ADOPTION OF LEAN PRODUCTION AND SIX SIGMA IN A MANUFACTURING ORGANIZATION: A CASE STUDY

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Abstract

Lean Manufacturing and Six Sigma are probably the most popular and most frequently utilised by several companies among the various continual improvement methodologies. The idea to combine such methodologies is not a new one, since in the 90s, companies started using LP and SS and difficulties since the two approaches have different goals and different methods of implementation. In the present study, the methodology dissemination plan includes: process concentration, organisational structure, measures, awards and instruments, according to the author. Six Lean Sigma divides views and the application is still unclear, mainly due to LP or SS's many companies, which make it hard to build a single application model. The subject below presents an integrated Lean SS model using MFV as a key tool to support the DMAIC's enhancement efforts. The study is based on the secondary data available on organization’s website, journals and past studies.

Keywords: Lean Production, Six Sigma, DMAIC, Continuous Quality Improvement.

1 Introduction

A continuous search for improvement is led by the current need to increase productivity and quality. According to Salah et al. (2010), the success of an organisation depends on the effectiveness of continuous methodologies of enhancement. Six Sigma (SS) and Lean Production (LP) are among the popular methods for companies in different industries (Salah et al., 2010). Lean manufacturing practise coincides with a number of continuous actions aimed at properly defining the value from the end customer's point of view, eliminating
waste generating activities, and causing added value to be generated by the continuous customer flow (Womack; Jones, 1996). The links between perceptions of quality and cost reductions (Henderson; Evans, 2000) were responsible for SSs. This is a wide-ranging methodology designed to achieve, sustain and maximise business success; its practise is Adequate customer needs, a disciplined use of facts, data and statistical analysis and a careful focus on business process management, improvement and reinvestment (Pande, 2000).

One of the most efficient methods available is the combination of LP and SS methods (George et al., 2004). According to the previous author, this practise uses tools in each of these methods to solve different types of issues to reduce waste variability and business processes. The success of this integration with some critical success factors including the leadership engagement and corporate culture of the company is an overall approach to the company. (Jeyaraman; Teo, 2010). Since it's relatively new, the integrated methodology of Lean SS has some shortcomings. The concept of Lean SS as an approach to process enhancement in academic research is still not fully developed, according to Bendell (2006). Many companies adopt Lean SS, but not all are benefiting from its implementation (Jeyaraman; Teo, 2010). A research issue not fully addressed in this regard is how companies use LP and SS practises jointly. The purpose of this paper is to show the results of a fieldwork which aimed at identifying key drivers for the implementation of SS in combination with the LP Principles. The main concepts for Lean SS are initially presented. Then, fieldwork in the cooling industry is demonstrated by a multinational company. In order to achieve the final outcome and conclusions, this analysis is compared to the current theory.

2 Lean Six Sigma
Lean Manufacturing and SS are probably the most popular and most frequently utilised by several companies among the various continual improvement methodologies (GEORGE 2002; SALAH et al. 2010). The idea to combine such methodologies is not a new one, since in the 90s, companies started using LP and SS and difficulties (SMITH, 2003) since the two approaches have different goals and different methods of implementation (although complementary).

LP and SS are widely accepted as complementary, and these methodologies are being followed by more and more businesses, especially after proof of results in companies like GE and Toyota. SS is linked to correcting individual processes and LP to create links between them (Arthur, 2007). There is a relationship between the two. The processes and operations flow are emphasised by both methodologies. LP focuses on waste reduction,
increasing productivity and streamflow, eliminating activities that add no value in order to reduce the cost; SS focuses on reducing variability and systematically combating the production of low-quality products in order to reduce costs. Antony (2010) presents a comparison of the various methodologies: The integration among the methodologies leads to a process based on the DMAIC structure, Lean SS (Salah et al., 2010), which is a process that eliminates waste and changes in processes in order to achieve customer satisfaction. In addition to all the benefits generated by the combining of those practises relating to quality, costs, lead time and customer satisfaction, the process improved and better financial performance for the firm are the focus of this methodology.

2.1 Integration of LP and SS
SS is expected to work with other methodologies for continuous improvement (Antony, 2004). As far as LP is concerned, Hines et al. (2004) show that it can be integrated with other approaches as well without conflicting with their customer value objectives. LP and SS should not be used in parallel, but at the same time so that synergy is established between the two, avoiding problems such as priority initiatives and resource allocation (Salah et al., 2010). Integration means an enhancement of the organisation's potential (Bhuiyan, Baghel, 2005). The integration enables continuous improvement, zero defects, and rapid delivery at low costs according to Smith (2003). The attempt to work with both methods is not always successful, because the tools for problem resolution are applied separately (Salah et al., 2010).

