudoba, Tomas Vercik, Alan Hylton, Christian Kropf, Jan Brand, with whom I tied in a special way and whom, at the end of these two years I can consider good friends, not just classmates. Finally I would like to thank all of my family, and my children; they gave me happy thoughts in difficult times. And I would like to thank the person who has been my true inspiration, my mentor and encouraged and supported me over the past two years, even when tiredness or professional engagements were very tight. Thanks A.M. for everything you did for me. I'll never stop thanking you.

From my heart I thank you all very much!

Abstract

This dissertation attempts at providing an alternative insight into business processes when compared to the current predominant view in the Western culture. It tries to go beyond the idea of just-in-time production to include a broader view on redesigning business processes aimed at increasingly leaner materials flow and, eventually, towards the application of the “pull” type production philosophy. Besides revisiting certain methodologies, I believe it manages to illustrate in a simple yet effective manner the winning aspects and the benefits achieved through the implementation of a strategy according to which production is based on a concrete demand, and is not… heavily relying on forecasts. The dissertation also illustrates the example of Johnson Controls and its thorough redesign of production methods, with the implementation of lean production. On the field activities included data collection, feasibility analysis of proposals, practical application of certain tools as is, for example, value stream mapping for the regulation of material flow and inventory reduction. I believe that the topics developed in this dissertation are valuable arguments for the competitiveness of automotive companies.

Aiming to show the weight of these arguments, the structure of the dissertation is rather simple, divided into two sections: the first includes the introduction of various aspects of lean production, illustrating certain well-known concepts, whereas the second part describes certain proposed methodologies and case studies. Chapter One introduces the main subject of the dissertation, lean production and its main features, following the theoretical approach of Womack and Jones. Chapter Two offers an illustration of a method for identifying the value flow within a company through its graphic map, its analysis and the outline of a map of a possible future moment, which poses the starting point for the planning of improvement strategies. The focus of Chapter Three is waste and its various types. The different techniques for its elimination, including 5S, manufacturing standards, poka yoke, are illustrated from the very Oriental point of view of continuous improvement (kaizen). Chapter Four deals with the flow analysis and the various systems used in production. Chapter Five and Six talk about Six Sigma. After completing the analysis of the various aspects of lean production, the

second part of the dissertation concentrates on case studies and on the conclusions to understand whether “LEAN” and “Six Sigma” together with their merger into “LEAN Six Sigma” provide truly valuable tools for the automotive industry.

Introduction

The idea behind Lean Production

What is Lean for you?

This ? or… This?

Fig.1 – Lean vs. Optimization, Johnson Controls Automotive Experience

To understand the LEAN philosophy we must begin not only to understand how to make the ideas, methods and processes flow in an orderly and coordinated way within our enterprises, in order to become more competitive, efficient and effective but also how to maintain the implemented status. Transforming a company's organization is neither a painless nor an easy process. It requires heavy investments in material and human resources. Change for change's sake is futile, unless there is clear desire and ability to continue to take the lead. Change for change's sake in 99% of cases leads nowhere except to a more rapid disintegration of resources. To change and maintain is the first secret of success and another big challenge, because - like many other things - implementing LEAN thinking means to know when it all starts, but not knowing when it ends. LEAN thinking and philosophy has no defined boundaries, it is not like building a fence around the backyard. To be LEAN means starting a process that will probably be unable to see its end – as it is seamless, but it can guarantee, if applied according to rules, more brilliant and valuable results to its users. Shall we attempt applying a few rules to become more efficient in something completely natural and completely away from any manufacturing enterprise and industry? Please take a look at the case studies below. It is called "Kitchen" and it illustrates that by the simple operation of brewing coffee you can waste time in redundant activities or by a sequence of futile actions and movements ineffective for the ultimate goal. In fact, the study shows how to optimize the process and how, through a precise and detailed planning process, you can improve efficiency, which in a manufacturing or – if you prefer – industrial setting – represents an increase in the 'productivity index. The need to standardize operation is a key point to install and maintain a new process. But, **what is a standard operation?** The Standard operation is only the best **current** method we have, ensuring Cost, Quality, Safety, and Delivery; it can and should be regularly reviewed.

What should a standard operation look like?

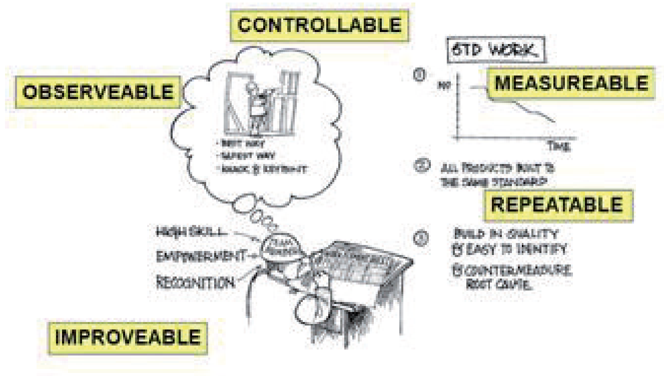


Fig.2 – The theory of a Standard operation, Skillab learning material

Which are the benefits?

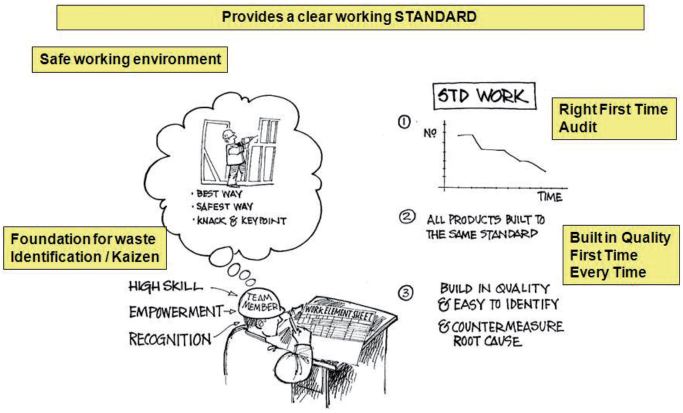


Fig.3 – Benefits of operational standardization, Skillab learning material.

In few words, to become efficient we need to install a Quality Process System. Why? Because it helps ensure stable standard processes which - once achieved - can be continually improved, whereas trying to continually improve processes without first reaching stability is a recipe for disaster. Let's try to demonstrate those concepts by a simple case study.

The Kitchen case study

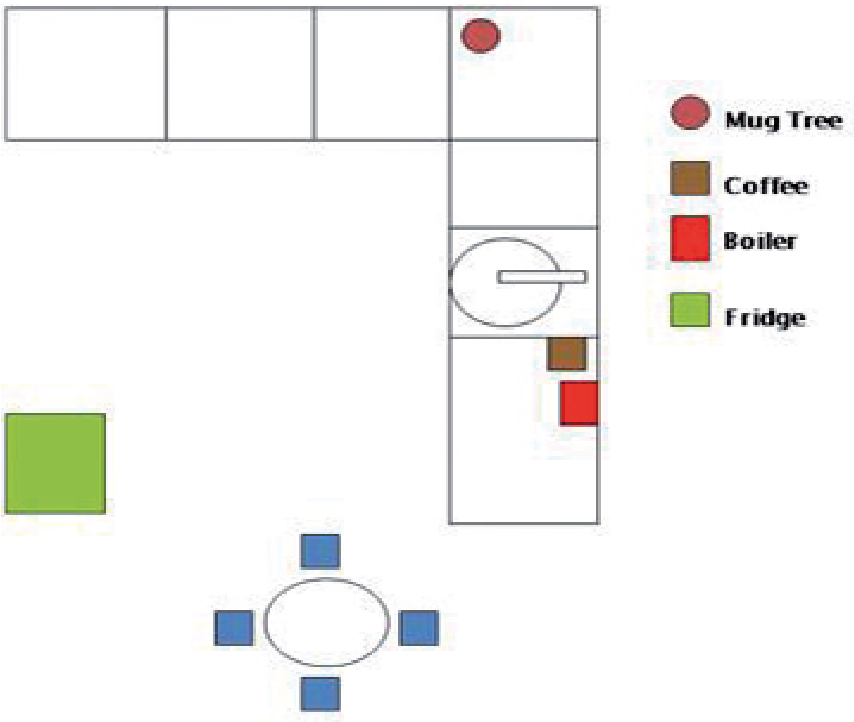


Fig.4 – The starting point; the layout

Basic demand: prepare 380 coffees within the available production time of 440 min.

380 Mugs of Coffee

$$\text{Takt time} = \frac{\text{Available production time}}{\text{Required quantity}}$$

$$= \frac{440\text{mins X } 60\text{s}}{380}$$

$$= \mathbf{70\ seconds}$$

Current stream

Step No	Work Description	WES No	Time		
			VA	NVA	Walk
1	Obtain Mug	C01		2	5
2	Put Mug Down			2	
	Obtain Spoon			8	
	Put Coffee in Mug	C02	4		2
3	Take Milk from fridge			6	2
4	Put Milk in Mug	C03	6		3
5	Return Milk			6	2
6	Add Water to Mug	C04	6		2
7	Place Mug on Table			3	5
	Return				
TOTALS		64	16	27	21

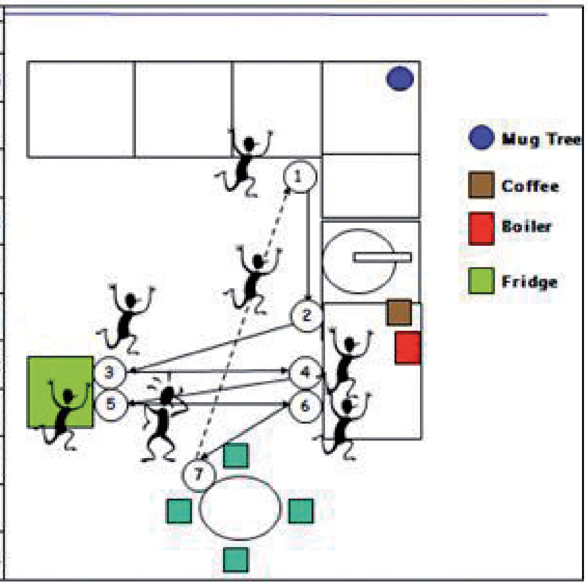


Fig.5 – The actual flow

Which is the way to measure time wise a standard process? The answer stands in the definition of Takt-Time.

What is the Takt Time? The Takt Time is the pulse of the Lean Manufacturing System. It is:

- Determined by actual customer demand
- A synchronized production rate from the first to the last process

Fig.6 – Value added Vs non Value added

Demand increase: volume by 20%:

380 Mugs of Coffee

$$\frac{440 \times 60}{380} = 70 \text{ Secs}$$

20%

456 Mugs of Coffee

$$\frac{440 \times 60}{456} = 58 \text{ Secs}$$

CHALLENGE ~ Minimize Spending $$ on Process

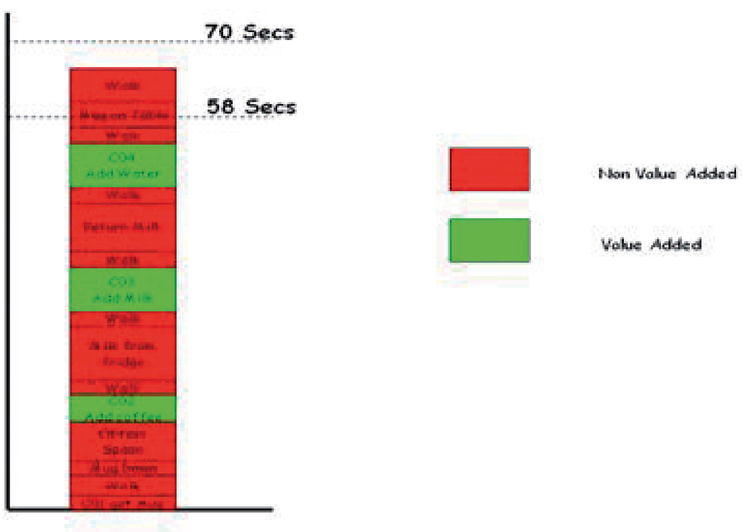


Fig.7 – Increasing the demand

The path towards improvement:

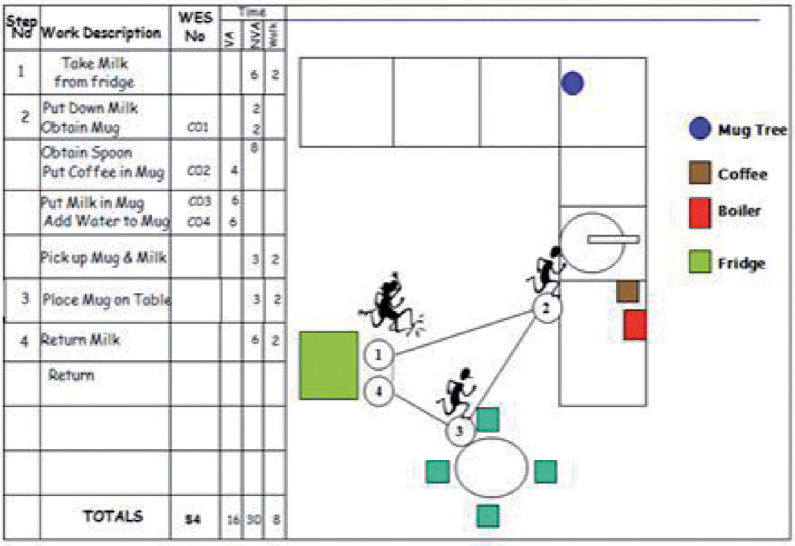


Fig.8 – The new flow

Comparison:

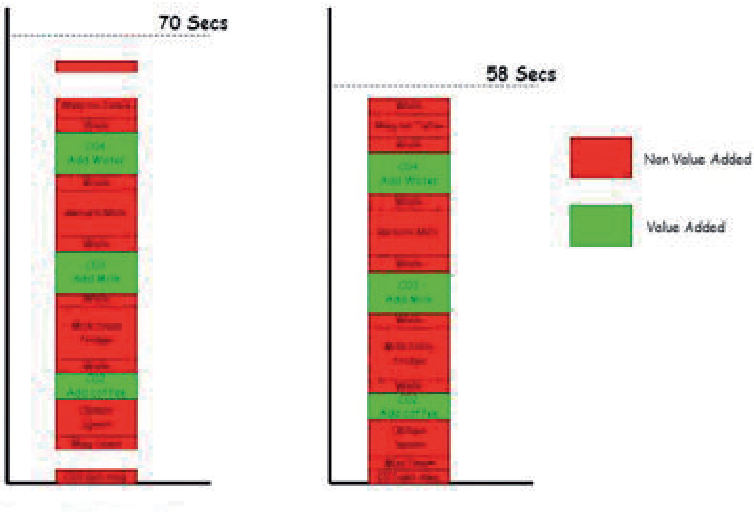


Fig.9 – The comparison

The result: From 70 to 58 seconds with 20% improvement without additional costs How: by the Elimination of Waste.

Here it is shown how to make more efficient a simple process that has nothing to do with pure manufacturing. So even coffee making can cause waste of time if the action is repeated throughout the day. Clearly, this is a trivial transposition of a way of applying Lean techniques from typically manufacturing complex environments and naturally nobody at home would be maniacal to plan and implement Value Stream Mapping method, a simpler method, in their daily lives. However, due to the frenzy pushing us through our daily routines, second saved can be a useful resource to reinvest into something rewarding… perhaps, a healthy siesta. In an industrial complex instead, a second earned can mark the difference between success and disaster ... in real life, in a hospital, it could mean the difference between life and death. Think of the checking-in stream of patients through the emergency department of a large hospital. If each operation is not carefully planned, tested, validated and applied, how many lives might suffer before the medical staff can take any action? On a couple of occasions, I happened to cross the threshold of a hospital or an emergency room- fortunately not as a patient - and I became sadly aware of how much inefficiency there is in such places and among the medical staff, which makes you think that several issues patients have with hospitals could be solved through efficiency alone. I often wonder on the appalling lack of understanding of the importance of a clear outline of work, a clear definition of processes, and a precise application of the same. Seeing patients lying on stretchers in hallways, interfering with routine operations or - even worse – emergency is truly upsetting. And now with a quick and big leap, let's have a look at the building industry... What would we think if there was no clear definition of work patterns, process sequencing, the flow, use, and implementation of materials? Can you imagine what would happen?! Maybe we might happen to see a house looking like this:

Fig.10 – Successful result![1]

[1] http://www.housedesignnews.com/home-design-ideas/upside-down-house-by-daniel-czapiewski-in-poland - (28th of October 2010)

Here are some examples of how the principles of lean thinking are applicable to any situation. Lean principles - as rules or indications - are tools for improving productivity and efficiency, and in pursuing stability which we might say is essential, either in situations where there is clear awareness of their importance and application or in situations where things evolve at a subconscious level. But, what are the cornerstones of this philosophy? How transfer them into a manufacturing enterprise? What is their specific function? In the following pages I will illustrate the main sources of waste and inefficiency, describe methods for addressing such obstacles, I will describe the available tools, and - last but not least – what are the impacts LEAN thinking can have on manpower. It is the heart of the change process and, as described in more detail further on, if there is no direct and complete involvement of all resources, the change process, however based on sound theory and tested, can only result in failure. If the process of change is not supported, most importantly, by the top management, whose task is firstly to show the need for change and then to lead the whole process, everything will crumble like a house of cards badly hit by a breath of wind. But is this not the secret of success for any action aimed at achieving a set goal? From this perspective, only one path will enables us to understand the need to prepare for this future undertaking, to assess its significance and believe in it unconditionally, and not by imposition.

