LEAN SIX SIGMA IN THE SERVICE INDUSTRIES

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SYNOPSIS

Compañía Logística de Hidrocarburos CLH, S.A. renders logistic services related to the storage, transportation and distribution of all kinds of hydrocarbon and chemical products in Spain. CLH's commitment to quality, health, safety and environmental stewardship extends from the Board of Directors to employees in the field. CLH has five certified QMS's, adapted to the new ISO 9001:2000 standard, and it is exploring new ways of improving quality, namely, the Six Sigma and Lean methodologies.

The aim of this paper is to explain what Lean Six Sigma is about and whether it can be used in service organizations as effectively as in manufacturing.

Lean Six Sigma combines the two most important and popular quality movements of today: Lean Production and Six Sigma:

Lean Manufacturing is a business method or technique that identifies and eliminates value stream waste to achieve speed and agility at lower cost. Lean aims at maximizing process velocity. It uses process flows and delay times analysis tools with each activity of each process and focuses on the discovering and separation of value-added and non-value-added activities. This done, the next step is to discover and eliminate the root causes of non-value activities and their costs.

Six Sigma is a structured framework (some people claim it is a Management System) that focuses on economic results, by the control and reduction of process variability of those product or service characteristics critical for the external and also for the internal customer (CTQ's). It requires the use of scientific methods and well-trained experts (Master Black Belts, Black Belts, etc.) in order to resolve and to eliminate the root causes of variability. The study and application of Statistical Methods is a must in this methodology. When correctly implemented, supporters claim it can improve the "bottom line" of the company by more than $ 500.000 per Black Belt per year.

While the focus in Lean is on eliminating Muda (waste), the Six Sigma focus is on reducing variation, i.e. to have processes with one defective item per one thousand million produced (The magic number of 3.4 defectives per million, if Process Mean is not controlled and allowance is made for a shift of the mean of 1.5 sigma in value).

Lean Six Sigma was born in the manufacturing environment, but can be very well applied to the service industries and transaction and services processes. References are given in the paper of the application and success of Lean Six Sigma to improve Services and transactions

WHAT IS LEAN MANUFACTURING

One can define **Lean Manufacturing** (often referred to as "lean") as a discipline that uses a set of tools and principles to shorten cycle time, reduce inventory, eliminate waste (Muda in Japanese) and increase throughput in the processes to make the products or to provide the services that customers demand. The goal of "Lean" either for Production or for Services is described as "to get the right things to the right place at the right time, the first time, while minimizing waste and being open to change"

Lean production is a methodology developed originally for Toyota and the manufacture of automobiles. It is also known as Toyota Production System (TPS). Three men were credited with creating TPS: Sakichi Toyoda; his son Kiichiro Toyoda; and one of their engineers named Taiichi Ono.

Sakichi Toyoda invented an automatic loom in 1902 that would stop automatically if any of the threads snapped. The invention reduced defects and raised yields.

In the 1930's Sakichi's son, Kiichiro, as the head of the newly started automobile manufacturing, travelled to the U.S.A. to the Ford Motor Company in Detroit for a year to study Henry Ford's Production Systems. When he returned to Japan he had a strong determination to adapt those Systems to the small production volumes of the Japanese market. In addition to the smaller production quantities, Kiichiro's System provided the different processes in the assembly sequence with only the kinds and quantities of items that they needed and only when they needed them. The solution provided for different processes in the assembly sequence of production, the logistic of materials simultaneous to production consumption, and a supplier network capable of supplying component material as required. Production and transport took place simultaneously throughout the production sequence, inside and between all the processes. He is credited for coining the term "Just in Time" (JIT), as the system was referred to in the Toyoda Group.