The availability of a common set of tools for problem resolution is a fundamental prerequisite for success in continuous improvement efforts in an organisation (Chapman; Hyland 1998). The tools used in LP and the SS can be seen as a toolbox in which the most suitable one can be chosen (Mcadam; Donegan 2003), depending on the nature of the problem and its origin, to use both quickly with Kaizen events and an in-depth analysis of more complex projects. Their use is also possible. This integration offers higher results than when it is used individually, according to Antony (2010). The author also says that, while LP is seeking to eliminate waste and non-value-added activities, SS is achieving improved performance and improved process capabilities through statistical techniques and means. List of application opportunities for Lean Salah et al. (2010).

2.2 Six Sigma found in organizations:
1. SS as an addendum tool in Kaizen events, and lean manufacturing as the main methodology.
2. The DMAIC implemented SS as the major methods and lean manufacturing tools.

3. In order to deal with various problems according to classification, LP and SS have been applied separately.

4. SS and LP used to solve the same issues in parallel but independently.

5. LP and SS are used to address the same problems continuously.

6. The simultaneous application of LP and SS.

George (2002) points out that LP and SS start to integrate organisations through three phases: I targeting, (ii) selection for people and projects (including training and diffusion), and (iii) culture implementation). The methodology dissemination plan includes: process concentration, organisational structure, measures, awards and instruments, according to the author. Six Lean Sigma divides views and the application is still unclear, mainly due to LP or SS's many companies, which make it hard to build a single application model. The subject below presents an integrated Lean SS model using MFV as a key tool to support the DMAIC's enhancement efforts.

2.3 Application of Lean Six Sigma

The integration of these techniques depends on the holistic vision of the ongoing improvement of organisations, in which LP and SS mutually reinforce each other, according to Salah et al. (2010). Although the DMAIC comes from SS, the authors claim that it can be used as a global model for ongoing improvement. George (2002) says improvements to DMAIC are taking place slower. DMAIC offers SS with a unique connexion and sequencing feature that enhances global improvement actions (Snee, 2004). Mader (2008) also says Lean SS has been developing in organisations in different ways, but most use MFV as a base. An organisational problem with the unknown solution needs to be mentioned in the project using the DMAIC methodology (Cleto; Quinteiro, 2011). According to the aforementioned authors, in order for the solution to improve continuously, a series of measurable targets must be linked to well defined indicators. Montgomery (2010) suggests the use of the DMAIC model is as effective in LP as in SS, although the used tools differ in their phases. According to data collected by George (2002), Enhancements not following DMAIC take place very slowly and unstructured, Snee (2005) and Antony (2010) state that the tools of LP are very effective in the first stage of implementing improvements. Many companies using the integrated method also apply basic instruments and techniques, like MFV, 5s and standardised work, etc., according to the authors mentioned. This enables waste to be
removed from the system and processes to be simplified. LP tools are also easier to understand compared to SS tools, which makes it easy to involve team members by making quicker gains from the beginning of LP (Antony, 2010). In a second phase SS tools and techniques can be used to offer more powerful and time-consuming solutions to chronic system problems (Snee 2005; Antony 2010).

The current state mapping (MFV) should be the basis of an integrated approach to Lean SS, follow the DMAIC prototypical to reach the future and thereby change the process structure. This line of integration must be followed by the model proposed by Salah et al. (2010), namely, an appropriate fusion between the LP philosophy of waste disposal and the SS production mentality in the search of perfection.

As the relation in Figure 1 illustrates, the integrated model presented by Salah et al. (2010) should follow the 5 LP principles and the DMAIC structure. As the authors say, the first phase, "Define," is where the customer identifies its value. A second phase "Measure" included mapping the current state (by MFV) The third phase, "analyse," is reached, where integration with LP makes measurement and analysis steps closer together. This results in an overview of the data collected and suggestions for improvement proposed. The fourth step, "improving," is the adjustment of the process to improve the flow of value and achieve future conditions, introducing the pulling concept. Finally, in order to establish controls and procedures to ensure that improvements not only remain but are continually reviewed so that the system can be continually enhanced (SALAH et al. 10, 2010), the fifth stage is linked to the search for perfection in the process. The same authors point out that LP and SS must be integrated on the basis of the DMAIC structure. DMAIC is widely recognised as a comprehensive and robust model which is very much in keeping with Salah et al. 's 2010 inclusion proposal. The following topic details the Lean SS model 's operation.
2.4 The DMAIC method applied to Lean Six Sigma
When performing any Lean SS project, DMAIC structure is always endorsed. In addition, MFV is frequently anticipated to be the initial step in the carrying out of the methodology. According to the authors, if LP tools are more used, the five phases of methodology need not be examined in such detail, as long as they follow that structuring different projects may have different approaches. If SS is to be used successfully, it should be known exactly where, why, when and how its instruments have been applied in DMAIC (Antony, 2004). It must work in the same way for LP and success is to know where every device fits precisely (Salah et al., 2010).