Despite many difficulties, and precisely because the key role in this process is played by manpower (human resources) change can be achieved. The process of change acceptance in complex enterprises and industries varies from 15 to 18 months on average, which is a very long period of time if we consider that currently the same period of time is applied by some OEMs' as a timeline for their new projects, as for the development of the New FIAT New 500 program, whose timing was only 18 months, from Development Start to SOP. Considering the above, on the one side we are compelled to go by the project planning, to avoid clashes with our customer, but on the other side we have to tackle the need for change to increase efficiency; simultaneously, our people will need time (the same time-frame required for the development phase) to adapt to the new situation, be it that of LEAN Manufacturing or that of LEAN Product Development. The point is that if you want to survive in the jungle of globalization, there is no escape from this ... sooner or later we must start somewhere, and both practice and experience say: the sooner the better.

But, what is then the difference between Japanese OEMs compared to OEMs from other countries? Why the need to go for a new “way of production”? Why to go “LEAN”? Why invest in something that nobody can tell will work? This dissertation, as it goes through the most widely known continuous improvement processes, starts with the Lean theories up to the rise of the Lean Six Sigma. It is important to have a look at how they are structured to understand how they can be applied but we still have to keep in mind that theory is nothing if not effectively translated into practice. The demanding job is to make this processes become part of our best business practice as this implies it has become part of the people, and in a broader view, of the business operating system. In my professional career I have practiced the business philosophy of the companies I worked for and observed how, in most of cases, almost no attention was paid to the *Plan-Do-Check-Act* (PDCA) loop. It was more of a “patchwork approach”, i.e. closing gaps from time to time when they appeared, with significant costs in terms of effort, resources, and money. As for everything we do in our lives, before putting anything in practice, first we should understand what we are going to do, what is the best approach, where are the possible gaps to fill, in the road ahead of us. The road toward success!

Chapter 1 - Lean: the origins and the concept deployment, tools and techniques

1.1 Mass production and Lean manufacturing

The first step towards understanding the birth of the Lean philosophy is to understand its historical background. It should be known that it builds the basis; it is the pre-requisite for running successfully the path of improvement. "Lean Manufacturing" is a production process which, if compared to mass production typical of the Western industry and in particular of the Automotive industry, uses less of everything compared with mass production – half the human effort in the factory, half the manufacturing floor space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site (and) results in - fewer defects. This is accomplished through: Teamwork, Communication, Efficient Use of Resources, and Continuous Improvement. In this way, it not only cuts cost, achieving profit levels equal to those of mass production with volumes lower by one-fourth. At the same time it also achieves a better product, since quality defects characterizing Taylor-style production are reduced by two-thirds in lean production.

Womack and Jones finally give a name to this new production philosophy, which brought Japanese companies to quality levels unthinkable of by Western companies in 70s and 80s, and which still struggle to follow the path of alignment. Though initially focused on the automotive industry it proved itself fully applicable to other industries. After initial craftsmanship and later mass production, lean production emerged as a third type of production developed by industrialized societies or, better still, as the "Happy combination of craftsman quality and low cost of mass production. No defects and low costs, this is the winning combination of the Japanese"[2]. In short, the concepts of kaizen (continuous improvement), kanban, and just in time, already known in the West, tools aimed at stretching the production line by fine-tuning the flow of components according to the production requirements, and thus reducing inventory stock to the

[2] Womack and Jones, 1990

minimum, are defined and integrated into lean production. Mass production, though crucial for the achievement of enormous production volumes required by the market in the past, left a deep imprint in the Western mindset and in the way of operating of all those involved in the production chain of our companies. Today, there is increasing awareness that the challenge has nothing to do with achieving high production levels at any cost, exploiting all the space and resources available, but with the elimination of waste, which is pivotal in lean production. The latter, indeed, uses fewer resources to develop new products in half the time compared to mass production. Furthermore, lean production requires a significantly lower inventory stock level, generates fewer and less relevant manufacturing defects, producing a larger quantity of products with the aim of maximum possible quality, i.e. to achieve the objective of zero defects.

1.2 The origins and development of the "Lean" concept

The new "way of producing" was created by Toyota, the renowned Japanese OEM.
In 1950, after many difficulties and important layoffs, Toyota realized that its survival depended on severe changes. Drawing on the experience of the Ford companies, leaders in terms of volumes at the time, Toyota understood that the production system could be significantly improved and, more importantly, that mass production at Japanese companies would have never worked.

With the contribution of a production guru, Taiichi Ohno[3], the OEM created the Toyota Production System, which later became father of lean production.

In 1950 Japanese government introduced new trade union laws, which bound the employees to their company for life, and improved the quality at the workplace by enabling salary increase with improvements in production, hence through production bonuses and local workforce who was less willing to accept the lowering of working standards, as was happening in Western mass production companies.

In this environment, Toyota's COO, Taiichi Ohno, opened his challenge of production excellence. First of all, he understood that the American Ford companies were too rigid and their long setup times did not allow rapid changes in production, so single-product machines were preferred to avoid changes and thus lower production. Naturally,

[3] Womack, J.P., Jones, D.T., and Roos, D., The Machine that Changed the World, Free Press, 2007

this went to the detriment of the customer who could not enjoy a diverse range of products. Toyota developed systems which would speed-up changes in production, without calling for more specialized workers but instead using the same workforce and reducing conversion time from one day to a few minutes. This enabled them to change production three to four times a day producing small diverse lots. They observed that the unity cost of producing few lots for certain production cycles were lower than those for the production of large quantities, since it eliminated the cost of having large stocks of finished products. Furthermore, the production of small lots immediately revealed the mistakes done before car assembly, thus preventing later re-work or scrap. But to make the whole production cycle work, the collaboration of all people was required to detect and eliminate the causes of defects. The motivation of employees and the will to create solutions was the only antidote to failure, as Toyota clearly understood.

Another element of ineffectiveness at the Ford plants and, in general, in Western companies, was the hierarchical structure, which gave solely to the person in charge of production the power to stop the line in case of severe issues, thus leaving car production to chance, with defects which would have to be corrected through later re-work and scrap at the end of the line, in specific departments. Those companies did not consider the incorrect assembly of a piece as a problem, because the mistake would be corrected at the end of the line, as production had to go on regardless anything. As Taiichi Ohno pointed out, the whole system was burdened by muda (waste) and no one, except for the assemblers, contributed to add value to the cars; he was so deeply convinced that the assembler's know-how gained along the line gave him the ability to solve related issues better than an expert, so Taiichi organized teams divided by different segments of the line, lead by a team leader who also worked on the line and was responsible for the work done by the others, and was also able to step in case of need, if one of his team members was missing, something unthinkable of in mass production plants. In addition, Taiichi installed switches at each workstation, allowing each operator to stop the line at the emergence of a defect, so the team would immediately tackle the issue.

The team had also the task of keeping its area clean at all times, to check the quality and make small repairs on the tools. Moreover, Taiichi invited the teams in the company to spend some time, occasionally, to discuss joint suggestions on how to improve the system. This method is also known as "kaizen", Japanese for continuous improvement.

The aim was to teach the workers to trace systematically the roots of each problem by asking themselves questions at each unsolved stage. At the beginning, the production line kept stopping, however over time the system reached an almost impeccable level of quality and reliability with a constant reduction in re-work activities. There is another critical point with companies and plants based on the mass production system, which still today is the root of several inconveniences and has to do with the internal supply of material.

Taiichi drew up a system to coordinate the daily flow of pieces within the supply system; this system is known as *just in time* or *kanban*.

His idea was to tackle the starting point of the supply chain, imposing to the suppliers to produce pieces immediately before they were required; in practice, when a container was emptied, it was sent back, which gave an automatic signal to start producing new pieces. Sounds simple, but is very difficult to put into practice, as it eliminates the need of warehouse and threatened to block the whole system. This is, however, where the strength of Taiichi lied, in his ability to remove safety barriers and focus each member in the production system on anticipating problems before they became too serious. Lastly, another key aspect of the management of the production line applied by the Japanese OEM was the continuous and immediate sharing of information, which the plant management used to maintain secret, convinced that the awareness and knowledge of the real situation of the plant was the secret of their results, either good or poor. On the contrary, in a lean plant all information including daily target production, the number of pieces produced in a day up to a certain moment, disruptions, lack of personnel, need for overtime, and all other information necessary to pursue concrete results, are visible on electronic panels, which can be seen from every workstation. Then, each time a problem, an issue is detected, anyone who can tackle it is asked to do so. By a way of conclusion, it is evident that at the center of a lean plant and, thus, of lean production, lies the dynamic teamwork. Creating such efficient teams is not simple, because of the need to teach all operations carried out by one's work group in a way to ensure job rotation and replacement of operators. Therefore, workers should be able to make simple repairs, keep the place of work clean, carry out quality checks, and be able to manage the material they need. Operators are suitably trained but also motivated and involved so they themselves can find a solution before a problem becomes critical.

1.2.1 Lean production tools

Toyota's lean production evolved over the years, while preserving its solid bases from the past; enterprises adopting lean production systems are based on a precise scheme of activities and tools. Lean production is a system focused on the customer who upholds the company-specific value added activities and looks for maximum quality, enabling an organization to bring to the market high quality products at low cost, rapidly and flexibly. Key to the system is the precision applied by producers in mapping their value flows from the beginning to the end and the strict standardization of processes which compels the operators to improve activities by applying scientific investigation methods. All improvements should be checked before implementation.

This leads to a continuous improvement (kaizen) of a production system, a constant increase in the quality of products, and to a constant decrease in cycle time, thus enabling the production of small lots with interchangeable parts.

1.3 Five steps towards lean production

The approach towards total elimination of waste and lean processes was introduced and later on more clearly highlighted by the authors who significantly contributed to the spread of lean thinking in Western industry[4]. This change was completed through five basic steps, following one another, i.e. the definition of value, the identification of the value flow, the lean flow of the stream, client-pulled flow and, lastly, perfection.

1.3.1 Definition of value

In a lean system all processes are conceived in terms of added value they can give and, as Womack and Jones (1996) teach us, "the value can be defined only by the end customer".

Contrary to this principle, many managers today apply the opposite process, by defining a product's value themselves, and later implementing adjustments to its features thus lowering its price when the customers do not show interest in what they defined as "having added value". In fact, the path towards being lean envisages that the value

[4] Womack and Jones 1990, 1996

of a product is defined by what the end customer wants. This is the first step of lean production.

1.3.2 Tracing the Value stream

The value stream is a set of all specific activities required to make a certain product (good or service or a combination of both) fulfill three critical tasks of any company management:

- The solution of problems, from the design till the launch phase
- The management of information, from the acquisition of orders to the detailed planning of deliveries
- The physical transformation of raw material up to the finished good in the hands of the customer

From the lean production perspective, identifying value stream means identifying all activities connected to the creation of a product (or family of products). These activities can be divided into three categories:

- Activities creating added value
- Activities which do not created added value but are inevitable due to the assets and to the technological level of the organization (type 1 of waste)
- Activities which do not create added value (type 2 of waste)

The tool for identifying this stream is the Value Stream Map (VSM) whose criticality does not lie only in the mapping of each single activity but in the dividing those activities in the three categories according to the value or waste they produce.

1.3.3 Value stream

Once the various activities have been identified, and VSM has been assessed and carried out, value added activities can be ordered within the value stream step by step, without delays. Where the stream has been implemented and the activities have been changed from production by lots into production by continuous flow, productivity doubles and defects decrease drastically. This is due to the reduction in handling time and related defects caused by the product during the various moves.

1.3.4 Setting up of a Pull system

The shift from the production by lots to a production with a continuous stream produces an immediate reduction in time required between the product concept and its launch on the market, between sale and delivery and between raw material and the finished good. This reduction of time, required to go through each of the above areas, allows to remove the function of sales forecast and to deliver the customers what they want at the moment they want it. This creates a “pull system” in which the organizations avoid impositions by putting on the market products which are not required (which is typical of a push system).

1.3.5 Reaching perfection

When the enterprise went through all the above steps for the introduction of the new philosophy and the customer is able to “pull” the product they need from the company, at the moment they need it, new areas of development start being analyzed within the company. This process which can be defined as continuous improvement helps the organization reach “perfection”, and it is the fifth and final step of lean production. Perfection is defined as total elimination of all waste so that each activity and each asset can add real value for the end customer. Each principle illustrated above compelled lean companies to keep developing their organizations, whereas their strive towards perfection helped them reduce costs of production and improve quality.

1.4 Lean Thinking towards the future

We could ask ourselves what is a Company to do once it has eliminated the bulk of waste and reached an almost full integration of lean thinking principles or, better said, what is there left to do in a company as advanced as Toyota? Womack and Jones, in the third part of Lean Thinking draft the guidelines for all those companies which, as for example Toyota, have reached a certain level of maturity in waste-free production. The emerging scenario, rather than a step further towards being lean and towards an increasing focus on the concept of value for the customer, is an overall re-haul of the current way of doing business, whose result is a new concept of the enterprise. In this new concept, priority is given to the sharing of methods and knowledge among all stakeholders, career opportunities of the people in the various functions are redesigned from scratch, within a concept of enterprise which is totally free of superfluous activities, in which the individual and value are at the heart of the new concept of production. The above illustrated scenario looks idyllic, indeed utopian, and maybe impossible to create, but it is worth analyzing some of its aspects.

Chapter 2 - Value stream and its analysis

Value stream mapping is said to be the first item in our Lean Tool Kit – the first step in creating our company's lean strategy. Womack and Jones (Lean Thinking, 1996) visualize the value stream as this: raw materials along with knowledge and information enter the system upstream (the suppliers); and, products or services of value flow out from the system downstream (the customers). The individual processes that take place in between are those that add value to the product or service as it flows through them. It is a simple but powerful model. Indeed, since its origins at Toyota it has been further conceptualized and molded, becoming a real tool "to learn to see"[5].

The key is to eliminate the non-value-added waste in the value stream. In value stream mapping focus is put on the process as a whole in addition to analyzing single activities. In this way, improvement is applied to the whole, contrary to what normally happened before lean concepts were introduced, and specifically in re-engineering operations, in which improvement is sought by concentrating on single processes, and neglecting the connection of the various phases contributing to the creation of the product. It is often the passage from one phase to another which most frequently conceals elements of waste and inefficiency. The tool offers a vision of the whole manufacturing value stream as the product progresses along the current value stream, enabling us to map the future state and define the shape of the value stream the product should follow. As material transformation processes are similar in all companies, the opposite is true for the information flow, which in a lean company should flow in such a way to ensure the timely and effective carrying out of a single activity at the moment required by the activity that follows it.

2.1 Basic steps for mapping

In applying this tool the starting point is the definition of a family of products, i.e. a set of products going through similar transformation and common tools during the manufacturing process, with special attention to the finishing phases. The following step is to draw the current state, which will logically be the starting point for the

[5] Rother and Shook, 1998

following phase, i.e. the drawing of the future state. This process is repeated overtime according to the principle of Kaizen to achieve continuous improvement.

2.1.1 Selection of the family of products

This phase includes activities aimed at identifying the family of products which we use as a model for the drawing up of the map. Once the product (or the family of products) is identified, information on the number of product codes comprised in the product family need to be collected, and the demand for these products by the customer should be analyzed. Once data is collected we will list the materials involved, the assembly phases they undergo (highlighting various features as for example the number of operators involved, cycle time, production lot dimensions and stock values), and eventually the tools that are used.

2.1.2 Second phase: Drawing up the Current State Map

The analysis of macro-processes which include the internal flow of the plant should start with the delivery from the plant and go backwards, upstream, so the processes more directly linked to the client are analyzed first, as they set the pace for all other processes further upstream.