Taiichi Ono did the most to structure the TPS as an integrated framework. He launched a new approach to just-in-time production after his stay in the U.S.A. in 1956 to visit automobile plants. His most important discovery was done not in the automobile sector, but in the service sector: the supermarket operation. He was really impressed at the way customers chose exactly what they wanted, when they wanted and in the quantities they wanted. The situation of Japan after WWII was, in the production sector, under severe conditions of material shortages as a result of the war. He developed improved methods of supporting the assembly operations. Ohno himself credited his system to two sources: a) the basis of a manufacturing production system from Henry Ford's book *Today and Tomorrow,* and b) the supermarket operation that he observed in the United States during his visit. Later he described his production system as if the production process was a supermarket. Each line became the customer for the preceding line. And each line became a supermarket for following line. The latter would come and choose the items it needed and only those items. The former line would produce only the replacement items for the ones that the following line had selected. This scheme, then, was a "pull system", driven by the needs of the following lines. It contrasted with the traditional "push system", which were driven by the output of the preceding lines.

The Ono's system can be illustrated by the TPS's "house". The roof of the house is formed by Highest Quality, Lowest Costs and Shortest Lead Time, and this roof stands on two pillars, **Just-in-time** and **Jidoka**.

Just-in-time: We have already talked about it. This concept refers to the manufacturing and movement of only what is needed, when it is needed, and in the amount needed. This increases efficiency and allows for fast response to change.

The Just-in-Time pillar contains the concepts of Continuous Flow, Takt Time and Pull System. The first and last topics have already been mentioned. Takt Time is often considered as one of the seven Lean Tools (the other being: 5S, the 7 wasted, changeover reduction, Kanban, Poka Yoke, Lean communication and TPS). We now briefly explain what Takt Time is. It is customarily defined as the pace of production to meet customer demand. That is, the quotient between "available time" and "customer demand". Let us look at some examples:

Automobile Assembly line:
Available time = 7.5 hr. x 3 shifts = 22.5 hrs or 1350 minutes per day.
Demand: 1600 cars per day.
Takt time: 51 seconds per car.

Aircraft Engine Assembly line:
Available time = 7.0 hr. x 2 shifts = 14 hrs / day x 250 days/year = 3500 hrs.
Demand: 500 engines per year.
Takt time: 7 hrs per engine.

You can very easily apply the Takt Time concept to the supply of services as well.

Jidoka: This defect detection system (recall Sakichi Toyoda and his automatic defect proof loom of 1902) automatically or manually stops the production operation, or the supply of a service, whenever an abnormal or defective condition arises. Any improvements can then be made by analyzing and improving the stopped equipment or service and it is done by the worker who stopped the operation. The Jidoka system trusts and empowers the employee as a problem-solving agent and allows any employee to stop the process he is working on.

The Jidoka pillar contains the concepts of "Stop and notify of abnormalities " and " Separate man's work and machine's work".

The foundations on which the two TPS's "house" pillars stand are **Heijunka**, Standardized Work and **Kaizen**.

Let us say a few words about Heijunka. This method of levelling production on the line makes Just-In-Time production possible. This involves averaging both the volume and sequence of different models types (or services) on a mixed model production line. The system does not build products according to the actual flow of customer orders. Heijunha takes the total volume of orders in a period, say a week, and levels them out so the same amount and mix are being made each day.

Demand levelling breaks down the total volume of orders for a given planning period (e.g. two months, one month) into scheduling intervals (weekly, daily). A heijunka calculation then defines a repetitive production sequence for that scheduling interval, which dictates the **model mix scheduled** on a given line. This schedule is put into operation through the production and distribution of kanban cards or signals for the mix of products. By running small, even batches of many models over short periods of time, producers can maintain low-level inventories, throughout the manufacturing process.

Heijunka is the levelling of production by both volume and product mix. This system does not build products according to the actual flow of customer orders. *Heijunka* takes the total volume of orders in a period and levels them out so the same amount and mix are being made each day. In a true build-to-order system you build products $\mathbf{P_1}$ and $\mathbf{P_2}$ in the production sequence of customer orders (e.g., $\mathbf{P_1}$, $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_2}$, $\mathbf{P_2}$, $\mathbf{P_1}$ …). This causes you to build products irregularly. If your orders are twice as much on Monday compared to Tuesday, you end up paying overtime on Monday and sending employees home on Tuesday. The answer is to build a level schedule everyday by taking the actual customer demand, determine the pattern of volume and mix, and building your level schedule. If you know you are making six $\mathbf{P_1}$'s and six $\mathbf{P_2}$'s, you create a level schedule of $\mathbf{P_1}$, $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_2}$, $\mathbf{P_1}$, $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_2}$, $\mathbf{P_1}$, $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_2}$ This is called mixed-model production.