On the basis of the structure of the DMAIC structures in companies such as Delphi, Xerox Consultant, General Electric and George's works (2002) and Antony (2004), Mendoza (2007), Mader (2008) and the American Society for Quality, Salah and al . ( 2010). Proper adoption of the lean six sygma initiatives in an organisation is extremely important for the success of their activities. There are also a number of critical factors that have been described below for your success.

2.5 Success Factors for Lean Six Sigma
Many companies adopt the Lean SS practises but do not need to benefit from it, according to Achanga et al . ( 2006). The authors argue that companies do not have any information on implementing costs, results and tangible benefits that can lead to failure in implementation. Jeyaraman and Teo (201) identified 25 critical factors in the successful implementation of Lean SS based on studies by other authors (e.g. Achanga et al., 2006). These factors are the key components without which initiatives are unlikely to succeed. The success of Lean SS
is supplemented by Pepper and Spedding (2010) and Martin (2007). The key success factors for implementing Lean SS are summarised in Table 1. There is a more convergence among the listed authors of some critical factors, while others are specific to one or two publications.

Noteworthy is the absence of any agreement on Lean SS ’s success factors and standard application models, which can be followed and used on any organisation, despite the opinions and proposals of different authors. Many researchers say that LP can be integrated with SS without contradicting their core ideas according to Proudlove et al ( 2008). But there are currently little agreement on how this can be done and the integrated methodology has still not been widely accepted.

Chart 1 - Critical Success Factors according to different authors.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Commitment and dedication of leadership</td>
<td>Commitment and dedication of leadership</td>
<td>Strategic and focused on the process</td>
<td>Leadership support</td>
</tr>
<tr>
<td>Award system and recognition</td>
<td>Award system and recognition</td>
<td>Balanced between complexity and sustainability of the approach</td>
<td>Choosing the right people</td>
</tr>
<tr>
<td>Organizational culture</td>
<td>Organizational culture</td>
<td>Balanced between the two methodologies</td>
<td>Selection of the right projects</td>
</tr>
<tr>
<td>Frequent communication and evaluation program results</td>
<td>Frequent communication and evaluation program results</td>
<td>Structured according to type problem</td>
<td>Effective communication</td>
</tr>
<tr>
<td>Prioritization, selection, review and monitoring of the program</td>
<td>Prioritization, selection, review and monitoring of the program</td>
<td>-</td>
<td>Effective characteristics of changes</td>
</tr>
<tr>
<td>Effective training program</td>
<td>Effective training program</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Best sharing project practices</td>
<td>Best sharing project practices</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
3 METHODS ADOPTED

In this area, the aim is to provide an overview of the methodological approach of research used in this paper and justify the selection of data collection and analytical methods and techniques used. The importance of the approach to the methodology of a work is justified by the need for an adequate scientific base which usually seeks to achieve the best methodological approach, and its respective methods and techniques for the design and implementation of a research project (Cauchick Miguel, 2007). The approach adopted in the present work was a case-studio that allows researchers to be more closely acknowledged and approached in the circumstances around the phenomenon that should be studied, given that multiple sources are used for the collection of data.

On the occurrences observed (Bryman, 1989; YIN, 2005). These factors are the features of this work, which justifies choosing this methodological approach. In addition, to deepen the understanding of a problem that is still not fully defined in the present study (Mattar, 1996), this research approach has to be applied, since it is still not fully empirically consolidated in the Lean SS methodology.

The first phase deals with define the topic Lean SS and the combination of LP and SS Practices. The purpose of this step is to conduct an assessment of the content available on Lean SS to analyse the LP application and the SS application within the selected company. The second step is to review the current Lean SS literature. While Lean SS has developed already, it still has structural gaps such as its integrated methodology (Proudlove, 2008) and company operations (Salah et al., 2010). In the third stage, a survey was carried out with a view to identifying potential study objects among the main manufacturing companies in the State of Santa Catarina. Contacts with some were then established to identify those that would meet certain minimum requirements for the work: billing size, access (companies with historical data, documents and information on the application available, operation, structure and results of LP and SS) and maturity level (companies adopting the two methodologies) The choice was Alpha, a major company with nearly 7 years of LP and

| Financial capacity of the company | - | - |
| Definition of the program's operation and its connection with the company | - | - |
access to data and organisational infrastructure. LP practises are implemented. As far as SS is concerned, the practises are still mature, as a result of the company's reformulation of the programme.