2.1.3 Customer Company

Fundamental aspects of the mapping process are the care we need to have towards the items directly related our customer demand. Therefore, in the map we will mark:

- The required monthly quantities
- The frequency of deliveries
- The packaging used and the produced quantities contained in them
- The minimum delivery lot for delivery used by your company
- The number of shifts applied by the customer company.

2.2 Preparing the Future State Map

The definition of a future state map is not direct, many aspects should be considered, therefore we should draw from the concepts offered by the Toyota experience, and from personal experience, which should constantly generate new maps in order to improve the previous ones.

Starting from these considerations, elaborating on several Toyota Production System concepts, and using their on-the-field experience, Rother and Shook defined seven lean principles which, combined with the analyzed manufacturing system, contribute to making it lean. These seven principles are very useful in understanding where we should operate to draw up the future state map.

2.2.1 Producing by Takt Time

Takt time is calculated by dividing the time available in a shift calculated in seconds by the customer’s requests per shift measured in units. The result is a rhythm expressed in seconds at which the customer acquires single pieces of a product. The objective to reach in the mapping of the future value stream is to uniform each process box cycle time to a pre-set takt time.

To reach this result the procedure requires you to choose between the so-called pacemaker processes, which is the starting point for synchronization. This process will dictate the time upstream the manufacturing chain and will define which value stream elements are part of lead time between customer’s order and the finished product.

2.2.2 Implementing the continuous flow wherever possible

Often, large stocks are identified in the intervals between one process and another. They clearly speak of stream discontinuity, i.e. raw materials go from one process to the following by “taking long pauses” in other areas. These “pauses” evidently generate waste and pose an obstacle to securing a continuous flow.

2.2.3 Using the supermarket system to control production

Where the continuous flow of materials cannot be applied, a compromise should be sought to reduce waiting time and lead closer to the pull system. The production manager should optimize production keeping in mind the variability of setup times for the change of production and is therefore compelled to produce by lots, to avoid delays and prevent stoppages caused by lack of components. The flow of goods can often be improved by making special agreements to ensure supplies are delivered several times during the week, but for critical suppliers or those located far away (long lead time), better and bigger coverage is required. As regards internal processes that cannot be managed by a continuous flow, supermarket-type of management can be set up, with a FIFO or a sequential pull line.

- *The Supermarket Method*: withdrawal kanbans from customer's process are used to signal that the material is withdrawn so the logistics receives input for the production to start. In this way the production of the supplier's process is controlled, without attempts of programming. The application of this management system is suggested in cases where the majority of other processes works at a continuous flow and do not require displacement of material.

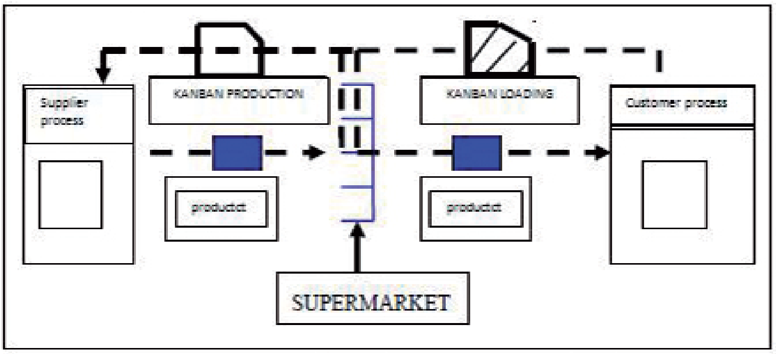


Fig.11 - The Management Method in Kanban with Supermarket, Skillab learning material

- *FIFO line method*: when there is a production of customized and often unique high obsolescence pieces or high cost products, it is not advisable to maintain a stock of all product varieties as in the supermarket system. In this case, FIFO lines can be applied, with a limited stock area with a certain number of pieces, which the customer process accesses from one side and the supplier process from the other. The supplier process interrupts production as soon as the line is saturated, and will start to deliver pieces to that part only when part of the stock is taken out. Here, the withdrawal kanbans communicate production kanbans only till the line is full, thus avoiding expensive over-production

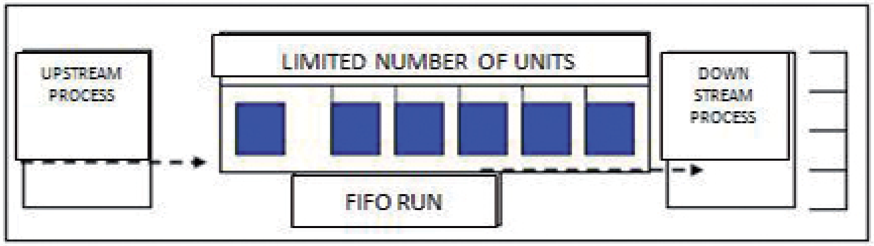


Fig.12 - The Management method by FIFO line, Skillab Learning Material

- *Sequential pull method*: when you can count on low lead time between customer process and supplier process, a sort of make to order can be set up and used, so that the customer process sends an order to the supplier process when required and this generates an established quantity of required products.

2.2.4 Sending the manufacturing program to the PaceMaker process alone

Once the pacemaker process is selected, it will dictate the rhythm of the downstream processes, which should be also managed at a continuous flow. After the pacemaker process no other processes managed by the pull or supermarket methods should be set up. In case of customized products, with processes managed by FIFO, the pacemaker process will be the one immediately preceding the latter.

2.2.5 Leveling the Production Mix

An optimal situation would be to produce the correct quantities of different products, leveling the production mix on the pacemaker process, and varying the production according to need. The eventual increase in the number of setups will be later offset by an increasing standardization of the components during assembly.

The leveling of the production mix, when applied properly, ensures the elimination of plenty of waste.

2.2.6 Leveling the production volume

When production volumes are leveled, the manufacturing stream becomes foreseeable

and making corrections becomes easier.
The steps towards the leveling of volumes are:

- Release of manufacturing programs with reduced working load, i.e. a maximum coverage of 60 minutes on the pacemaker process with subsequent withdrawal of finished product
- Measuring of released workloads taking as a reference unit the quantity of product contained in a standard container or its multipliers.

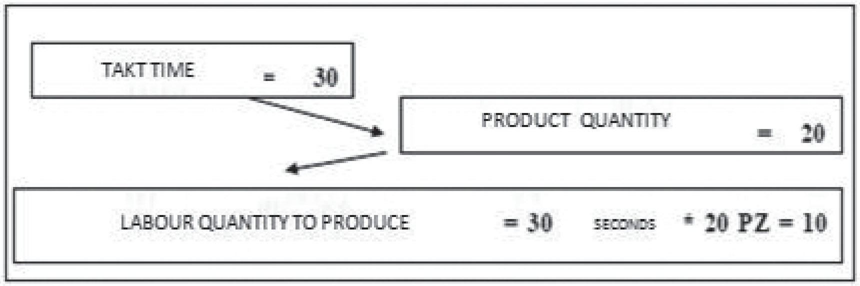


Fig.13 - Production pitch to be released to Pacemaker process, Skillab learning material

2.2.7 Develop the ability to produce the right piece at the right time

By adjusting setup times and reducing production lots upstream the ability to respond to changes in demand will increase and speed up, and the stocks in the supermarket-managed processes will be reduced. However, these improvements require a piecemeal approach.
A typical example is to dedicate to the setup approx. 10% of the available time. Clearly, the reduction in lots goes in parallel with the lowering of the setup times and with the improvement in equipment availability.

2.3 Creating the Future State Map

The primary objectives to be pursued are connecting each manufacturing process through the continuous flow or through pull-type systems, and trying to produce only what the customer wants at the time he wants it. The starting point is a feasible configuration, well connected to currently available resources, bearing in mind all technical requirements that cannot be overcome at the moment, then changes are implemented over time, including in the design, in technology, and in the setup of the equipment.

Chapter 3 - The Elimination of Waste

Once the value stream is clearly defined, a Company is able to identify the processes and activities which create added value (activities which need improvement) and those which do not (activities that should be gradually reduced and eventually eliminated). As regards the last group of activities – or operations – they can be additionally divided into those necessary for production and pure waste.

3.1 Identifying waste: the seven types of waste (plus one)

A thorough elimination of waste requires their identification and classification to simplify the analysis of effective counter-measures. A wide-spread waste classification method consists in dividing waste into seven different types, known as 7 types of waste. I thought it might be useful to add an eighth waste, as defined by Womack and Jones (1996), from a purely lean point of view.

3.1.1 Overproduction

The first type of waste to analyze is connected to overproduction, which occurs any time *Work In Progress* (WIP), i.e. half processed material circulating within the enterprise exceeds customer demand. We easily realize that this type of waste goes hand-in-hand with the push-type manufacturing philosophy, which aims at the minimum possible number of setups and focuses on pieces that require a similar type of processing in a single production batch, thus creating excessive stock of finished products and making it impossible to respond quickly to a sudden change in customer demand.

3.1.2 Excess stock

The second type of waste causes hidden costs within a range of 20 to 40% on income. These costs are embedded in a series of activities required for material handling, including:

- Transport
- Storage

- Handling staff
- Logistics management
- Lack of traceability of defect components
- Waste of energy
- Equipment costs
- Overall waste of time

The most obvious solution for this type of waste is the setting up of a pull-type manufacturing system drawn by the direct demand from the customer.

Pull systems allow to adapt more quickly and easily to the variations in demand, and will be further analyzed in the next chapter.

3.1.3 Rework

Rework and, more generally, poor quality consumes time and material and negatively affects company profits. The application of lean concepts directly enables to improve the product quality, but this does not suffice. Improvements should be introduced into the way a single process works, together with a system of checks to prevent mistakes (*poka yoke*).

3.1.4 Excess transport

A correct layout of manufacturing lines contributes to reduce waste. An effective technique to improve processes layout within a plant is known as process razing[6], which is a very effective tool to redesign a plant's layout. In short, it requires an accurate analysis of the processes and of their layout, and then looks for the best possible setup for a flawless stream.

One of the results of process razing is that a U-shaped layout allows drawing work stations closer and improving communication among them, while speeding up material transfer.

[6] Aray and Sekine 2006, Ch. 5

3.1.5 Excess movements

Excessive movements can be reduced by applying the above process razing within single workstations, by introducing an ergonomic design alongside the manufacturing line: this eliminates superfluous and even dangerous movements.

3.1.6 Waiting time

Waiting time between the various processing phases has different root causes, including the difference in cycle time of the various processes, an inadequate leveling of operations or the poor management of stock and half-processed goods.
Lean methods can eliminate waiting time through the value stream mapping analysis and planning. Based on the obtained results and the action plan, workstations can be designed in such a way that operations are carried out at maximum flow and minimum waiting time.

3.1.7 Superfluous processes

Superfluous processing phases are often caused by quality checks requiring repeated product inspection, which might be easily avoided. Moreover, superfluous operations are reduced by the introduction of a method of continuous quality control by the operators.

3.1.8 The eighth type of waste: designing goods and services which do not meet the requirements of the customers

To avoid the development and, later, the manufacturing of goods and services which do not meet customer requirements or needs, calls for a thorough analysis of the customer itself and – above all – of the elements the customer believes have the highest value. To put it short, we should analyze the value as perceived by the customer.

3.2 Tricks and techniques eliminating waste: 5S

5S is a set of methods enabling the company to reach excellence through the

improvement of the work place, in terms of order, organization, and cleanliness.
The first application of the 5S theory was carried out by Taiichi Ohno, who made up the acronym inspired by the following terms/words:

Seiri (pick and select): expresses the idea of analysis of the tools and materials at the place of work, in order to keep only the fundamental ones. All unnecessary things should be stocked or eliminated.

Seiton (order and organize): focus is put on the need to have an orderly place of work, where order stands for the organization of the line to enable the work stream.

Seiso (check order and cleanliness): highlights the need to keep the place of work clean and orderly. Preserving cleanliness and order should become a daily routine, not an occasional activity to be carried out when things get out of control.

Seiketsu (standardize and improve): standardizing working practice is more than a standardized cleaning operation. It stands for doing things in a consistent and standardized manner, where everyone clearly understands their responsibilities.

Shitsuke (support discipline): it means maintaining cleanliness standards achieved through the implementation of the first 4S's, which becomes the new way of doing things.

5S can be applied in any area of the plant, be it tooling, equipment, operations, and their full implementation can be achieved with a joint effort, technicians, maintenance staff, and assembly line operators.
Benefits deriving from the application of this method are:

- More safety
- Better ergonomics
- Better performance of the process affected
- Improved communication and, hence, better engagement of the workforce

3.2.1 Standard Work

Outlining standard work requires the identification of the best way to carry out a task within the available timeframe, ensuring that the work is done well the first time, and then it requires the setting up of a control method so that the operation is always carried out in the same way.

The following results can be observed:

- Overall improvement in output product quality
- Reduction of scrap and rework
- Improvement of employee morale
- Cost reduction

3.2.2 Poka yoke (error-proof)

Japan-based poka yoke was introduced by Shigeo Shingo and became a regular expression in business in defining all those measures aimed at eliminating root causes of defects in manufacturing. Poka yoke refers specifically to all those fail-safe mechanisms introduced during machine operations, aimed at identifying or preventing defects and thus improving quality. It can be divided into three types based on the method applied:

- **contact poka yoke**: the systems identify a defect caused by the contact between a tool and the product being manufactured. The group includes tools activated by the identification of a certain color or other features of the product.
- **fixed value poka yoke**: the systems aim at identifying if a certain number of movements have been made
- **motion step poka yoke**: the systems check if the various passages have been carried out correctly.

The behavior of a poka yoke can vary: some only send out signals, others can control and prevent an incorrect action. The choice of the correct poka yoke should be based on the type of process it is applied to. The results obtained through the application of the poka yoke are a gradual improvement in quality and a reduction of rework.

3.2.3 Kaizen (Continuous process improvement)

Kaizen is a method aimed at a continuous assessment and redressing of manufacturing

process, aimed at gradually eliminating waste. It engages all company functions and pursues the improvement of quality and the reduction of forwarding time. It is a series of daily activities for the identification of all sources of waste carried out by analyzing the situation and eliminating them at minimum cost.
When carried out correctly, the process facilitates the achievement of important milestones, including:

- Considerable improvement of the climate at the place of work (both mentally and physically)
- Training of employees in the use of a scientific method to identify waste and try out new improvements

Kaizen involves everybody at every level of an organization, both individually and in groups, and it is based on the principle that many small improvements lead to big results, when put together.
The basis of this method highlights the idea of "learning by doing", which is at odds with the philosophy of "command and control" on which XIX century improvement programs were based.
The application method follows what is known as the Deming cycle or the *PDCA* (Plan Do Check Act) cycle, where changes have to be planned, carried out, checked and improved again.

Chapter 4 - Towards the creation of a pull stream

Having identified the stream, what is waste and how to eliminate it, we now analyze how to improve plant productivity by creating a continuous flow of material and the adoption of a system pulled by the requests of end users.

4.1 The pull system

Often there is confusion on the definition of a pull based system, and occasionally it is confused with *Just in Time* (JIT). This is oversimplification, as Just in Time (JIT) represents simply the best manufacturing method currently available for the implementation of the pull philosophy which includes a much broader vision, focused on the relationship with the customer. The spreading of this methodology brings, in the short term, a dramatic reduction of stock and the speeding up of ROI (Return On Investments), however the most significant result is the ability to design, program, and produce exactly what the customer wants at the precise moment he wants it and throw away the sales forecasts to create only what the customers say they need[7].

4.2 Just In Time

JIT is a manufacturing management method aimed at producing only determined quantities of each required good in the short period, not what according to forecast an enterprise believes could sell in the future. Each product has to be prepared and ready “when necessary”, not before. Therefore, there is no stock or, if there is some, its purpose is to act as a backup solution ensuring supply between one manufacturing point and another. One of the winning features of JIT is the flexibility of operations, i.e. the ability of the plant to produce a very varied mix in the short term, including extremely small mixes or single pieces. To produce with a limited level of stock JIT adopts a manufacturing mindset which strongly differs from the Western one. It is based on four main points: manufacturing of single lots, leveling of cycle times, setting up of an efficient information exchange system and improvement of the plant layout.

[7] Womack and Jones, 1996

4.2.1 Manufacturing of single lots

To achieve this objective, first you have to optimize setup, as long tooling time increases manufacturing costs per piece and decreases production capacity and flexibility. Then, a program for a gradual change in technology is also useful, to replace large powerful machines with smaller, more flexible ones, those that can produce single pieces too.