By reducing changeover time and employing other Lean methods, the producer is able to build his products in any order he wants to on the mixed model assembly line. The four benefits of levelling production are: a) Flexibility to make what the customer wants when they want, b) Reduced risk of unsold goods, c) Balanced use of labour and machines, and d) Smoothed demand on upstream. *Heijunka* will eliminate waste, but most important will level out the demand for labour, equipment, and supplies.

The other two concepts that are in the foundations of the pillars of the Lean House are: Standardized Work and Kaizen.

Standardized Work: In the TPS consists of three elements: Takt-Time, Working Sequence , and Standard In-Process stock.

Takt-Time, we have already referred to.

Working Sequence refers to the sequence of operations in a single process which allows the worker to make quality goods efficiently and safely.

Standard In-Process stock refers to the minimum quantity of parts always on hand for processing.

Kaizen refers to continuous improvement and it has already been treated extensively in this and previous Congresses.

We can summarize "Lean" by indicating its ten rules, its eight tools, part of which have already been mentioned, and its seven wastes:

<u>The Ten Rules</u>

1. Eliminate waste (Muda)
2. Minimize inventory
3. Maximize flow
4. Pull production from customer demand
5. Meet customer requirements
6. Do it right the first time
7. Design for rapid changeovers
8. Partnership with suppliers
9. Create a culture of continuous improvement
10. Workers' Empowerment

<u>The Lean tools</u>

1. The five S' (Seiri, Seiton, Seiso, Seiketsu, Shitsuke: Sort, Straighten, Scrub, Systematize and Standardize)
2. The seven Wastes (See below)
3. Changeover reduction (Single Minute Exchange of Dices - SMED)
4. Kanban (Pull signalling system)
5. Poka Yoke (Fool proofing or creating failsafe mechanisms)
6. Lean Communications (Team briefings)
7. TPS (see above)
8. Takt-Time (see above)

<u>The seven Wastes</u>

The seven wastes as described by Ohno are:

1. Overproduction
2. Idle time (time when no value is added to the product or service). Here, SMED will help to reduce setup and adjustment times from hours to minutes,
3. Unnecessary moving or handling
4. Unnecessary raw materials in stores, work in process (WIP), and finished stocks.
5. Movement of equipment or people that add no value to the product.
6. Over-processing, work carried out on the product which add no value.
7. Defective unit production or reworking scrap.

In 1990 James Womack wrote a book called *"The Machine that Changed the World"*. Womack's book was the result of five years of research led by the Massachusetts Institute of Technology (M.I.T.) and he coined the term "Lean Production" to indicate that TPS was so much more effective and efficient than traditional American and European automotive assembly mass production plants

WHAT IS SIX SIGMA

You have already heard a lot of Six Sigma in this Congress and its DMAIC process. Let me only address a couple of topics in relation to the Six Sigma Metric.

The term 6 sigma was coined by Motorola Corp. in the early eighties, when Motorola's CEO at the time, Bob Galvin started the Company along the quality path. After Motorola's director of quality Richard Buetow and other company executives made a trip to Japan the company adopted the program Six Sigma that reduced defects by 99,7% and saved the company US $ 11 billion from 1987 to 1996. Credit has to be given to two Motorola engineers: Bill Smith, who coined the term "Six Sigma", and Mikel J. Harry, who introduced the concept of Six Sigma to the Company. In 1998, Motorola Corp. became one of the first companies to receive the Malcolm Baldrige National Quality Award.