The fourth step is to collect, sort and analyse field information. Methods and techniques for both data collection and analysis must be established in these phases, according to Cauchick Miguel (2007), and multiple evidence sources must be employed in that sense. It was then considered: staff interviews, questionnaire application and access to company submissions. Interviews with key employees of the company were conducted between March and August 2012 in applying the methodology (Black Belts, Master Black Belts and Quality Manager). The interviews were recorded later (by about two hours per interview) for data collection. The aim of the interviews has been to obtain the most relevant information for LP and SS implementation and integration. The authors sought to address the company's characterization of the SS and Lean Manufacturing programmes in the first part of these interviews. They addressed in the next instance the main points of the programmes, such as their advantages, challenges and reasons for implementing them. The purpose of this analysis was to portray the current state of the research object with regard to LP and SS practises.

In the 5th and final stage of work, the data collection was transformed into a structure that can be compared to literature. As recommended by Cauchick Miguel (2007), it resulted in a research report that was close to the theory. In this step, we aim at describing LP and SS’s operations in Alpha in order to analyse both practises. The analysis was aimed at understanding the level of maturity of the methodologies and at verifying, based on theory, what is possible to integrate them both within the study subject.

3.1 Work Context - Object of Study
Alpha is the world leader on the hermetic compressors market, acting as a business unit for a major American company in Brazil, operating in the design and production of domestic and commercial cooling. Furthermore, it manufactures other components for installing condensing and screening equipment and electronic systems for home equipment. Founded in 1971, it has around 12,000 employees worldwide, with production capacities of around tens of millions of compressors a year in plants in Brazil and other countries. As a global market leader, Alpha must continue to be competitive and invest constantly in methodological improvements to maintain its market position. The following sections present a context of LP and SS organisational practises.
The system consists of a set of principles, standards, and metrics systemically applied to the processes of Alpha. The system aims to run the value chain and aims to synchronise flow, reduce lead time and improve customer service at the lowest cost in the chain. This system was designed to support basics like 'pulled flow,' 'standard work,' 'visual management' and 'incessant improvement' in Lean production.

The system consists of the tools, methods and standards and separated by the Lean Thinking Model phase used in the system. This content makes it possible to manage the production and better understand the operating sequence not in isolation by the parts cells but by seeing the product family flow from the entry, assembly, tests and shipment to the customer of the raw material to be processed. The system seeks to provide information about the tools of Lean production, the dissemination of culture and its routine management with a view to supporting the ongoing improvements and ensuring the sustainable achievement of results achieved with the Gemba Kaizens.

3.2 Results of LP in the Company

With the employment of LP in the firm Alpha, expressive results have been achieved since 2005. Part of these results are confidential and cannot be explained in detail in this work. These relate to reducing product lead times, raw material inventory, process and finished product material, increasing productivity and manufacturing, decreasing defects in ppm, improving working conditions and reducing costs generally. The improvement of other fields and systems, which makes it difficult to measure its results individually, is also linked to several improvements in the programme. The gains in Gemba Kaizens from 2006 to 2010, Table 1. Table 1 shows. It is important to emphasise that $8.73 was earned for every $1 invested in shares from Gemba Kaizens.

Table 1 - Results of Gemba Kaizens between 2006 and 2010.

<table>
<thead>
<tr>
<th>Measurement form</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Global Productivity</td>
<td>17.64%</td>
</tr>
<tr>
<td>Quality Actions (use of poka-yoke, and on, standardized work)</td>
<td>2308</td>
</tr>
<tr>
<td>Ergonomics or Safety Actions (general improvements in work points)</td>
<td>1514</td>
</tr>
<tr>
<td>5s actions (productive and administrative)</td>
<td>3041</td>
</tr>
<tr>
<td>Accessibility Actions (aimed at special operators)</td>
<td>44</td>
</tr>
<tr>
<td>Increase in global production capacity between 2006 and 2012</td>
<td>43%</td>
</tr>
<tr>
<td>Increase in the overall production rate between 2006 and 2012</td>
<td>50%</td>
</tr>
</tbody>
</table>

Source: Presentation of the 2012 Corporate Lean.
The following topic illustrates the importance of quality in the company along with SS practices.