4.2.2 Balancing the rhythms of different departments

The correct stream flow requires all departments to produce with the same interval between the exit of a piece and the entry of the new one.
Since the pull system is activated further downstream, the first important step is to level the final assembly line based on market demand thus balancing the production flows of the other departments.

4.2.3 Implementing a perfect information exchange system

An information exchange system is required to ensure an undisturbed flow of the stream and to inform each process of what is to be produced at each moment. Western systems use Material Requirement Planning (MRP) systems to define the production of each department. The difficulty lies in the complexity of information to be managed and in the lack of connection between upstream and downstream processes. In JIT, there is a simple and quick method called kanban (sheet, card), which does not require any external programming, so MRP is used to manage orders and material supply.

4.2.4 Creating an adequate plant layout

The implementation of the JIT system requires a series of measures aimed at improving the plant layout, both at a single cell level and at manufacturing process level. The correct functioning of a pull system requires a layout with an optimized sequence of steps within each process, avoiding any unnecessary movement and any other type of waste. This is achieved by assessing the position of each cell or workstation, normally inspired by the U-cells logic. Furthermore, the distribution of manufacturing departments within the plant should be optimized, to enable a quick and flawless stream. All this can be achieved through process razing[8].

4.3 Kanban

A very simple yet quick method to exchange information is the kanban system, which is based on the circulation of sheets among various processing and stocking centers within a plant, in such a way that the delivery of a sheet authorizes a certain operation. Basically, there are two types of kanban sheets:

Handling sheet: a document (similar to a bill of material) authorizing the withdrawal of a certain number of pieces (normally, a standard container) of a certain material between two adjacent workstations.

Production sheet: a document authorizing a department to produce a standard container of pieces. In short, when a certain number of pieces exit a workstation, the launch into production for an equivalent number of pieces is authorized.

The kanban system is activated by the final assembly line which takes the pieces from its stocking entry point and goes upstream to the stocking area at the previous processing station, and so on. In this way, each processing center knows exactly what to produce and at what pace. Most importantly, it will produce only what the processing center downstream will use.

To establish the optimal number of necessary kanban the average of lead time and safety stock are summed up and divided by the number of pieces in each container.

Over and above the traditional kanban, there are alternative ways of conveying information, based on the principle of visual checks:

- Kanban squares
- Container system
- Color balls

4.4 Heijunka

The Japanese word *heijunka* expresses the leveling of a type and quantity of production over a certain period of time. Leveling production means enabling it to respond

[8] Aray and Sekine, 2006

effectively to the customer's demand, avoiding large lots, reducing stock, cost of capital, workforce, and lead time along the entire value stream.
The two main elements of the production planning based on heijunka are:

- **The leveling of production volume**, i.e. the uniform distribution of production over a period of time
- **The leveling of the production mix**, i.e. the uniform distribution of the variety of production over a period of time.

Moreover, heijunka ensures the uniform distribution of workforce, material, and movements in the various departments, balancing the workload within the cell.
The tool used to level the mix and the volumes of production via an accurate distribution of kanbans within the plant (at fixed intervals), is the heijunka box (also known as leveling box), which consists in a grid where at fixed intervals a certain number of kanbans are inserted, so the people in charge of production take out one kanban after another and carry out production accordingly.
Instead of assigning the plant a program for the whole shift, once a week the heijunka box allows to level the demand in small intervals (for example, a pitch) or – alternatively – by setting up tables for each manufacturing cell, with clear indication of the upcoming deliveries (normally, on a daily-basis.

4.5 Plant layout

In a traditional company manufacturing plants are generally separated from warehouses where raw material, half-finished goods and finished goods are stocked.
In a pull system based enterprise, on the contrary, the raw material and finished goods practically disappear, whereas the half-finished goods are replaced by small buffer areas containing sufficient quantities of material, which cover the requirements of a few hours (up to a day, in the case of certain specific components). All this material is set in the production area close to the processing centers.
In this way, the materials produced or waiting to be processed are visible to the operators who can immediately realize if there are excess stocks or if there is lack of components, so they can adopt countermeasures immediately.
This type of stock management goes parallel with the setting up of small processing

departments (cells) in which the bulk of operations necessary to complete the product is carried out: this type of layout is also known as *cellular manufacturing*.

More concretely, a suitable layout for a pull system requires the following:

- Production has to be organized in processing centers, so each center has an entry and an exit stocking area. The stock of the material being processed and of the components will be placed exclusively in those areas
- There has to be a single point of supply for each material within the plant
- The path of each material has to be precisely and accurately defined, as it goes through the processing centers and the related stock areas.

Chapter 5 - 6σ: the growth of a new system

In separate articles by two Motorola veterans, Mikel J. Harry (1998) and Dennis Sester (2001), each author explained how the idea of Six Sigma was first conceived by experts at Motorola in the early 1980s. Bob Galvin, who was chairperson of Motorola at the time, presented an incredibly demanding quality goal to his employees in 1981, which may have been the stimulus for Six Sigma. Engineer Bill Smith's research regarding process capability and defect reduction around 1985 became the basis for Six Sigma innovation. Leadership at Motorola later asked Mikel J. Harry, then part of Motorola's technical staff, to pioneer the strategic methodology that would soon become Six Sigma. Harry and his colleagues refined the Six Sigma strategy by decade's end.
Since then Six Sigma has been touted in numerous articles for having improved countless business processes as well as the overall vitality of several major organizations. Motorola, GE, Allied Signal (now Honeywell), Ford, **Johnson Controls**, TRW, Delphi, Raytheon, Lockheed-Martin, Texas Instruments, Sony, Bombardier, Polaroid, 3M, and American Express are some of the organizations that have implemented Six Sigma[9].

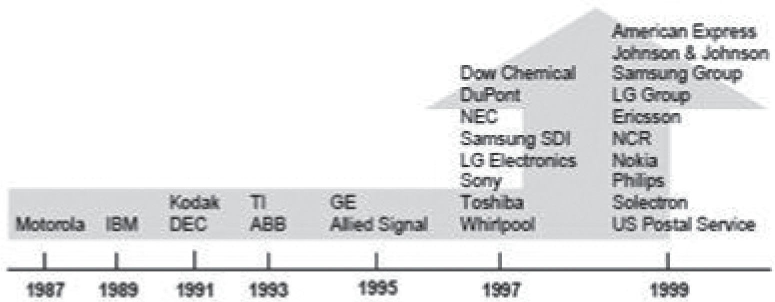


Fig.14 Globally well known Six Sigma companies, Skillab learning material

Most organizations on this growing list claimed to have saved millions of dollars with Six Sigma. However, provable figures were not available. Motorola, GE, and Honeywell, three notables that all claimed to have saved an exorbitant amount of money with Six Sigma, are revered in literature as the Six Sigma organizations to follow[10]. Six Sigma activities and achievements, seen mainly in large manufacturing

[9] Hahn et al., 1999; Harry, 1998; Lanyon, 2003; Miller, 2001; Snee, 1999; Williams, 2003
[10] Hahn et al., 1999

plants, are starting to prevail in small businesses, in cross-function business processes (e.g., HR and Purchasing), and in the service sector[11]. Smaller companies have had similar financial success compared to larger companies though on a smaller scale[12]. From a financial perspective at least, it appears that Six Sigma has had a considerable impact on numerous organizations across a variety of industries.

5.1 What is Six Sigma?

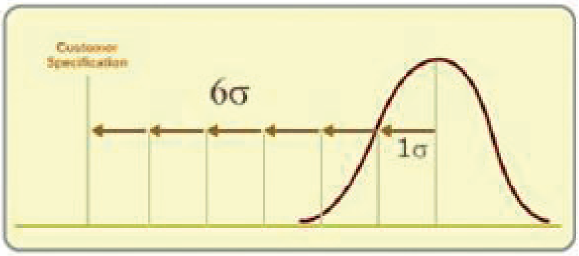


Fig.15 - The idea of deviation, Skillab learning material

Some scholars and practitioners have attempted to give one or two definitions[13] of Six Sigma. However, many have concluded that there are at least three definitions[14]: Six Sigma can be viewed as a metric, a mindset, and a methodology. The **first** logical and commonly found definition for Six Sigma is that it is a statistical expression of a metric[15].

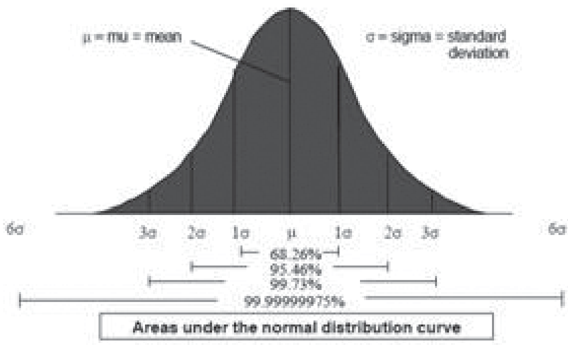


Fig.16 - The "*Normal distribution*", Skillab learning material

[11] Gnibus & Krull, 2003; Goh, 2002; Hammer & Goding, 2001; Harry, 1998; Smith, 2003
[12] Brue, 2002; Gnibus & Krull, 2003; Harry, 1998
[13] Breyfogle, Cupello, & Meadows, 2001; Dambolena & Rao, 1994
[14] Adams, Gupta, & Wilson, 2003; Brue, 2002; Eckes, 2001; Pande & Holpp, 2002
[15] Breyfogle et al., 2001; Brue, 2002; Dambolena & Rao, 1994; Hahn et al., 1999; Harry, 1998; Pande & Holpp, 2002

As a **second** definition, Six Sigma is considered an organizational mindset that emphasizes customer focus and creative process improvement[16]. With this mindset, individuals are prepared to work in teams in order to achieve Six Sigma and its ultimate goal of reducing process variation to no more than 3.4 defects per million opportunities As a **third** definition, Six Sigma is viewed as a strategic improvement methodology termed DMAIC[17]. DMAIC is an abbreviation of the five systematic steps in the Six Sigma methodology. The steps used for breakthrough thinking and improvements are: define, measure, analyze, improve, and control. This methodology is used to carry out the structured philosophy of Six Sigma in places that include but are not limited to manufacturing, design, engineering, human resources, purchasing, and customer service. Fig.16 is showing the Six Sigma strategic table that was developed to illustrate the steps and various tools that can be utilized in Six Sigma. Six Sigma's DMAIC Methodology.

Strategic Steps	Common Strategic Section Deliverables	Traditional Tools
Define	Project Charter or Statement of Work (SOW) -Process and Problem -Scope and Boundaries -Team, Customers & Critical Concerns -Improvement Goals & Objectives -Estimate Sigma & Cost of Poor Quality (COPQ) Gantt Chart / Timeline High Level Process Map Step Documentation and Next Steps Exit Review	Spreadsheet/Word Processor Critical to Customer Concept Project Charter or SOW Gantt Chart / Timeline Flowchart or Process Map Balanced Scorecards Pareto Chart & Control Charts QFD / House of Quality Suggestions / Complaints Surveys / Interviews / Focus Groups
Measure	Baseline Figures (Sigma & Cost) Process Capability Measurement System Analysis (MSA) or Gage R&R Refine Project Charter, including COPQ Refine Process Map Fix Gantt Chart / Timeline SIPOC or IPO Diagram Step Documentation and Next Steps Exit Review	Data Gathering Plan Surveys / Interviews / Focus Groups Checksheets / Spreadsheets SIPOC or IPO Diagram Descriptive Statistics & Capability Pareto Chart / Control Charts Measurement System Analysis Flowchart or Process Map Project Charter or SOW Gantt Chart / Timeline
Analyze	Identified Root Cause(s) -Cause and Effect -Statistical Analyses Validated Root Cause(s) Step Documentation and Next Steps Exit Review	Fishbone Diagram (5-Why) FMEA Interrelationship Diagram Histogram Scatter Diagrams (Correlation) Hyp Testing / Chi-Square Confidence Intervals Pareto Chart / Control Charts Regression ANOVA DOE Response Surface Methods Flowchart or Process Map
Improve	Selected Root Cause(s) & Countermeasures Improvement Implementation Plan Validated Solutions or Improvements -Statistical Analyses Revised Flowchart or Process Map Step Documentation and Next Steps Exit Review	Affinity Diagram Hypothesis Testing Confidence Intervals DOE FMEA Trial and Error / Simulation Flowchart or Process Map Implementation & Validation Plan
Control	Control Plan -Tolerances, Controls, and Measures -Charts and Monitor -Standard Operating Procedures (SOP) Response Plan -Ownership or Responsibilities -Corrective Actions Validated In-Control Process and Benefits -Process Capability -Measurement System Analysis (MSA) or Gage R&R Step Documentation and Final Report Exit Review - Project Completion and Handoff to Owner	Control Charts Process Map / Monitor / Response Plan Poka-Yokes Standardization SOP / Work Instructions Process Dashboards Capability Studies MSA or Gage R&R Documentation Final Report Presentation

Fig.17 – The Six Sigma strategic method, Skillab learning material

[16] Brue, 2002; Dambolena & Rao, 1994; Hahn et al., 1999; Harry, 1998; Pande & Holpp, 2002
[17] Breyfogle et al., 2001; Brue, 2002; Eckes, 2001; Hahn et al., 1999; Harry, 1998; Pande & Holpp, 2002; Pande et al., 2002

Define (D) is the first step of the Six Sigma methodology where leaders are expected to select projects, set initial goals or targets, and develop a project charter or *statement of work* (SOW).

Measure is the second step of the Six Sigma methodology and is denoted by the capital letter M. This is where a baseline measure is taken using actual data[18]. Pareto diagrams and controls charts as well as methods mentioned above in the define step are possible data sources for baseline measures.

The third step, A, is **Analyze**. Here teams identify several possible causes (X's) of variation or defects that are affecting the outputs (Y's) of the process. One of the most frequently used tools in the analyze step is the cause and effect diagram[19]. A Six Sigma team explores possible causes that might originate from sources, such as people, machinery and equipment, environment, materials, and methods. Another highly effective technique to expose root cause is asking "why" to a possible cause at least five times[20].

The team then enters the **Improve** (I) step. Here a team would brainstorm to come up with countermeasures and lasting process improvements that address validated root causes. The tool most preferred for this process is the affinity diagram, which is a brainstorming technique where a topic or issue is presented to a small team who then quickly list ideas or solutions[21].

The final step for at least the black belt and many of the team members is **Control**, which is signified by the capital letter C. At this point devices should be put in place to give early signals when a process is heading out of control. Teams may develop poka-yokes or mistake proof devices that utilize light, sound, logic programming, or no-go design to help control a process[22]. The ultimate goal for this step is to reduce variation by controlling X's (i.e., the inputs) and monitoring the Y or Y's (i.e., the outputs)[23].

[18] Eckes, 2001; Pande et al., 2002; Snee, 2003
[19] Eckes, 2001; Snee, 2003
[20] Eckes, 2001
[21] Eckes, 2001
[22] Breyfogle et al., 2001
[23] Pande et al., 2002

5.2 Roles & Responsibilities for Six Sigma

When a company decides to launch a Six Sigma project, it is particularly important to train the staff who - at different levels - has to implement the methodology. A Six Sigma project is managed by a team of 5 or 6 units (Team Members, TMS) selected according to their working knowledge and skills; those are the key players:

- **Team Leader (TL)** heads the team and, based on his expertise and leadership skills, has the task of pulling the entire organization in the setting up of quality standards.

- **Yellow Belts (YBS)**.

They have a knowledge base, first level, and the entire staff. The YBS involvement in projects is on a part-time basis.

- **Green Belts (GBs)**.

Their level of competence is certified by a Manager or a person in charge of operating the company. They provide support to the projects of the Black Belts and guide the projects in their area of expertise and scope. Green Belts are responsible for the achievement of goals and well-defined benefits.

- **Black Belts (BBs)**. People with tested and certified performance.

They are primarily responsible for the carrying out of the project with the aim of reaching clearly defined objectives and the benefits. If required, they also coach and train other team members. The Black Belts report directly to the person responsible for implementation and have a close relationship with the sponsor of the project during the project life.

- **Master Black Belts (MBBS)**.

They are involved in the education of *BBs* and *GBs*, through sessions training and communication, they identify new projects to be developed, monitor the integration of projects among the different business functions and ensure a proper and rigorous application of statistical techniques in ongoing projects.

- **Sponsor**.

Occupies a commanding position, is the first to remove the barriers and introduce Six Sigma into the company. The sponsor is responsible for selecting the project and is responsible for achieving business objectives, identifying deficiencies and opportunities improvement activity. He manages the implementation, monitors the progress of the project continuously, removes obstacles, prepares resources, and implements improvements in the process.