Citibank, the international financial division of Citicorp, undertook the six sigma method in the spring of 1997. Its goal: to reduce defects within its various divisions by a factor of 10 during the first three years. The corporation has already seen reductions from five to 10 times. General Electric, which launched a six sigma initiative in late 1995 says the $ 300 million invested in quality improvements in 1997 has delivered some $ 400 to $ 500 million in savings.

Besides Motorola and G.E., Dupont, Black&Decker, Wipro Corp. and many other Companies claim that using six sigma methodology 3.4 defects per million opportunities can be obtained –not perfection, but almost.

The Six Sigma Metric

In classical (Shewhart) Statistical Process Control (SPC), control charts determine if the process is in <u>state of statistical control</u>, <u>statistical uniform</u>, or <u>stable</u>. They do not tell us if the process is meeting specifications and producing good products. It is necessary to get the process in control <u>and</u> within specifications.

A product (or service) is said to be defective if it lies outside the specification interval, x > upper specification limit (USL) or x < lower specification limit (LSL).

Let us assume that the target value for the mean of the process is at the midpoint of the latter [m=(USL-LSL)/2]. By the control chart we determine the standard deviation of the process and we define PROCESS CAPABILITY as 6s. This is a measure of the repeatability of the process and is commonly called the 6-sigma range for individuals.

We assume that the distribution of our quality variable is normal and, accordingly, its values will lie inside the interval $m \pm 3s$, 99.73 % of the time, and if we set the specification limits at $m \pm 3\sigma$ we will get on average 0.27 % of detective values or 2.7 per thousand or 2.700 defects per million. If one considers only one tail, there will be 1.350 ppm failures.

The **six sigma method** states that, under the above conditions, to obtain 1,350 defective per million is rather high. Thus, we should have a variation so that in order to be within the same specification limits as before the "natural tolerances of the process" must be set at $m \pm 6s$ (from which derives the name Six Sigma). This is to work with a 12-sigma range for individuals. If this is the case, the process will produce 0.00198 defective per million, approximately 2 defective per billion, or 0.001 defectives per million or one defective per billion if you consider only one tail.

But this is not what the six sigma experts tell us. They claim that working with the 6 s methodology you get 3.4 defective per million. How can this be, if the exact figure is 0.002 ppm (or 0,001 ppm, if we consider only one tail)?

Once the specification limits are set and the process is under control and the target value is at the midpoint of the specification interval one can calculate an index, **Cp** or Potential Capability Index, defined as: **Cp = specification range / process capability = (USL – LSL) / 6 s** .

The greater the **Cp**, the better the process meets specifications, **if process mean is at target value m**. **Cp** not only tells us if the process spread is small enough to allow us to meet specifications, it also tells us by what amount (what factor) our process quality has the potential ability to show excellence beyond the minimum specification requirements.

We have already seen that the Six Sigma Method tries to reduce variation of the process, so that, the specification limits are set at m ± 6s. Cp will be, in this case: C_p = 12 s / 6 s = 2. To work with a 6s process, simply means, that we are working with a process that has a potential capability index **Cp** of **2**.

We have to note that **Cp** only addresses the spread of the process. It only gives an indication as to whether or not the process is potentially capable of meeting specifications. It does not give any indication as to whether or not the process actually meets specifications.

If the mean of the process, let us call it $\bar{\bar{x}}$, is not at the target value m, the process may not be satisfactory because it is making products or providing services beyond the specification limits. **Cp** does not reflect this fact. **Cp** only reflects whether or not the process variation would be acceptable for **a perfectly controlled process**. Hence, another index is needed to describe how well the process has demonstrated conformity to specifications and to tell us how well the process has narrowed around the midpoint of the specifications.

The process capability index that accomplishes this it is called **Cpk**. If **Cpk** is equal or larger than 1, the closest specification limit is far enough from the process centre so that very few products are being made beyond specifications. **Cpk** is defined as: **Cpk = (USL - $\bar{\bar{x}}$) / 3 s**

Where,
$\bar{\bar{x}}$ = process mean, 3 s = half process capability, USL= Upper Specification Limit

Cpk is an index that measures how narrow the process spread is, compared to the specifications spread – tempered by how well the process centres around the midpoint of the specification interval, given that the target value is at this midpoint.