4 Six Sigma in the Alpha company

Awareness of the importance of quality concepts in Alpha has evolved from the 1980s with the implementation of certification (ISO 9001, ISO 14001, OHSAS 19001, QC 080,000), programmes (5s, SS, CCQ – Circles Quality Control) and management systems (Guidelines Management and routine management). (Statistical Process Control, QC Story, SS tools)

The SS programme began in 1998 with the introduction of belts (Green Belt, Black Belt and Champion) to implement projects. Projects were implemented. Employees appointed to the management and selected for certification courses on the belt, in accordance with certain company criteria, could develop SS projects to cut costs, improve quality or increase productivity. As far as SS projects are concerned, they have been classified to decide on acceptance according to certain criteria such as: attractiveness, duration, scope and expectations of return. Data from 435 SS projects in the Alpha project management system were found between 1998 and 2004. The projects involved a number of areas of the company: operational and management (Quality, Maintenance, Logistics, Product Development, Marketing, Sales and Human Resources). The reasons for discontinuing the programme were not identified in the collection of data. In reality, the data relating to the programme during that time are little known. Although SS was then extinct, SS methods and statistical tools for troubleshooting remained in use to minimise defects and process variability. By May 2011, only to resolve quality problems in production, used as an application of methods and tools, without defined central management, and not strategically, with only factory use, have SS instruments been used.

Table 2 - Classification of SS projects at Alpha Company.

<table>
<thead>
<tr>
<th>Status</th>
<th>Number of projects</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perfect</td>
<td>29</td>
<td>7%</td>
</tr>
<tr>
<td>Completed</td>
<td>94</td>
<td>22%</td>
</tr>
<tr>
<td>In Review</td>
<td>98</td>
<td>23%</td>
</tr>
<tr>
<td>In progress</td>
<td>150</td>
<td>34%</td>
</tr>
<tr>
<td>Rejected</td>
<td>64</td>
<td>15%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>435</td>
<td>100%</td>
</tr>
</tbody>
</table>
In 2011, SS was re-introduced and, currently, it is in the initial steps to return to being a strategic program for the company. The program uses the SS model of problem solving and the belts structure, however, it is called the Quality Improvement Program. The current program, described below, did not take advantage of the work carried out between 1998 and 2004 and receives this name precisely for not referring to the practices used in that period.

The plant management team collects weekly the main quality indicators (ppm from customers - external, ppm in the field - internal, customer complaints, cost of failures, etc.). Through these indicators, an analysis is made of the main problems and possible quality improvement projects. The projects generated from these analyses are divided into a portfolio of quality improvement projects and can be of the following types: "projects following the method of solving problems through the PDCA", "quality kaizens" or "introduction of new products and processes" With the definition of the project format, the team, the necessary resources and responsibilities are defined. The current method of solving quality problems is detailed in the next topic.

The results are split and the main indicators (KPIs) monitored monthly with the directors and vice-presidents and quarterly with the presidency. The improvement program ensures the involvement of top management and strategic character within the organization. Among the benefits identified with this program can be mentioned:

- Increase synergy within and between plants, by allocating the same resources to support and investigate similar quality problems. The use of a standard problem-solving method can speed up the exchange of knowledge and the standardization of solutions.

- Achieve quality and customer satisfaction goals. The idea is to make visible how the main quality problems that affect costs and customer satisfaction are being solved at each plant. Quality improvement projects must be monitored weekly to adequately monitor their progress.

- Greater leadership support and commitment, defining clear attributions to the manager responsible for each quality problem according to the problem solving method. It was also necessary to connect the problems solved by the method with the cost savings of failures (internal and external). In order to relate this way of conducting projects with the results and data of the SS program, the next topic presents an overview of this program in the company.
4.1 Overview of Six Sigma at Alpha

Based on a questionnaire of the work of Andrietta and Cauchick Miguel (2007), some data related to the adoption of SS in the company Alpha are presented in general lines. The questionnaire was answered by the company's Master Black Belt (at that time for a year at the company and with seven years of experience in SS). It is important to highlight that the questionnaire does not take into account the results of the SS program during 1998 until 2004, but as of 2011. The data collected about this period were presented previously, but most of the information from that time was unknown to the people interviewed, and it was not possible to identify other professionals who participated directly in the program at that time. The SS data at Alpha from 2011 are then compared with the data collected by Andrietta and Cauchick Miguel (2007), which summarizes the results of 78 companies that apply SS in Brazil. These data are shown in Tables 6, 7 and 8; one must take into account in this comparison the fact that the work of was carried out longer, but it is considered that the work cited serves as an analytical reference for this work.