5.3 How does Six Sigma work?

The first step in the Breakthrough Strategy is to ask a new set of questions, questions that take you out of your comfort zone, that force you to query what you have taken for granted, and that ultimately provide you with new direction. Six Sigma forces businesses to let go of bad habits. By questioning the speed with which products are produced and services are rendered, people begin to think about new systems that can be put into place to produce a higher-quality product or service in a shorter amount of time. As those closest to the work discover more effective and profitable ways of working, they are able to inform senior management about what changes need to be made, and as a result, push those higher in the organization to reexamine the ways in which they do business. Six Sigma is about asking tougher and tougher questions until we receive quantifiable answers that change behavior. Through Six Sigma, companies relentlessly question every process, every number, every step along the way to creating a final product. Managers, employees, and customers ask different kinds of questions of each other than they've asked before. As Six Sigma takes hold across an organization, it creates an internal infrastructure that includes executives, managers, engineers, and operations and service personnel. When 50 percent or more of an organization's staff embrace Six Sigma, those individuals are able to mobilize massive changes in the way business is done, dramatically increasing profitability. The methodology behind Six Sigma is designed to pave the way to find the right answers for your company. The fact is, organizations need ways of measuring what they claim to value. Measurements, or "metrics" as we prefer to call them, carry relevance to every member, for every activity, of an organization. You can't change what you can't measure. The foundation of Six Sigma uses metrics to calculate the success of everything an organization does. Enthusiastic speeches, colorful posters, and corporate mandates will not produce quantum change-only measuring the things a company values can do this. Without measuring a company's processes-and its changes to these processes-it's impossible to know where you are or where you are going.

Six Sigma tells us:

We don’t know what we don’t know.

We can’t do what we don’t know.

We won’t know until we measure.

We don’t measure what we don’t value.

We don’t value what we don’t measure.

So, in a general way, Six Sigma is a process of asking questions that lead to tangible, quantifiable answers that ultimately produce profitable results

Chapter 6 - The rise of Lean 6σ

The current standard of quality output offered, the speed and mode and the promptness of delivery, together with the introduction of new products and services have become crucial factors for the success of a business. This context fits perfectly the *Lean Six Sigma* (LSS) model, which addresses the need of all companies aiming to pursue customer satisfaction through improvement and a "lean" manufacturing process. The Lean Six Sigma is a method of problem solving order that allows significant changes in the ways in which businesses operate and in the results they obtain, through a management philosophy and operational production activities and organizations. *The Lean Six Sigma* (LSS) approach not only aims to modify and improve the business performance of an industry, but also to create in each employee involved an awareness of the importance of this new way of acting and of the continuous improvement concept. The methodology bases its effectiveness on removing all the defects and all those activities that prevent an optimal performance of the production processes and aims to reduce the cost of poor quality which often absorbs a significant share of turnover. In contrast to the multiple and diverse methods of continuous improvement Lean Six Sigma right now proposes to quantify the savings from the economic point of view, highlighting the feasibility and the cost of a project. Implementing this method means, first of all, to approach the problem with order and clarity, leaving nothing to chance. It is therefore necessary to define precise objectives to be achieved, consistent with the resources a company has made available and a working group of heterogeneous individuals, the Team, who, with their skills and readiness to improve, are able to involve all the organization, to pursue and achieve excellent results. Implementing *Lean Six Sigma* (LSS) cannot have too long time horizons: the conclusion of a project must be made no later than one year from the beginning, limiting waste of time and resources, both indispensable tools for the business. The strategy is based on carefully listening either to the *Voice of the Customer* (VOC, Voice of Customer), i.e. to all customer requests, and to the *Voice of the Process* (VOP, Voice of Process), coming from the production processes that can either deliver or fail to deliver what is required. All these considered, the tasks is to identify the critical characteristics (CTQs, *Critical*

To Quality) for the process which has direct impact on customer satisfaction. This aspect allows you to focus on what is really important to a successful business, with considerable savings both in cost and resources used. By measuring these characteristics that affect more or less significantly the business performance we can understand what the real problem is, and hence improve.

6.1 Voice of Customer (VOC)

The need to apply the Lean Six Sigma to a specific process or to the development of a family of products should be based, as mentioned, on an accurate market demand analysis. To make this type of analysis, we need to have a structure able to relate effectively with our customers, so to derive the information needed to carry out the assessment of "Voice of Customer".
The first step, very often overlooked, is identifying the customer.
There are three kinds of clients:

- **Existing customers**, who use the product / service company.
- **Potential customers**, including the aspects to insist on, for a possible approach to the company.
- **Lost customers**, who represent a serious economic loss for the company, but also an opportunity to see and understand the mistakes made and to improve. There are several tools for collecting information, such as surveys, interviews (phone, email, direct), or comment card (used to gather feedback about the service) and field report (with information that a sales agent collects during the meeting with a client). To understand and realize the customer satisfaction is one of the most critical but profitable activities the company could run.

By choosing to adopt the Lean Six Sigma (LSS) method, we first decide to take action to improve the conditions deemed essential by the market, to be sure that the use of resources in certain areas is justified by true potentials offered. In the definition of VOC the following is of the essence:

- Clearly understand who are the customers (and are they internal or external to the company) through the market analysis and detailed mapping of the production processes.

- Identify consumer needs, as mentioned, through interviews, surveys, or other methods for data collection;
- Assess clients in a dynamic way, constantly monitoring the performance and satisfaction levels;
- Use information and data as inputs for planning and designing a strategy for customer satisfaction.

The ultimate goal of identifying the VOC is, in fact, to bring out the CTCs "*Critical to Customer*" features having an immediate impact on its satisfaction.

6.2 Voice of the Process (VOP)

For an overall assessment of a company it is useless talk about the customer if we do not know the process that delivers the goods required. It is therefore vital to understand the production processes and flow and to measure them. Each process must always be associated with indicators that allow defining performance. These values, collected over time, define the VOP, "*Voice of the Process*". Analyzing a process means quantifying the VOP in terms of:

- Waste or anything that brings no added value to the customer;
- Fluctuation in the value of deviation from a target that causes a drop in performance of the process, scrap and waste;
- Speed and value. Only through reliable data and objective business processes is it possible to identify where, how and when to intervene effectively to achieve a significant performance improvement.

6.3 Critical to Quality (CTQs)

Identifying Critical to Customers (CTCs) and understanding the Voice of the Process (VOP) analyzed so far, allow not only to implement the best possible measures aimed at increasing customer satisfaction, but also – most importantly – to focus on the key aspects of the process and on the product markets, which have a significant impact on the achievement of the final target (CTQs). The "*Critical to Quality*" (CTQs) represents the starting point for improvement and allows importing the Voice of the Customer (VOC) in the organization. In certain situations, the critical features for the customer (CTCs) can coincide with the characteristics critical to quality (CTQs). Generally, quality is the ability of a set of characteristics inherent a product, a system or a process to meet customer and other stakeholders' requirements. In Six Sigma, quality is defined by the customers through their specific requirements translated into an excellent product or service, which meet and exceed their expectations, but quality is also a set of actions and concepts generated by your business with a view to continuous improvement.

6.4 Methodology

The reproducibility of an event is impossible to achieve in enterprises, even in the most accurate working conditions. This is due to many factors including, first of all, the variability of row material, the tools, and the different degree of skill of the operators in carrying out their duties. As already observed with natural variability, the distribution of values measurement is not chaotic but follows the Gaussian model. According to the *Lean Six Sigma* (LSS) theory, the objective is to have 6 standard deviations between the upper specification and the center of production boundaries, and also between this and the lower limit. In other words, production must have a standard deviation of not more than one-twelfth compared to the width of the specification. In general practice this is not strictly followed and the method is considered as a tool for reducing defects. From an operational standpoint, Six Sigma is a rigorous, highly goal oriented and highly efficient statistical techniques and principles of quality; this methodology makes extensive use of the resources from traditional corporate quality, with the aim to make them more effective, with the target to achieve a global performance almost free of defects. It would be limited, thinking of Lean Six Sigma as a purely statistical method: it is first of all a business strategy that bases its success in engaging the resources of an organization and in the application of tools for improvement.

6.5 The DMAIC roadmap

To improve the existing situation in a company, Lean Six Sigma applies a rigorous problem solving method, DMAIC, which is divided into five phases: Define, Measure, Analyze, Improve, and Control (fig.18).

The improvement plan is developed for the project, coordinated by a heterogeneous working group, with skills and willingness to improve, but it can also involve the entire organization to pursue and obtain the wanted results. Indeed, Six Sigma lacks a vision of a streamlined production flow, focusing mainly on analysis and on the reduction of variability. Lean Production needs, on the contrary, a structured method of application, which allows it to integrate the company in an orderly and rigorous way. The DMAIC is not a random sequence of phases. It is a real philosophy in which each step has its logical justification.

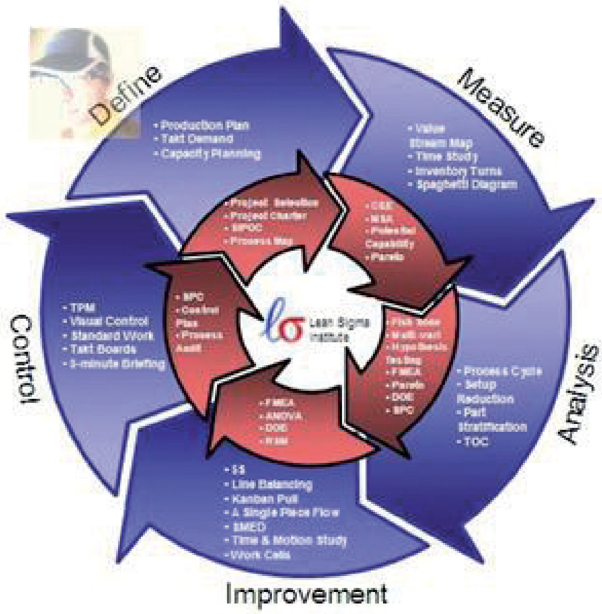
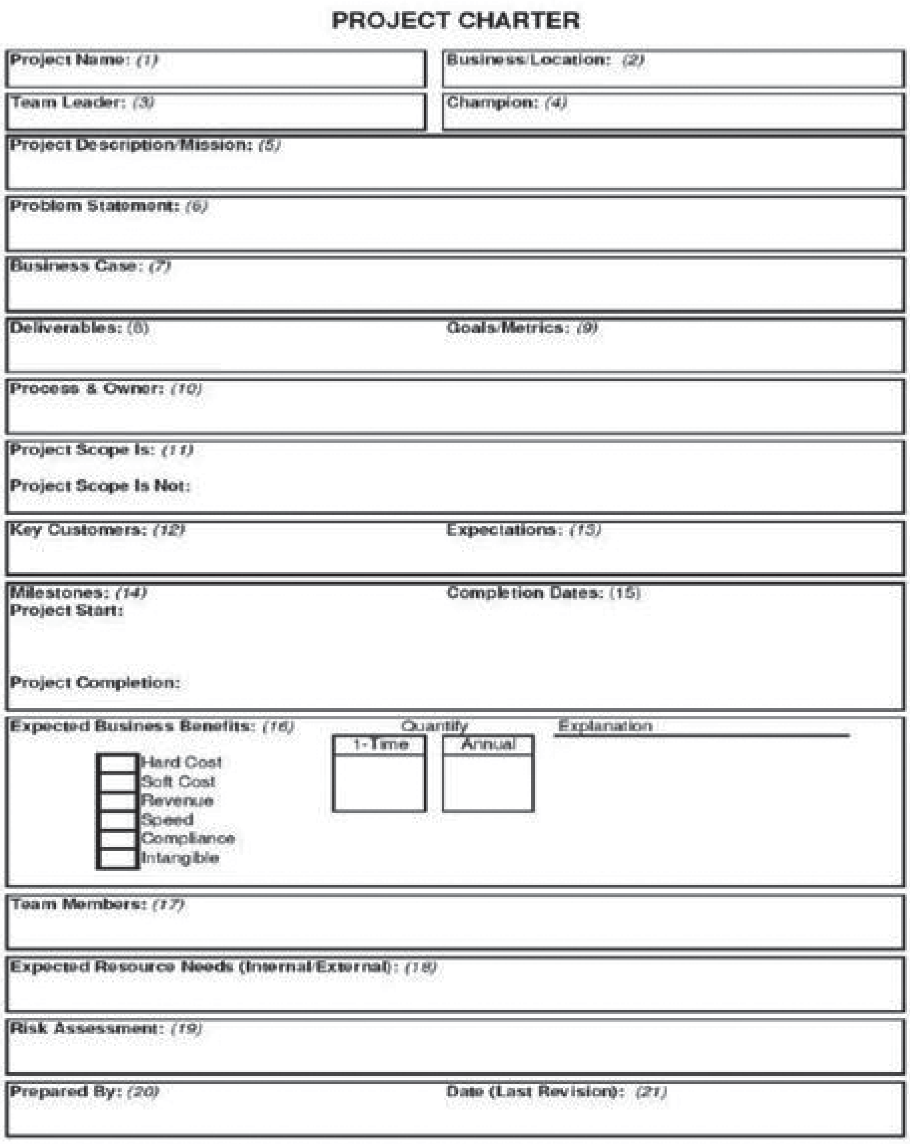


Fig.18 - DMAIC roadmap, Skillab Lean studies.

The method should be considered as a kind of mindset and is a structure to be followed to investigate and unravel an analysis at any level of detail. The DMAIC roadmap is divided into five operational steps, which allow achieving the goals through a rigorous path definition, measurement, analysis, improvement and control of a business problem. It is characterized by fundamental questions to which the project team should answer, and by tools to be used to provide those answers.

Improvement activities influence each other significantly. Obviously, performance errors can be fatal to the success of a process. The effective use of problem solving provides a non-linear course, sometimes cyclic: in fact, whenever new information and findings suggest a return to a previous stage, the project should be redefined or a change in approach might help reach a conclusion. Before a DMAIC work plan is drawn up, a Team Leader often defines a Project Charter, a document (Fig.19) formalizing the process.


PROJECT CHARTER

Project Name: (1)
Business/Location: (2)
Team Leader: (3)
Champion: (4)
Project Description/Mission: (5)
Problem Statement: (6)
Business Case: (7)
Deliverables: (8)
Goals/Metrics: (9)
Process & Owner: (10)
Project Scope Is: (11)
Project Scope Is Not:
Key Customers: (12)
Expectations: (13)
Milestones: (14)
Project Start:
Project Completion:
Completion Dates: (15)
Expected Business Benefits: (16)
Hard Cost
Soft Cost
Revenue
Speed
Compliance
Intangible
Quantity
1-Time
Annual
Explanation
Team Members: (17)
Expected Resource Needs (Internal/External): (18)
Risk Assessment: (19)
Prepared By: (20)
Date (Last Revision): (21)

Fig.19 - Project Charter, Skillab Lean studies

It should include:

- Economic and financial justification of the project;
- Defining the problem;

- Definition of objectives / expected benefits;
- Project plan, with a first time division;
- Roles and responsibilities of team members;
- Plan meetings (with the participants, objectives and deadlines). As the team is formed and works, the Project Charter will be updated improved and expanded, still under the control of Sponsor, first author of the project.

6.5.1 Define

Before it is chosen, a Lean Six Sigma project is preceded by a phase of selection and analysis of various available development alternatives. To implement a proper phase definition is useful to develop a set of interlinked activities, which are used to determine the objective achieved and the way forward. In general, an LSS project should be SMART, an acronym that serves as guide for selection. This means that a project must be:

- *Specific*
- *Measurable*
- *Achievable*
- *Relevant to the business*
- *Time-bound*

and therefore specific, measurable, feasible, important for the company and limited over time. The basic steps of the Define phase are:

- Identification of the objective to be achieved;
- Choice of the team that will follow the project and involvement of resources necessary;
- Determination of the Voice of Customer (VOC) and its Critical to Customer (CTCs);
- Mapping of the processes involved and identification of the Vice Process (VOP);
- Identification of the relevant Critical to Quality (CTQs), through the integration VOP of the CTCs.

The definition of the objectives must be carried out by the Project sponsor, which provides a comprehensive, structured activities, priorities and needs of a company. It is important that the objectives are clear and consistent with available resources. A prerogative critical to the success of a project Lean Six Sig-ma is in delineating the timing of application of the methodology, which must be relatively limited and must be capable of showing, and monitor constant progress of the improvement project. The setting of targets is joined to the creation of a valid working Team that manages to drag the organization towards the achievement of objectives. There is no standard procedure to identify what profiles are better suited for the development of problem-solving. The choice, in fact, must be done consistently with the objectives to be achieved and the characteristics of the personnel available.