To simplify the exposition let us assume that the process mean $\bar{\bar{x}}$ has shifted from the target value m, to, say to the right, a distance of 1.5 s (which is the figure six sigma quality experts consider).

When we work with the six sigma methodology, even if the process mean shifts, let us say to the right, an amount of 1.5 s, the number of defective products that we make are only 3.4 per million. So, we can establish a one-to-one correspondence between **Cpk** index and the ppm derived from the six sigma methodology.

To work with a six sigma process, simply means, that we are working with a process that has a **Cpk** value of **1.5**.

The reasoning behind the method is as follows: in real life, even if a process is under control it is not infrequent to see that the process mean moves up (or down) to target mean plus (or minus) 1.5 s. If this is the case (the worst case), working with the six sigma philosophy will guarantee that we will not get more than 3.4 defective per million products or services out of specifications.

Take note that if the six sigma process is under control (process mean at the target value), we have only one defective per billion opportunities. On the other hand, if the process is out of control, we will have 3.4 defectives per million opportunities, which is the figure that is usually mentioned by the Six Sigma specialists.

Dr. Genichi Taguchi´s concept of quality can be stated as the loss that a product or service produces to society in its production, transportation, consumption or use, and disposal. The lower the losses to society produced by a product or service, the higher the quality of it will be. He developed a method to forecast and measure quality, in economic terms, under the assumption that tolerance limits are correct. The method calls for calculating the “Quality or Loss function” of a process.

Historically, among other means of measuring quality: the percentage of defectives, the above-mentioned Process Capability Indices and the Warranty Costs have been used. Of the three ways, the second one is the most abstract and difficult to interpret. For instance, what is the real improvement of going from a Cp of 0.9 to one of 1.2?. On the other hand, the other two ways are more intuitive in nature: we can measure the percentage of defective or the warranty costs in terms of money, and any person can assess the result of a change in the process or any other measure that affects quality. Nonetheless, the warranty costs, despite being very valuable, are not useful for taking immediate measures, due to the large time lag which is involved. A similar comment can be applied to the percentage of defectives of already manufactured products.

What we need are appropriate methods that could forecast quality before the product has been shipped or during production, and that could measure this quality in monetary terms. Thus, Dr. Taguchi, through the Loss Function, introduces a monetary products quality assessment (under the assumption that tolerances are correct). By means of this function, even Cp or Cpk, which were previously difficult to interpret, can have an instant monetary reading. It is a classic example in the literature, the case of the manufacturing of TV sets, by the same Company, in the US and in Japan and how consumers prefer the Japanese ones because of their better quality, even though they were producing a higher percentage of defectives.

Dr. Taguchi argues that even if the product complies with the tolerances or specification limits, if it is not at the target value there exists a loss to society. The loss function can be well approximated (using the Taylor expansion) by a quadratic function such as: L =

$k\,(x - m)^2$ where k depends on the loss to society at the point where the variable just exceeds the tolerances. The quality or loss function is then measured in monetary terms and its expected value is: E: $L = E\ k\ (x - m)^2 = k\ s^2$. Thus, the expected loss is proportional to the variance.

If the mean of the process is at the target value m, we can establish a one-to –one correspondence between Cp, ppm. defectives, and the Loss Function.

If in the above correspondence the standard deviation of the three sigma process, **s**, is taken as “numeraire”, then, the standard deviation of the 1s process is threefold the latter, and the one, of a 6s process, half of it. The capability index, **Cp,** is 0,33 (158.655 ppm defectives, with a Loss Function of $9\ k\ s^2$) for of the 1s process; and **Cp** = 2 (0,001 ppm defectives, with a Loss Function of $0{,}25\ k\ s^2$) for a 6s process.