Table 3 - Characterization of the Survey Companies Group and the Studied Company.

<table>
<thead>
<tr>
<th>Features</th>
<th>Data Collected in the Type Survey</th>
<th>Data Collected at Alpha Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td>50% located in the state of São Paulo</td>
<td>Headquarters in Joinville</td>
</tr>
<tr>
<td>Industrial sector</td>
<td>Almost 40% of the automotive segment</td>
<td>Cooling</td>
</tr>
<tr>
<td>Number of employees</td>
<td>65% of large companies (over 500 employees)</td>
<td>About 5,800 employees in Brazil</td>
</tr>
<tr>
<td>Annual billing</td>
<td>60% of the companies are among the 500 largest in Brazil (Exame, 2005)</td>
<td>Billing billions of reais</td>
</tr>
<tr>
<td>Market position that act</td>
<td>41% are market leaders</td>
<td>Market leader</td>
</tr>
</tbody>
</table>

The data presented in Tables 3, 4 show some differences and similarities between the 78 companies in Alpha. Some data related to the results and the number of professionals involved in the program are difficult to compare due to the fact that the SS program is restarted at Alpha. The company studied had 3 projects completed at the time (in the
manufacturing area, but without quantitative measurement of results), with another 23 in progress (all in the manufacturing area), with the prospect of an increase. The results of the projects were not measured and, for this reason, do not allow comparisons with data from other companies.

Table 4 - Implementation of the SS Program.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Data collected</th>
<th>Data Collected at Alpha Company 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program implementation year</td>
<td>As of the year 2000, significant growth has been observed</td>
<td></td>
</tr>
<tr>
<td>Reason for implementing the SS program</td>
<td>Almost 75% was as a &quot;company strategy&quot; and over 50% as &quot;a decision by the parent company&quot;</td>
<td>Company Strategy</td>
</tr>
<tr>
<td>Areas of the company that started implementing the SS program</td>
<td>Senior management (50%) and quality (40%)</td>
<td>Corporate Quality</td>
</tr>
<tr>
<td>Areas of the company where the SS program was effectively applied</td>
<td>70% of cases indicated &quot;company-wide&quot;</td>
<td>Manufacturing and later Product Development</td>
</tr>
<tr>
<td>As for the &quot;customization&quot; of the SS program</td>
<td>More than 75% of respondent companies</td>
<td>Adapted program, &quot;personalized&quot; according to the company's molds</td>
</tr>
<tr>
<td>Criteria for choosing professionals</td>
<td>More than 75% are by indication</td>
<td>Career plan and mainly indication</td>
</tr>
<tr>
<td>Specific coordinators to conduct the SS program</td>
<td>Present in almost 95% of respondent companies</td>
<td>Yes</td>
</tr>
<tr>
<td>Qualification of professionals</td>
<td>Master Black Belts in almost 40% of companies, Black Belts in almost 80%, Green Belts in more than 50%</td>
<td>Master Black Belt, Black Belts and Green Belts</td>
</tr>
</tbody>
</table>
Professional training (average training hours) | Approximately 65% of Black Belts have "201 to 400 hours" of training and more than 80% of Green Belts have "1 to 200 hours" | Master Black Belt over 400 hours, Black Belts between 100 and 200 hours, Green Belts between 1 and 100 hours.

Recognition granted to professionals | Present in more than 50% of companies | none

Types of recognition | In more than 50% of companies "career boost" | Activities are considered to be within the employee's scope of work

Most of the data collected shows that the SS program at Alpha, although relatively new, follows a similar pattern to that adopted by other companies. We highlight three points that deviate from this observed pattern: (i) use of PDCA instead of DMAIC; (ii) using Statistica® software instead of Minitab®; and (iii) failure to recognize the professionals involved. It is considered that the type of software is not a factor influencing the program, since it is only a support tool. Methodological aspects such as the use of PDCA instead of DMAIC and cultural aspects such as the recognition of professionals involved, deserve more attention and are discussed in the next topic, which also presents the results obtained by SS and with quality management at Alpha.

4.2 Results of Six Sigma and Quality in the Alpha Company
With the use of the tools and practices described above, the company has achieved significant results since 1990. The evolution of the company's main quality indicator (global ppm). Since it is a confidential number, this index has been put into perspective. It can be noted that in the period from 1990 to 2011, the index was reduced by more than 10 times its initial value.