6.5.2 Measure

When a problem is defined it means it can be measured, improved and monitored. In the Measure phase is necessary to identify critical inputs and outputs and define a method and metrics. The measurement is the basis of every Six Sigma project, as they guide the operations of the team and provide a reliable feedback which is essential to make progress. Relegating measurement to a specific section would mean oversimplification. The numerical approach can occur at any stage of DMAIC, each time data and information are required. The Measure phase includes a set of procedures that are easily adapted in any business situation and suggest a clear and ordered method to collect the data. The main step of the measurement phase are:

- Identification of the qualitative characteristic that helps to assess the processes analysis;
- Choice of the measuring instrument and reliability analysis;
- Measurement and data collection;
- Definition of value-added activities;
- Calculation of the main indices of capacity.

These variables are measured periodically in enterprises, without considering if they describe realistically the behavior of a system or process. Only through reliable data, we may identify where, how and when to intervene to obtain an improvement of corporate performance. In the absence of reliable and meaningful measurements, the line to follow is of course uncertain. That's why during the Measure phase, particular attention has to be dedicated to the collection data.

They must be:

- **Sufficient**: You must perform a sufficient number of surveys, as the higher is the number of parts analyzed the more you can trust in the output of the analysis, as it will be as much as possible adherent to the reality.
- **Relevant**: they must be collected only useful data which will assist in the framing of more problematic aspects.
- **Represented**: data must represent the "normal" conditions (with possible deviations and instability) of the process.
- **Contextual to Process**: together with data on variables it is useful to collect also the qualitative results of the process (such as yield, defect, DPMO).

6.5.3 Analyze

The analysis phase is at the heart of the LSS process. It is developed through careful evaluation of the data collected during measurement. These data need in fact to be compared with the required target in order to study and identify the gaps in place. The first objective is undoubtedly to assess the level of performance, focusing on chains of cause and effect between a company's products and their impact on customer satisfaction. The different tools that can be used allow us to identify the boundaries of the process variability root cause and to isolate the most influencing inputs from those less relevant for the process.

6.5.4 Improve

With the Improve phase, DMAIC reaches the top of its potential. In this phase, the aim of the Team is to apply to the system those adjustments that are necessary to increase the level of performance of the system, and thus ensure that outputs are perfectly in line with the required target. Then they need to find the solutions to the measured and analyzed issues and define the most effective one. Once the solution is defined, it has to be implemented and validated through a “pilot batch”, whose purpose is to validate effectiveness. Beyond the statistical analysis, the solution to be adopted can be chosen through brainstorming activities, dividing the solutions that can be implemented in the short term from those which cannot wait. At this stage, the role of the Project Leader is essential, as he/she has to try to encourage creativity and involvement of everybody, encouraging dialogue and considering all ideas, even the hypothesis that seem less effective.

6.5.5 Control

This phase represents the completion step of a Lean Six Sigma project; through it we want to check the process. Its objective is twofold: on the one hand, to verify if the process has reached or has failed to reach the expected level of improvement (monitoring) and whether it is able to sustain the achieved target over time and, on the other hand, to share expertise within the team. To achieve the first objective, it is necessary to implement an effective feedback system, which can be achieved through the “control plan”. It contains a matrix made up of a list of critical steps under control, with related targets, the implemented methods and improvements applied at this time. The validation of the control plan involves:

- Correctness of the solution, to be approved at an appropriate level.
- Review of the economic performance of the project.
- Adaptation/review of existing control plans.

During this phase, you must also:

- Confirm the economic benefits of the process.
- Define the project owner and the modification/improvement made.
- Close the project, recognizing the merits of the team and emphasizing savings from a financial and organizational point of view.
- Last but not least, update the Project Charter, verifying the results and showing the validity of the process.

Chapter 7 - The real world: some examples of real life

After all the theory illustrated in the previous pages, it is now time to show how all the concepts described can be applied in real life, which for us means: "manufacturing life". I will go through some issues raised over the last years and through the efforts pulled in solving them to show how clever enterprises can benefit from transformation. As previously mentioned, the change is a never ending process, a process which can show its start but not really the end, hence the name "*Continuous Improvement*".
Going through the examples, the problem is always the same: how to implement Lean philosophy smoother and how to get rid of waste. I would like to highlight at the very beginning that because of specific company policies some indications and names are fictitious. For the same reason I had to choose some examples from 3-4 years ago. Nevertheless, the flow of change was fully achieved and the results are absolutely real.

7.1 Case Study 1: XY-50 & QU-55 Front Seat driver assembly

Problem statement:

Currently, the process flow and the efficiency in the driver line (JIT) are rather poor. Current efficiency is 79% and the internal manufacturing system assessment is 62% (the lowest value in the whole plant) and there are pull systems only for trim covers, tracks, frames and foam.

Objective:

- Reduce DL manning from 26 to 24
- Improve DL hours/EQU from 1.08 to 1.02
- Improve the internal manufacturing process from 62% to 80%
- Add plastic components to Kanban process

The time plan:

	Original Completion	Revised Completion
Definition	03/06/2008	03/06/2008
Measure	10/06/2008	10/06/2008
Analyze	30/06/2008	30/06/2008
Improve	21/07/2008	21/07/2008
Control	30/07/2008	30/07/2008
Validation	30/10/2008	30/10/2008

Floors line Lean Assessment:

Fig.20 - The Lean assessment

Mapping the actual line layout:

The following picture shows which was the status of the assembly line for XY-50 & QU-55 Front Seat driver, highlighting the main roadblocks to be removed.

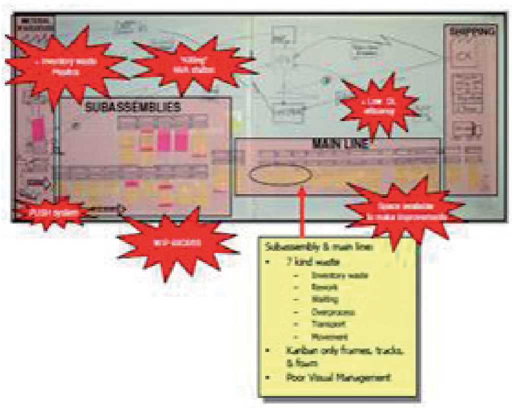


Fig.21 – Mapping the production line

Which are the steps to be progressively taken to come to the point? Which is the way for improvement? Let's check step by step.

1 - Overview of the actual stream:

The following picture shows where main focus was put considering the entire flow. The picture shows the detail of the actions to be implemented. For clarity sake, DL stands for "*Driver Line*".

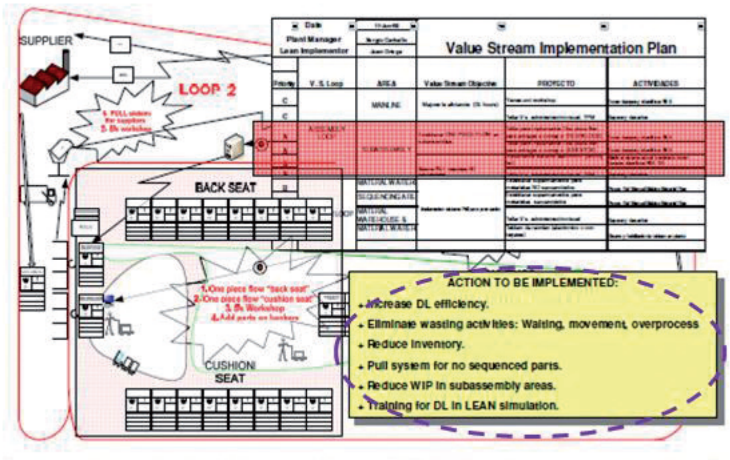


Fig.22 – The actual stream

2 - Determine what to measure (Y) and validate the measurement system:

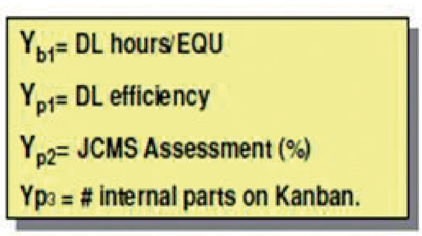


Fig.23 – The parameters to be measured

To better understand the above relations, it is useful to describe what is meant by EQU. A key Best Business Practices for a company is the principle to compare on an "**apples-to-apples**" basis. For this reason, JCI has developed an equivalent unit (EQU) measurement system based on the **product complexity**, **novelty** and **design responsibility** for a program. For example:

- seat EQU = one new row of bucket seats, new structures, minor mechanism changes and new foam, trim and plastics

- 0.15 seat EQU = one row trim refresh
- door panel EQU = two rows of all-new door panels
- overhead console EQU = one new overhead console

The company uses EQU values to evaluate the cost per EQU performance of completed or active programs.

3 - Quantify current performance and set improvement target:

In this phase we need to measure the process Y:

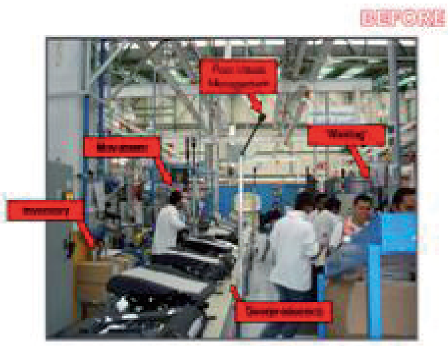
Yp (Baseline Process Y & Improvement target)

Measurable	Baseline	Objective
Yb1 = DL hrs/EQU	1.08	1.02
Yp1 = DL efficiency %. (std. Work charts)	79	85
Yp2 = Manufacturing system assessment (%)	62	80
Yp3 = # internal parts on kanban	80	80

Fig.24 – The measurables

4 - Muda is everywhere:

Now I will show what has been physically changed to achieve the target of Lean implementation and waste reduction.



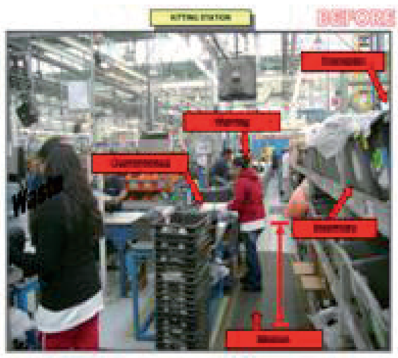


Fig.25 and 26 –Waste is everywhere

In the photos we can see how much waste was affecting the achievement of quality and production targets. To put it short, nearly all 7 types of muda as described by Womack and Jones are visible. That was the starting point to “put on a diet”, meaning implement cuts to improve, because we know we need to consume less (waste reduction) and exercise more even if this is something we never really want to do. But, it is necessary.

I – The path of improvement:

The following pictures will show the basic improvements to the old status. Those were simple but effective changes to the old status. As always change starts with small things.

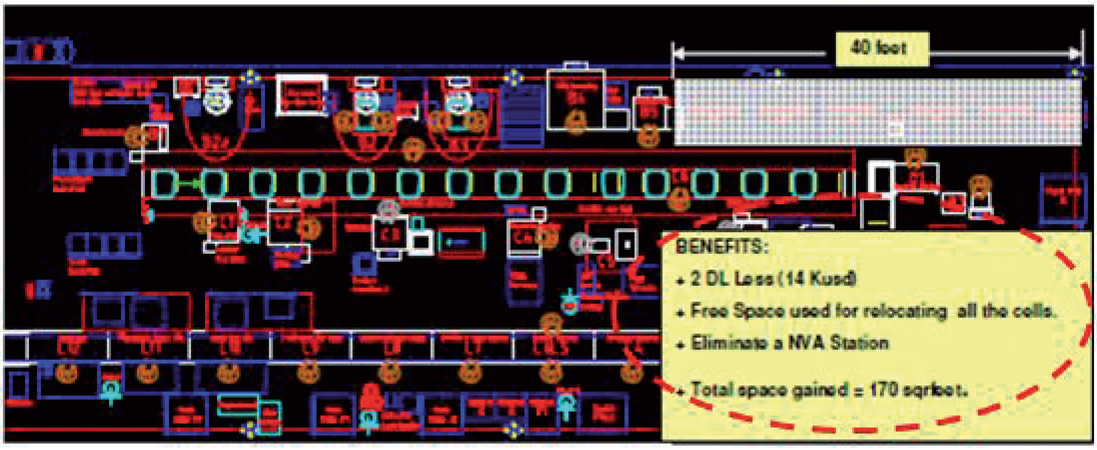


Fig.27 - Eliminating kitting station to enable material flowing at the point of use

Before

Fig.28 - The old status

After

Fig.29 - The new status

The result: All plastic shields relocated to the Point of Use (Main line) and Kanban implemented.

II - Eliminating ropacks on the line

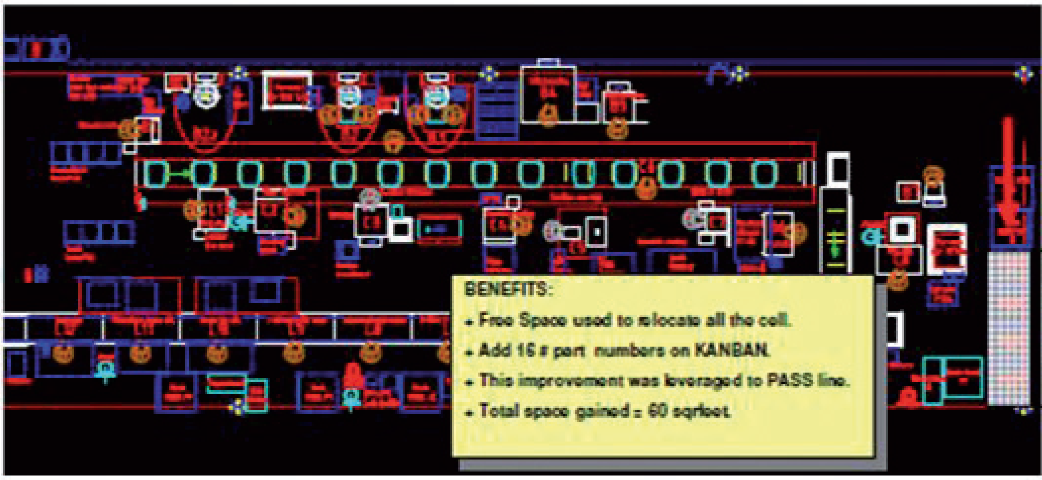


Fig.30 – Saving space

Before | **After**

Fig.31 - XY-50 headrest = 16 part numbers

Fig.32 - The new system

The result: Instead of having all the material at the shop floor, it has been sequenced directly from the warehouse area.

III - Headrest guide station relocated from subassembly cell to the main line

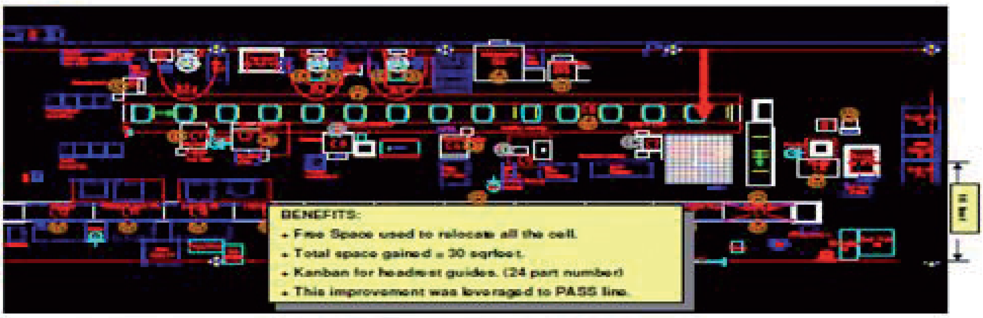


Fig.33 – Rationalization of the headrest flow to final assembly line

Before	**After**

Fig.34 – The old status

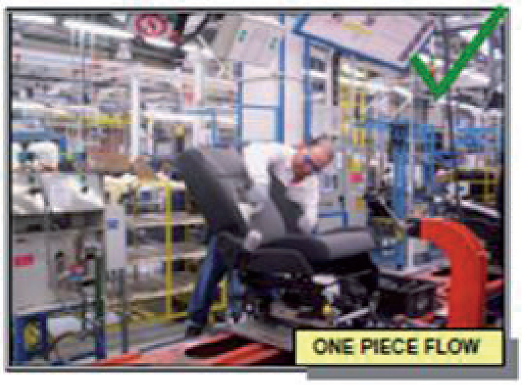


Fig.35 – The new status

The result: Introduction of the "one piece flow" methodology.