If the mean of the process is not at the target value m, but at m+1.5s (the standard assumption in the Six Sigma methodology, sometimes called “long run shift”), the **Cp** ratio is not the one to use but **Cpk,** and the expected value of the loss is no longer ks^2. Statisticians will tell us that now $E(x\text{-}m)^2$ is equal to the mean squared error, namely: $E\,(x - m)^2 = (\text{bias})^2 + s^2 = (1{,}5\ s)^2 + s^2 = 2{,}25\ s^2 + s^2 = 3{,}25\ s^2$

If in the above correspondence the standard deviation of the three sigma process, **s**, is again taken as “numeraire”, then, the standard deviation of the 1s process is, as before, threefold the latter, and the one, of a 6s process, half of it. The capability index, **Cpk,** is –0,16 (691.464 ppm defectives, with a Loss Function of $29{,}25\ k\ s^2$) for of the 1s process; and 1,5 (3,4 ppm defectives, with a Loss Function of $0{,}8125\ k\ s^2$) for a 6s process.

On stressing the focus only on the ppm defectives the Six Sigma Methodology may not be taking into account all the richness and satisfactions for customers that the Taguchi’s Loss Function implies.

Thus Taguchi’s Loss Function will tell us that, from the point of view of society (customers, partners, stock holders, suppliers, employees, etc.), a centred process working with four sigma $\lfloor L = 0.56Ks^2 \rfloor$ may very well be preferred to an out-of-target process (mean = m+1.5s) working with six sigma $\lfloor L = 0.8125Ks^2 \rfloor$.

Then, if a centred 4σ process is better than an out-of-the-target 6σ one, is the effort of going from 4σ to 6σ worth the cost that it encompasses? Why do the 6σ advocates not control the mean? Why have the companies been forced to make the extraordinary and expensive effort of going from 4σ to 6σ, when controlling the mean on target seems to be much less expensive than reducing the variance so much?.

The reasons are not so clear in the literature:

Pyzdek (2000) states: “Since Control Charts will easily detect any process shift of this magnitude in a single sample, the 3.4 PPM represents a very conservative upper bound on the non conformance rate”.

Noguera and Nielsen (1993) state: "Motorola's choice of 1.5σ was based on both theoretically and practical grounds. Theoretically, an X bar control chart will not quickly detect a process shift until the magnitude of the shift is +/-1.5σ (based upon a sample size of n=4)".

Harry and Schroeder (2000) claim: "The average time-to-time centring error for a "typical" process will average about 1.5σ….Years of theoretical and empirical research on this subject have proven this to be true. This amount of shift and drift is inevitable, and has to be accounted for during the design cycle of the process, product, or service".

The point is: if we have a centred 4σ process, can we detect or not a shift of the mean of 1.5σ in a reasonable time period?, and if we can detect it, we most likely can correct it. If this is the case, it seems that it is not worth to going on to reduce the variance and to reach a 6σ process, as bringing the mean on target may very well be less expensive than reducing the variance. And, most important, we may question the "inevitability" of 1.5σ shift in the long term because we can detect and correct this after few SPC samples.

To clarify this point, let us assume that we have an SPC scheme based on samples of size n=4, that process mean and σ are known, that process mean is at the target value m, which is at the mid-point of the specification interval, and that we allow the process mean to shift 1.5σ.

Let us also consider that we apply this control to a 3σ, 4σ, 5σ and 6σ process.

If we take, as before, the standard deviation of the 3σ process as "numeraire", let's say σ_3, the standard deviations of the other processes will be: $\sigma_4= 0.75\sigma_3$; $\sigma_5= 0.6\sigma_3$; $\sigma_6= 0.5\sigma_3$. Let us also assume that the specification limits are at $m\pm3\sigma_3/\sqrt{n}$. For n=4 and a shift, say, to the right, we can calculate the probability of defectives and the average number of samples (ARL or Average Run Length) to detect a change in the mean of 1.5σ (the expected value of a geometric distribution, with the probability of defectives as the "*p*" probability).