Numerous inventiveness has been taken to improve process control, reduce risk due to the implementation of improvements in products and processes, and improve quality efficiency in general, through belts training and CTQ assessments. The results achieved with these initiatives were related to: reduction of rejection of products in line (internal ppm), reduction of rejection of products at the customer (external ppm), reduction in the cost of external failures and response time for customer complaints.
The data presented in this topic depict the history, structure and results of LP and SS at Empresa Alpha. It is possible to notice that both methodologies are relevant in the company. This importance exists because the methodologies are capable of providing significant results for the organization. The next topic discusses these practices based on Lean SS theory.

5 DISCUSSION OF RESULTS
LP and SS are expected to be integrated with other approaches and methodologies for continuous improvement to enhance the organisation's potential for improvement (Antony, 2004; Bhuiyan, Baguel, 2005). LP and SS must be used simultaneously to take advantage of the synergy between both and avoid difficulties such as prioritizing initiatives and allocating resources (Salah et al., 2010). Although this integration is beneficial, it is difficult to achieve. Alpha uses LP and SS separately through two different management systems, discussed in this topic.

5.1 Adoption of LP and SS Practices
Regarding the six application categories of Lean SS found in organizations (SALAH et al., 2010), the company is placed in category 3: “LP and SS separately to deal with different problems according to the classification from the project”. The company has neither defined LP nor SS as its main methodology and also does not apply its practices and tools in an integrated manner. The two methodologies are worked on separately. The projects and methods of problem solving are used according to your need. The advantages of this application sequence are the removal of process variability. In a system that follows LP practises, a deficiency is identified, and a number of hidden waste occurs. These waste can be solved through the elimination of variations and the interruption of the process. The company does not use SS as a toolkit within Lean Production, nor does it use it as a toolkit embedded in SS. According to Hines (2004), the adoption of Lean SS in this way (only as a set of tools) is a problem, as it prevents the benefits of DMAIC from being taken advantage of. Also according to the mentioned author, LP and SS must be treated through a holistic view in which one reinforces the other mutually. The next topic discusses the integrated methodology of Lean SS in the company.

5.2 Integration of Lean Six Sigma in the Enterprise
George (2002) says enhancements to DMAIC are taking place slower. DMAIC provides SS with a unique feature of connecting and sequencing upgrading activities in a global way. The previous author states that, in order to reach the imminent standing and thus change the
process organisational structure, the integrated Lean SS approach must work with the MFV, map the current status on the basis of application for the LP and SS tools and follow DMAIC. Mader (2008) continues to suggest that Lean SS has developed in organisations in different ways, but MFV is mostly the starting point. There is a strong convergence of the authors’ statements and the adoption of Lean SS practises by two main aspects: (i) the integration of LP and SS practises by the MFV and (ii) the improvement of actions by the DMAIC model can be perceived. In the next topics, these two aspects are analysed for the company.

5.2.1 Integration of LP and SS by the MFV
As per George (2002), improvement activities which do not follow DMAIC take place more slowly. Mader (2008) still suggests that Lean SS has developed in different ways in organizations. It is possible to perceive a great convergence of the statements of the authors mentioned. Two main aspects for the adoption of Lean SS practices: (i) start the integration of LP and SS practices through the MFV and (ii) follow the actions improvement through the DMAIC model.

5.2.2 The LMA SSDMAIC and the PDCA Model of the Company
In conducting the Lean SS projects, Salah et al. (2010) recommend the DMAIC structure, however it should be understood precisely where, why and when tools should be inserted in the phases (ANTONY, 2004). Alpha uses a QCStory, Falconi (2006) method, which follows the PDCA configuration and methods are similar, as mentioned above. It seems that QCStory covered the DMAIC phases, as shown in figure 8, through interviews with Master Black Belt. Alpha ’s methodology lacks greater statistical rigour in respect of your tools, despite the similar sequence of phases. Most of them have a simplified character when compared to the more complex statistical tools available in SS.

The main difference between the DMAIC model and Alpha model is that LP practises like MFV and Gemba Kaizens are not integrated into QC ‘s history. In Alpha, MFV as a central tool for process improvement was the primary step to the integration of Lean and SS concepts in a Lean SS methodology. The second phase is to integrate the MFV with the QC Story. The steps of the MFV and the tools and techniques used by LP at Gemba Kaizen events should be included in QC Story for this purpose. Through these actions, the management model used by the enterprise can be brought closer to the Lean SS model proposed by Salah et al. ( 2010).
5.3 Success Factors for Lean SS in the Enterprise

Many companies have no information on implementation costs, results and tangible benefits generated by LP as well as SS and can lead to their execution failure according to Achanga et al. (2006). Jeyaraman and Teo's (2010) work identified 10 key successes in implementing Lean SS practises. These factors are again listed in Box 10 in relation to Alpha's practices. Many of these factors are difficult to measure or require more detailed analysis beyond the scope of this study of the company and its organisational culture. In the conclusions, together with some recommendations, certain factors are highlighted. Such factors are particularly important because they are essential for the success of Lean SS practises.