IV – Relocation of 13 stations from subassembly

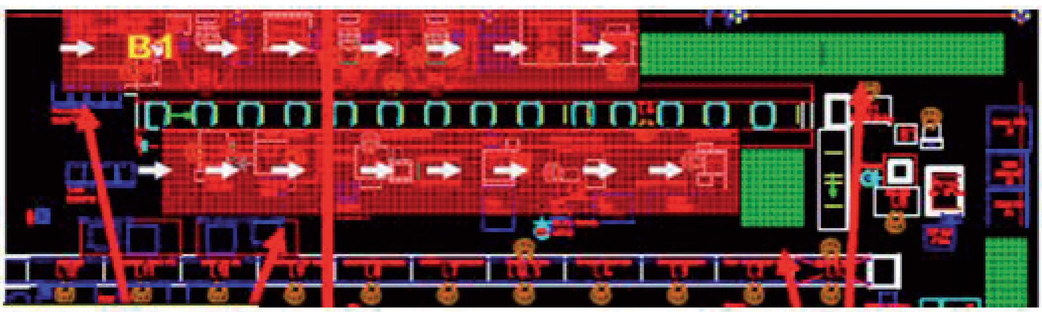


Fig.36 - Both back and cushion cells have been relocated to reduce work in progress (WIP)

Fig.37 - (Two) Belt conveyor modules have been eliminated

V – The last steps to improvement.

The following pictures will show the last 3 actions implemented to transform the old process into the new Lean one.

Before	**After**

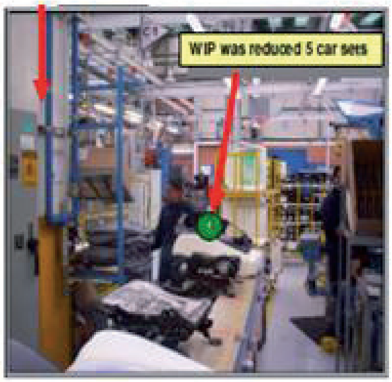


Fig.38 and 39 – Plenty work in progress

Fig. 40 and 41 – Reorganizing the ropack location

Fig. 42 and 43 – New racks implemented

VI – Finally!

The following matrix summarizes the improvements achieved by applying the above described corrections to the old processes. As shown, the results are significant although there is always room for improvement.

Measurable	Before	After	% Improvement
Yb1 = DL hrs/EQU	1.08	1.072	NA
Yp1 = DL efficiency %. (std. Work charts)	79	85	6%
Yp2 = Manufacturing system assessment (%)	62	80	18%
Yp3 = # internal parts on kanban	80	320	90%
Footage (sq feet)	0	600	100%

Fig.44 – The result summary

The improvements achieved in implementing all the above brought to a net saving in operation costs of 1,500,000Eur, which is not bad considering that it has been achieved just by changing the process on one production line.

7.2 Case study 2: Launch of CBY XX-49

Problem statement:

Launch of CBY XX-49 platform; the program has a forecasted volume of 161,850 pcs/year and 17 part numbers to be delivered to the customer.

Objective:

To implement the new CBY XX-49 processes based on Lean Manufacturing methodology. The developed layout must be flexible (w/o dedicated processes), have *Quick Changeover* and maximized machine utilization.

The Time plan:

	Original Completion	Current Estimated
Definition	01/03/2007	01/03/2007
Measure	03/03/2007	03/03/2007
Analyze	05/03/2007	05/03/2007
Improve	08/03/2007	08/03/2007
Control	14/03/2007	14/03/2007
Validation	14/06/2007	14/06/2007

Identifying what is important for the customer; *defining the scope*.

Fig.45 – The actual capabilities assessment

In defining what is important for the customer we found out the following key points:

- Culture& Awareness: Better understanding of Lean principles.
- Visual Management: Quicker reactions to problems and better overview of production area where improvements have to be carried out.
- Quick Change Over: Reduced Change Over time and flexible production plan.
- Material Control: Better stock control material flow.

Determining what to measure:

The following matrix summarizes all related actions and objectives to be measured. Those at the end compose the operational target of the activity.

Measurable	Objective
Operational Data Sheets Assessment (monthly)	5
5S ssessment (weekly)	95%
Number fof Kaizen Suggestion (Qty monthly)	15
Pokayoke Assessment in process (% monthly)	95%
TPM Assessment (% monthly)	8
Change Over Time (mins)	0.15
Parts on Kanban (pcs)	23
Supermarket areas (m²)	6
DL trained in Problem Solving (Qty)	3

Fig.46 - Production system Metrics

Measurable	Objective
Safety Assessment (weekly)	0,96
TPPM (RPPM+CPPM) (weekly)	31
RWPPM (weekly)	1260
IPPM (weekly)	7000
% Scrap (weekly)	0,17
LPA (Layered Audit) (monthly)	0,86
Production Plan Accomplishment (weekly)	0,98
Inventory Accuracy (weekly)	0,98
Machine Utilization (weekly)	0,835

Fig.47 - Operational Metrics

Indentifying the sources of waste:

The initial layout, from which the analysis started, had the following opportunities areas of improvement:

- Non-flexible design.
- Batch production (1 day on inventory).
- Non calculated supermarket areas (based on consumptions).
- Conveyance waste

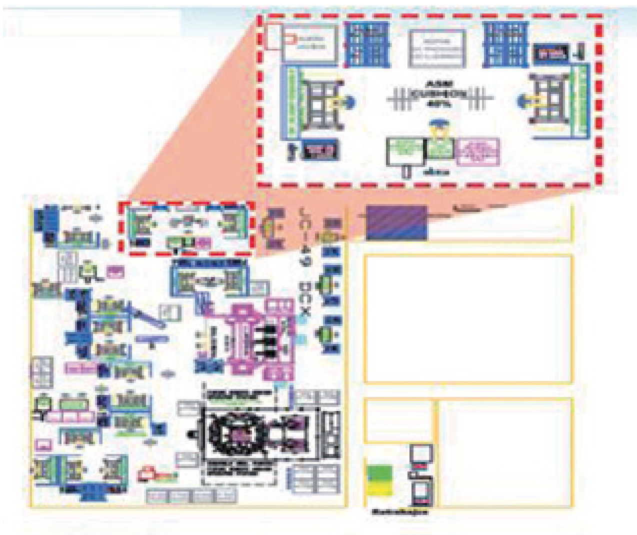


Fig.48 The starting point for the analysis

Evidence that the sources of waste are real:

Here I want detail why we considered real the source of waste identified.

Non-flexible design: - There was insufficient space for the Change Over.

- Distances between operations were too large.

Batch Production: - The layout has forecasted One Production Day as Inventory of finished Goods due to the lack of Tools Change Over Non calculated

Supermarket areas: - The layout does not include supermarket areas.

Conveyance Waste: - The layout location provoke large distances for material transportation from welding to painting area.

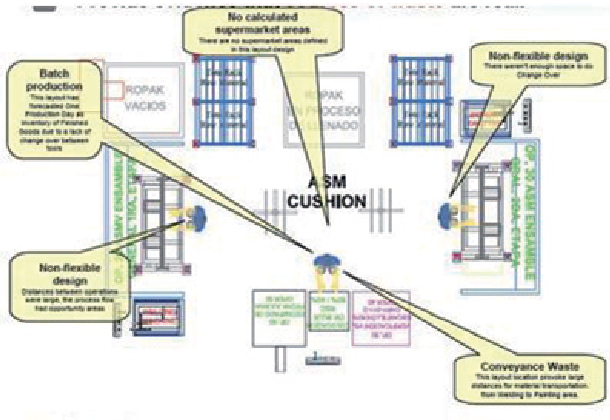


Fig.49 – The identification of waste

Determining solutions:

Here we describe how the team tackled causes, along the path of improvement.

Loop 1 – A productivity Kaizen was done to set continuous flow between general subassemblies.

Lean tools used: Lay-Out improvement, Balanced Operations.

Furthermore a *Quick Change Over* workshop was performed in order to implement all cushion models in these processes.

Loop 2 – A *Quick Change Over* workshop was performed in these operations (Norton Bushing to Pivot & Riveting Pop to Brackets) in order to produce withdrawn subassemblies from supermarket (applies to all models).

Loop 3 – A *Material Flow* workshop is being launched with the purpose of make logical “milk routes” (with a reordered board to suppliers), define part numbers in the *point-of-use* location and the creation of supermarkets on site.

Therefore, the original layout was changed due to the new tool racks to include supermarkets and thus improving material flow and a CI area. This new configuration allowed a flexible design, eliminated production batches, included supermarket areas (based on consumptions), and conveyance waste was reduced.

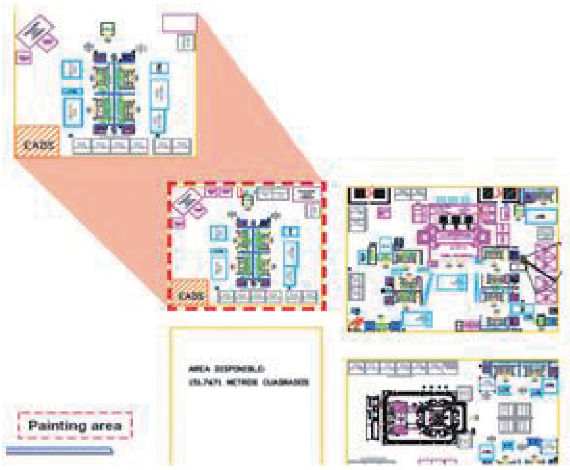


Fig.50 - The improved layout

Evidence of the improvements:

Here there are the details of the improvements brought by the reorganization of the existing layout.

Flexible design: - The new layout design allows implementing QCO: material racks, tool racks and processes flow were prepared in order to set a new model of production line

Elimination of Production Batches: - The new process flow allowed Quick Change Over, therefore production batches were eliminated.

Supermarket areas: - Supermarket areas were calculated based on customer requirements versus material consumption. All material was evaluated through the *Plan for Each Part* analysis

Conveyance Waste Reduction: - The new layout brought the Welding process close to the Painting one.

Some pictures of the improved areas.

1-Cushion Frames 2nd row 60% and 40% (5/7 passengers).

Fig.51 - Before

Fig.52 - After

2-Supermarkets: definition & identification at production area

Fig.53 - Before

Fig.54 - After

Implemented solution: evidence that solutions work.

As nobody can trust solely words, here is the indication of the net results of the improvement run on the production layout.

Measurable	Baseline	Objective	Current Results (Apr)
Operational Data Sheets Assessment (monthly)	N. A.	5	5
5S Assesment (weekly)	N. A.	95%	89%
Number of Kaizen Suggestions (Qty monthly)	N. A.	3	14
Pokayoke Assessment in process (% monthly)	N. A.	95%	85%
TPM Assessment (% monthly)	N. A.	95%	75%
Change Over Time (mins)	N. A.	35 min	35 min
Parts on KANBAN (pcs)	N. A.	23	0
Supermarket areas (m^2)	N. A.	6	6
DL trained in Problem Solving (Qty)	N. A.	3	5
Safety Assessment (weekly)	N. A.	96%	98%
TPPM (RPPM + CPPM) (weekly)	N. A.	31	0
RWPPM (weekly)	N. A.	1260	0
IPPM (weekly)	N. A.	7000	0
% SCRAP (weekly)	N. A.	0.17 %	0.05%
LPA (Layered Audit) (monthly)	N. A.	86%	N. A.
Production Plan Accomplishment (weekly)	N. A.	98%	100%
Inventory Accuracy (weekly)	N. A.	98%	100%
Machine Utilization (weekly)	N. A.	84%	N. A.

Fig.55 – A first summary of results

All improvements and best business practices generated in this area were then also implemented in Lower Frame and Back Frames layouts.

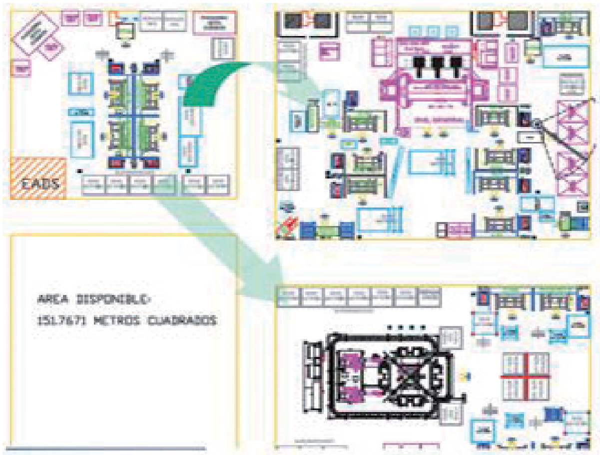


Fig.56 - The transferring to the Lower and Back frames

The key measure result summary:

Here we are at the end. The resulting summary is ready and the evidence of improvement has been sorted out. What has to be underlined is – again – the rationalization of operational processes that led to a net saving of more than 1,000,000 Eur.

Low Frames

Measurable	Baseline	Objective	Current result
Operational Data Sheets Assessment (monthly)	NA	15	15
5S ssessment (weekly)	NA	95%	90%
Number fof Kaizen Suggestion (Qty monthly)	NA	9	8
Pokayoke Assessment in process (% monthly)	NA	95%	65%
TPM Assessment (% monthly)	NA	95%	75%
Change Over Time (mins)	NA	NA	NA
Parts on Kanban (pcs)	NA	34	0
Supermarket areas (m^2)	NA	6	6
DL trained in Problem Solving (Qty)	NA	10	15
Safety Assessment (weekly)	NA	96%	96%
TPPM (RPPM+CPPM) (weekly)	NA	31	0
RWPPM (weekly)	NA	1280	0
IPPM (weekly)	NA	7000	0
% Scrap (weekly)	NA	0,17%	0,05%
LPA (Layered Audit) (monthly)	NA	86%	NA
Production Plan Accomplishment (weekly)	NA	95%	100%
Inventory Accuracy (weekly)	NA	95%	100%
Machine Utilization (weekly)	NA	84%	NA

Back Frames

Measurable	Baseline	Objective	Current result
Operational Data Sheets Assessment (monthly)	NA	5	5
5S ssessment (weekly)	NA	95%	87%
Number fof Kaizen Suggestion (Qty monthly)	NA	2	11
Pokayoke Assessment in process (% monthly)	NA	95%	85%
TPM Assessment (% monthly)	NA	95%	75%
Change Over Time (mins)	NA	NA	NA
Parts on Kanban (pcs)	NA	58	0
Supermarket areas (m^2)	NA	0	0
DL trained in Problem Solving (Qty)	NA	5	5
Safety Assessment (weekly)	NA	96%	96%
TPPM (RPPM+CPPM) (weekly)	NA	31	0
RWPPM (weekly)	NA	1280	0
IPPM (weekly)	NA	7000	0
% Scrap (weekly)	NA	0,17%	0,05%
LPA (Layered Audit) (monthly)	NA	86%	NA
Production Plan Accomplishment (weekly)	NA	95%	100%
Inventory Accuracy (weekly)	NA	95%	100%
Machine Utilization (weekly)	NA	84%	NA

Fig.57 The results summary for Lower and back frames

Measurable	Baseline	Objective	Current Results (Apr)
Operational Data Sheets Assessment (monthly)	N. A.	25	25
5S Assesment (weekly)	N. A.	95%	89%
Number of Kaizen Suggestions (Qty monthly)	N. A.	8	33
Pokayoke Assessment in process (% monthly)	N. A.	95%	85%
TPM Assessment (% monthly)	N. A.	95%	75%
Change Over Time (mins)	N. A.	35 min	35 min
Parts on KANBAN (pcs)	N. A.	115	0
Supermarket areas (m^2)	N. A.	21	21
DL trained in Problem Solving (Qty)	N. A.	18	25
Safety Assessment (weekly)	N. A.	96%	97%
TPPM (RPPM + CPPM) (weekly)	N. A.	31	0
RWPPM (weekly)	N. A.	1260	0
IPPM (weekly)	N. A.	7000	0
% SCRAP (weekly)	N. A.	0%	0%
LPA (Layered Audit) (monthly)	N. A.	86%	N. A.
Production Plan Accomplishment (weekly)	N. A.	98%	100%
Inventory Accuracy (weekly)	N. A.	98%	100%
Machine Utilization (weekly)	N. A.	84%	N. A.

Fig.58 Overall results or of the improvement

7.3 Case study 3: Stamp Components – Increase Machine Utilization

Project Highlights:

- Increased Press Department MU from 47% to 57%
- Decreased Dept. Downtime 544 min. per week.
- SMED (Single Minute Exchange Die) on die and coil changes
- 100% Stamping area trained in safety, receiving steel, coil handling, changeovers, press operations.
- Die Repair Procedure Improvement €723,000 Annual Improvements

The Time plan:

	Original Completion	Revised Completion
Definition	08/27/06	09/10/06
Measure	09/30/06	10/07/06
Analyze	10/31/06	10/31/06
Improve	02/28/07	02/28/07
Control	03/20/06	03/20/07
Validation	06/20/07	06/20/07

1 - Identify what's important to the customer. Define the scope.