For the above mentioned processes we get: In the base case, we can detect a shift of the mean, on average, in two samples (not in one sample, as Pyzdek states), and, for a 4σ process, we can detect it in 6 or 7 samples, which can be considered a fairly quick detection.

On comparing the Six Sigma Metric with the Taguchi Loss Function it seems that, from the point of view of Society (customers, partners, stockholders, suppliers, employees, etc.), a centred four sigma process may very well be preferred to an out-of-the-target six sigma process, even if the latter produces 3.4 defective per million and the former 32 defective per million (almost tenfold).

Is the effort of going from a four sigma process to a six sigma one worth the cost that it encompasses? Why does the six-sigma methodology claim the "inevitability" of a 1.5σ shift in the mean of the process (and so the need to go to six sigma), if we can detect such a shift in six or seven samples (and bring the process back on target), for a 4σ sigma process?

The richness and the important consequence of the Taguchi Loss Function is the fact that the farther the product's characteristic varies from the target value, the greater the loss. Further more, this loss is a continuous function and not a sudden step and it illustrates the point that merely making a product within the specification limits (and, therefore, only measuring the percentage or ppm defective) does not necessarily mean that the product is of good quality, since good quality is defined by Dr. Taguchi as keeping the product characteristic **on target** with **low variation**.

WHAT IS LEAN SIX SIGMA

Lean Six Sigma (LSS) is a robust combination of a **Production System** and a **structured method of variation or error reduction**. This combination is flexible and shares the same values for breakthrough improvement of the results (profits) of a company. LSS is a programme based on the drastic improvement of Quality and Productivity and it is focused on the economic results, which are what makes a company the leader in its class.

Lean Six Sigma addresses quality improvement as an integrated methodology and supports the view that Six Sigma and Lean must be applied side-by-side, not as independent improvements, or first-one-then-the-other approaches.

We have already seen what Lean and Six Sigma are. What are the "pros" and "con" of each one? How can we meld them together?

Lean followers argue that Six Sigma pays little attention to anything related to speed and flow. On the other hand, Six Sigma specialists claim that Lean does not say anything about customer needs and variation. Both points of view are correct but it seems that they are backed by supporters who prefer one methodology over the other. Both methodologies are perfectly complementary and their symbiotic association has been proved to increase Quality and Effectiveness (Six Sigma) and, at the same time, Productivity and Efficiency (Lean), and together they both lead to a higher increase in economic results for the company than if applied separately.

Most of the Lean Six Sigma efforts of in the last five years have been done on the manufacturing sector. However, Service operations now form more than 80 % of the GNP in the USA. Similar rate can be found in Europe and Japan. Even within manufacturing companies is common to find a 20/80 ratio in the Production/ Services processes.

For Lean Six Sigma applications, the word "Service" entails both service organizations (Logistic services, retail, healthcare, local and national governments, banking, insurance, etc.) and the service processes in both service and manufacturing organizations (Billing, production control, internal consultants, hiring, sales, marketing, accounting, R&D&I, engineering, etc.). Successful applications in services processes can be found in the ASQ's *Quality Progress* reviews of the last three years. The Juran Institute is also a good source for Lean Six Sigma applications in the Service industries worldwide. Also George (2003) explains 12 cases in his *Lean Six Sigma for Service*. Internet Web pages on Lean Six Sigma is another good source for information on the subject

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Lean Six Sigma is a systematic approach to reduce or eliminate activities that do not add value to the process. It highlights removing wasteful steps in a process and taking the only value added steps. The lean six sigma method ensures high quality and customer satisfaction in the manufacturing. The main purpose of this chapter is to explore the Lean Six Sigma (LSS) in the manufacturing sector. This chapter focuses on the different critical aspects of LSS.Â manufacturing industry. The final section of the chapter contains the conclusions and suggestions. It is important for practitioners to be aware of Lean six sigma benefits, impeding factors, Tools and techniques, methodologies etc. before starting the Lean six sigma implementation process.