Table 5 - Critical Success Factors for Lean SS and its level at Alpha Company

<table>
<thead>
<tr>
<th>Critical Success Factors (JEYARAMAN, TEO, 2010)</th>
<th>Factor level in the company according to the present author</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Leadership Commitment and dedication.</td>
<td>Moderate</td>
<td>Great focus on results, however, apparently lacks greater monitoring of the functioning of Lean Thinking and SS within the company</td>
</tr>
<tr>
<td>2. Award and recognition system.</td>
<td>Weak</td>
<td>No system for Lean Thinking or SS results exists.</td>
</tr>
<tr>
<td>3. Organizational culture.</td>
<td>Moderate</td>
<td>The organization, but apparently focused on the short deadline, has a culture of excellence</td>
</tr>
<tr>
<td>4. Frequent communication and evaluation of program results.</td>
<td>Moderate</td>
<td>Even if the results are disseminated and communicated, follow up on the same</td>
</tr>
<tr>
<td>5. Prioritization, selection, review and monitoring of projects.</td>
<td>Moderate</td>
<td>There is a lack of monitoring in the MFV of projects if what had actually been planned was done</td>
</tr>
<tr>
<td>6. Effective training program.</td>
<td>Weak</td>
<td>Lack of a training center or university within the company, training is given when the need arises.</td>
</tr>
</tbody>
</table>
There are people working on SS projects other than a Green belt.

7. Sharing of best project practices.  
   Strong  
   Weekly presentations of the results of the gemba kaizens held and monthly meetings to exchange practices between the plants.

8. Financial capacity of the company.  
   Moderate  
   Limited resources due to excessive focus on reducing company costs.

9. Definition of the program's operation and its connection with the company's strategy.  
   Moderate  
   Ongoing routine management project to standardize the performance of Lean Thinking and SS and link strategic to operational goals

10. Competence of Master Black belts and Black belts.  
    Moderate  
    Despite competence, there is only one Master black belt and very few Black belts

6 Conclusions
First, it should be noted that, because the object of study does not adopt Lean SS in an integrated manner, it was not possible to fully analyse its operation. However, the fact that the company adopts LP and SS separately made it possible to compare what the Lean SS theory proposes as ideal and what would be necessary to achieve it. Thus, it is considered that it was possible to make a satisfactory analysis of the current state of the organization and also of the way in which the Lean SS methodology should work. Despite not having an integrated methodology, the company has initiatives to integrate people, areas and systems, so that it is possible to verify the potential for methodological integration towards Lean SS.

Regarding integration, it may be concluded that LP and SS, as shown in the study, can and should work together, whenever possible adapting to the project reality. Although anticipated, the company found that different kinds of projects depend on the nature of the problem and its complexity, require various approaches and tools. It was also possible to observe the existence of two main aspects in the adoption of Lean SS. First, the use of Value Stream Mapping should be the initial step towards methodological integration and should serve as a guide for improvement actions. The other (most expected) aspect is the use of the DMAIC model to conduct Lean SS projects. Improvement actions must go through the five

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phases of the model, and it must be directly linked to the MFV. The studied company has initiatives to use the MFV as a central tool in order to guide the various improvement projects. In addition, it uses a methodology very similar to DMAIC for conducting SS projects. The future challenge is to unite the MFV as the DMAIC to obtain the benefits that the Lean SS methodological integration can offer.

When managing methodologies using two methodologies, it is possible that limitations may arise and the potential for improvement will not be reached. As there are usually more improvement projects than the resources available to carry them out, managing LP and SS separately, can generate competition for resources, both human and financial. However, due to limitations in data collection, it was not possible to obtain evidence in this regard, in the studied organization. When working with practices separately, it becomes more difficult to prioritize among them, which are the most important improvement projects. Thus, it is concluded that the company's practice has some limitations. Finally, we highlight the fact that the results of the study's analysis are in line with what the theory on the topic proposes. In this way, it is considered that this confrontation between theory and practice made it possible to analyse, preliminarily, the operation of Lean SS. However, the present work is limited to a single case, which restricts the generalization of results.

Reference