Problem Statement: Lack-of press time for new business resulted in outsourcing dies.

Project Objective: Improve MU to 77% by reducing downtime; Address Top Downtime issues, Improve First Run Capability, Operators' Skill Set, and bring in additional business

Y_C = Improve MU%

Y_B = Cost of MU% ($ / press-strokes)

2 - Determine what to measure (Y) and validate the measurement system.

- Measure the defect/problem: "MSA Data Entry".
- Y_C Press Department MU is 47%.
- Y_B Downtime cost 241,000 Strokes per Week.

3 - Quantify current performance and set improvement target.

- Define and measure the process Y: (strokes per week) "Large Scale Effort".

479,000 Strokes/Week Capacity	Strokes/Week	
Downtime Reasons	Q406	Q207
Yp1 = Scheduled Down	57,450	29,056
Yp2 = Scheduled Tool Change	42,708	27,583
Yp3 = Maintenance Issues	40,838	20,842
Yp4 = Tooling Issues	29,421	15,576
Yp5 = Clean-up/Oper. Adjustments	16,607	12,571
Yp6 = Coil Change	15,856	10,278
Yp7 = Quality Issues & Set-up	3,030	1,088
Yp8= Tool Restricted SPM	268	58

Fig.59 – The available measured data

(Yp1) Scheduled Down, (Yp3) Maintenance Issues:

Issue - Scheduled Down & Maintenance Downtime averages: 98,000 Strokes/Week

Counter Measure:

- By-shift Maintenance Assignments Special Projects
- New "Die Lube" Supply and roller system
- Transfer Bar Sensor / Wiring
- Pretest gage developed
- Scrap Doors Rebuilt

- Bolsters' Drive Systems Improved
- Counter Balance & Overloads update
- Bolster Pump Relay upgrade
- Light Curtains Update
- PM / Repairs to feed line
- Nut Feeder Tracks improved
- Hydraulic Clamps Replaced

Results: 50,000 Strokes / Week $\Delta = 48,000$

€ 279,000 per Year Improvement

(Yp4) Tooling Issues, (Yp8) Tool Restricted Stroke Per Minute (SPM):

Issue - Downtime averages: 29,000 Strokes / Week

Counter Measure: Top-5 Worst Performing Dies Graphed & Road-mapped

- Scheduling System
- Die Line-up per Demand
- Die Status Communication
- Die PM tracking improved
- GRN / RED Tagging
- Work Order system
- Status Communication board implemented
- Relocate Tooling Specific components to Tool Room
- Point-of-use inventory management
- Dedicated Scrap Chutes per Die (off fall mgt)
- SPM Improvements
- Tooling Updates
- Larger Leader Pins / Bushings
- Localized Gravity Pins
- Scrap Shed rates increased
- Cycle gram Tuning (Transfer System Improvement)

Results:

16,000 Strokes / Week $\Delta = 13,000$

€75,000 per Year Improvement

(Yp7) Quality Issues, Training Effectiveness:

Issue - Downtime averages: 3,000 Strokes / Week

Counter Measure: Operator Training (JCI – Fundamentals, VU P1, 2)

- Rockwell Hardness Testing
- Inspection of Parts
- Gauging Parts
- Types of Defects
- Lot Traceability
- Last piece / First piece Inspection

Results: 64 hrs of OJT - 22 Operators 100% Trained Power Press & Die Setter

TRAINING EFFECTIVENESS:

(Pre-Test to Post-Test Scores)

Phase	*I*	*II*
	21%	18%
FINAL EXAMS		
	93%	91%

1,100 Strokes / Week $\Delta = 1{,}900$

€ 11,000 per Year Improvement

(Yp1) Changeovers, (Yp6) Coil Change, (Yp5) Operator Adjustments:

Issue - Downtime averages: 61,000 Strokes / Week

Counter Measure: Nitrogen Tanks updated from (1) one per press to (6) six per press

- Operator Skill Training
- Coil Handling
- Steel Issues
- Straightener / Feeder Adjustments
- Finger Adjustment
- Crane Operation
- SMED

Results: 39,000 Strokes / Week $\Delta = 22{,}000$

€128,000 per Year Improvement

Fig.60 – The Single Minute exchange Die (SMED) diagram

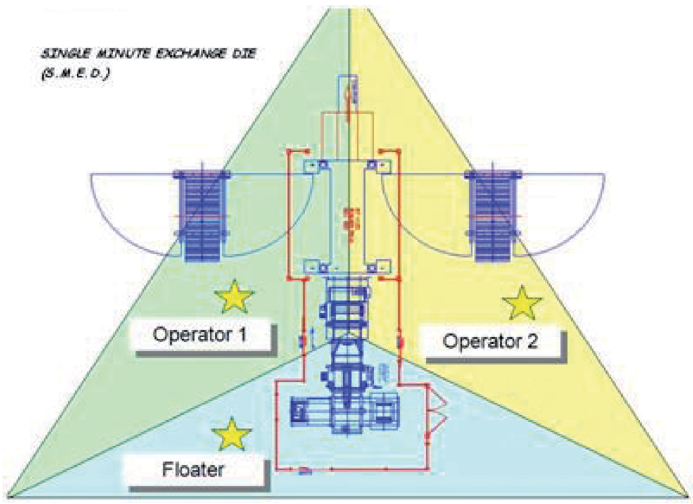


Fig.61 – The Single Minute Exchange Die (SMED) Layout

SMED Results:

- Twelve Changeovers Performed,
- Six Changeovers Videoed, Reviewed, and Analyzed
- Two S.O.P.s written
  - ↳ Three Man Changeover &
  - ↳ Two Man Changeover

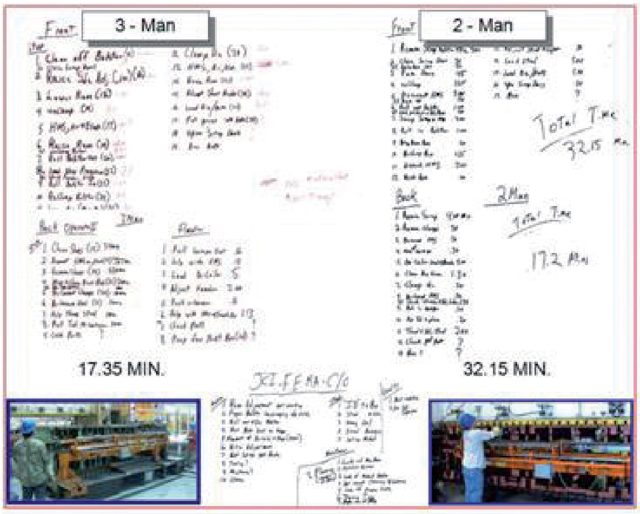


Fig.62 – The single Minute Exchange Die (SMED) results

Summary:

Measurable	Baseline	Objective	Results
Walking Distance	405 ft (6.75 min.)	150 ft (2.5 min.)	135-202 ft (2.25-3.38 min.)
Changeover time	27 min.	20 min.	17.35 min.
Head Count	2	2 + 1 indirect	1-3
Coil Stock on KANBAN	0	72	72
Stock Value On Hand	€930,000	€460,000	€250,000
Trained Press Operators	75%	100%	100%

Fig.63 – Single Minute Exchange Die (SMED) Key Measures

Project Savings: Downtime 93,000 Strokes per Week Gain and all dies back Feb-07

€573,000 Improvements Three operators reassigned $150,000

€723,000 Improvements

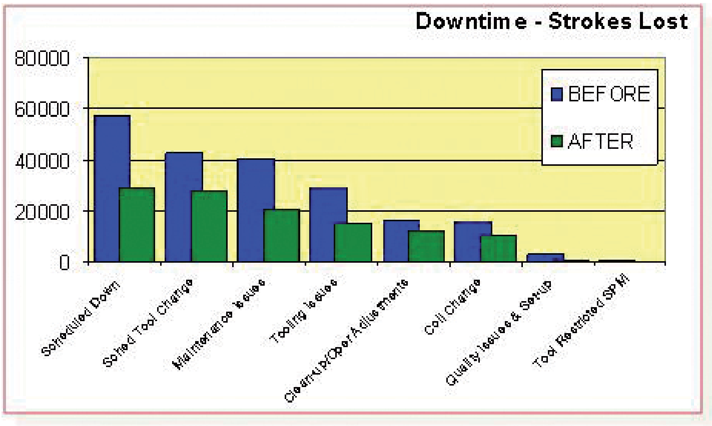


Fig.64 – Downtime vs. Strokes lost

The developed case studies illustrate whether it is possible to benefit from the application of the techniques deriving from the Lean and Six Sigma philosophy. Doubtless the process is long and complicated and has to be run as smooth as possible, but it is necessary. It is necessary because enterprises need to be "light" and flexible. There is no space left for the obsolete dinosaurs of the mass production age. Today things run 10 times faster than10 years ago and speed is increasing not year by year, but program by program; it is the way to compete in today globalized market.

Chapter 8 - Conclusions

It is true, theory is important and the techniques and tools are fundamental but what added value do they have without manpower?

Consumers all over the world now have more vehicles to choose from than ever before, and the variety of choices has put tremendous pressure on car manufacturers to deliver innovative vehicles with high quality as efficiently as possible. Miss the mark on any one of the requirements and it is highly probable that the consumer will pick something else. Competing in this global environment, automotive and transportation companies must be able to:

- Develop vehicles on a global basis leveraging common architectures but meeting local requirements;
- Leverage low-cost country opportunities to reduce development and production costs;
- Make certain that vehicles are appealing to consumers and contain the innovations they demand;
- Maintain an effective supply chain strategy that keeps costs down and captures innovation at all levels;
- Maintain or improve the quality levels that have become the price of entry in the minds of consumers;
- Squeeze every bit of efficiency out of the design, engineering and production operations to ensure cost competitiveness.

While every change is different, the typical obstacles to change usually include some of the following:

- Employee resistance. Sometimes it can derive from a lack of understanding of what is driving the change and the immediate or long-term benefits of making a change.

- Employee morale issues. Often times these are due to fear of how the change may affect them personally.

- Communication breakdown. This can include the full spectrum of communication issues, from no communication whatsoever to excessive communication that leads to confusion and frustration.

- Insufficient or lack of training. Changing processes, work habits, or policies often requires significant employee re-training.

- Employee turnover. Even though change may be beneficial to the organization, some employees will feel their values are no longer aligned with the company values, and decide to leave.

- Budget restraints. Significant changes in an organization can sometimes bear a heavy upfront cost, despite their long-term potential to save money.

While successful change implementation requires buy-in and support at all levels throughout an organization, first line managers in particular play a significant role in ensuring the success of change initiatives as of their relationship with their respective teams, and because they can drive operational change in a very hands-on and involved way. This could be the way a manager could operate to address them in a very direct way:

- *Employee resistance*. To address "employee resistance", a manager can explain the rationale behind change initiatives and highlight immediate and long-term benefits for the organization at large and the employees themselves.

- *Employee morale issues*. By addressing concerns, questions and anticipating employees' fears, a manager can help improve morale during difficult transition times. Building the relationship with employees can also help in this area, as employees will feel more comfortable voicing their concerns if they have a good working relationship with their managers and peers.

- *Communication breakdown*. Communication – clear, concise, timely – is a crucial component of any change initiative, and can have a huge impact on its success or failure. Communicating key information in a timely manner, providing feedback to upper management, and addressing questions and conflicts right away can make a world of a difference during the implementation phase.

- *Insufficient or lack of training*. Providing training, feedback, and supervising employees to ensure adherence to new processes are all key ingredients and represent a key part of a manager's responsibilities.

- *Employee turnover*. A Manager should continuously gauge their team members' motivation and loyalty, to ensure turnover is kept at reasonable levels.

- *Budget restraints*. To ensure budgets are appropriate, a manager should ideally provide input into budget discussions and give feedback along the way to upper management, letting them know of any budgetary concerns and possible solutions.

Whatever change we will run, most likely the above-mentioned "rules" will not be working in isolation. More and more, results can only be achieved through people working in collaboration – in teams. People, and only people, can make the organizational change happen. The time spent in developing this paper provided the opportunity to learn about a whole new world as interesting and as large and dense in issues, which are not only of technical and technological nature, but are specially and above all related to people, as it is from people where change comes from. Each change-driven experience is closely based on the continuous collaboration between multiple entities, distinct and different one from another, with a continuous exchange of views and the awareness of how important the work of peers and subordinates is for the carrying out of one's duties. This supports the belief - if proof is still needed – that teamwork is of the essence, with the sharing of responsibilities, the accountability of resources, and the praise and reward for achieving good results. This first-hand experience is tremendously helpful because - as detailed in the previous chapters - the theory of change and continuous improvement is not an exclusive legacy of the manufacturing environment, but is a philosophy that can be applied in our daily routine and in everything we do... it is a philosophy of life!

Glossary

Analyze - The third phase of the DMAIC process in which the details are analyzed for improvement opportunities.

Black Belt - A Team Leader, responsible for measurement, analysis, improvement and control of key processes that influence customer satisfaction and / or productivity growth. A full time position.

Change Agents - Figures considered points of reference within the Team whose task is to introduce, motivate and support the coming change within the company. These resources have basically two tasks: first, to identify priorities that characterize different areas, motivating decisions taken and the necessary planning for technical support, and speed-up the deployment of the other LSS, with the aim of avoiding unnecessary extensive the deployment of resources.

Client - In the LSS, refers to any person inside or outside involved by the output (product or service) process. Understanding the impact the process has on both the internal and external customers is key to management and process improvement.

Control - last phase of DMAIC in which the stability of performance improvements is checked once solutions are implemented.

Critical to Customer, CTCs - Features critical for the customer, as determined by the Voice of the Customer, directly impacting their satisfaction.

Critical to Quality, CTQs - The starting point for improving process. These are the qualities that have the biggest impact on the asset yield.

Define - The first phase of DMAIC in which problems, opportunities, and customer needs are defined.

Defects - Failure of a product or service to meet customer expectations.

DMAIC: Define, Measure, Analyze, Improve, Control - Process for continuous improvement. This closed-loop process eliminates non-productive phases, focusing on new measurements and applying the technology for improvement.

DPMO - Metric or LSS index introduced in order to standardize the values detected and allow a proper benchmark. The calculation allows quick assessments on process dispersion and variability.

Green Belt - Team Leader, responsible for measuring, analyzing, improving and controlling key processes that influence the satisfaction reviews and / or productivity growth. A part-time position.

Improve - Fourth stage of DMAIC in which ideas and solutions are generated.

Lean Production - management and organizational model that allows achieving a structure in which the main objective is to optimize the production system, in terms of process speed and waste elimination.

Lean Six Sigma, LSS – A comprehensive, flexible and highly disciplined methodology for achieving, maintaining, and increasing the success of a business.

Sigma Level - Metrics based on the number of defects that occur each million possibilities.

Master Black Belt - Teacher and mentor for the Black Belts organization. The selection criteria for the MBB are quantitative skills, teaching and mentoring. It is a full time position.

Measure - Second phase of DMAIC in which key measurements are identified and data are collected.

Metric – Performance index of a company that wants to indicate whether a goal is reached or not.

Minitab - Statistical analysis program and complete graphics, designed entirely for Quality Control, management of statistical analysis, the creation of control charts and, in a particular way, the approach to Lean Six Sigma methodology.

Process - A set of sequential operations, usually functional, organized on the basis of a given result.

Project Charter - A document that defines the context, specifications, and plans of a proposed improvement, including definitions, problems and objectives, constraints and assumptions, roles and preliminary plan. Periodic reviews with Sponsors ensure alignment with business strategies.

Quality - The ability of a set of characteristics inherent in a product, system or process to comply with requirements of customers and other stakeholders.

Six Sigma - An approach to the continuous business improvement aimed at customer satisfaction. Performance of the processes that achieves 3.4 defects per million opportunities for each product or service.

Sponsor - Person giving final approval to the projects allocates resources to the projects, Black Belts and helps the implementation team to overcome obstacles.

Voice of the Customer, VOC - Data, such as surveys, interviews, market research, and inquiries that represent the vision and expectations of the customer or the company.

Voice of the Process, VOP - Set of production processes that deliver the required goods and identify Critical to Quality, CTQs.

Yellow Belt - Joins the project by joining the team requiring support. A part-time position.

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