EFFECTIVE IMPLEMENTATION OF THE SIX SIGMA PROGRAM IN AUTOMOBILE MANUFACTURING

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Abstract

The Six Sigma program redefines quality as the added value of a productive effort and seeks to ensure that the company achieves its strategic objectives. Every time an error occurs, the company wastes time and money to correct it, that is to say, by designing and manufacturing products almost without defects, or preventing the possibility of errors, it is containing expenses. One of the keys to the success of the Six Sigma program is the step-by-step or roadmap approach, using definition, measurement, analysis, improvement and control. A strategy and a systemic approach, Six Sigma leads to a profitability benefit through product / service efficiency, customer loyalty and productivity. The main objective of this is to defined in a simple way to achieve zero errors in all management performance in the company. The present study was about understanding the six sigma concept's, its tools and a case based examination of six sigma application.

Keywords: Manufacturing, Six Sigma, Losses, DMAIC, "Green Belt", "Black Belt", "Master Black Belt".

INTRODUCTION

Companies are constantly looking for ways to reduce costs and satisfy their customers to be competitive. Six Sigma is a powerful tool that has a structured methodology focused on reducing cycle time, drastically reducing defects and customer satisfaction.

The Six Sigma methodology emerged in the 1980s at Motorola, which, faced with a strong loss of competitiveness of its products for competitors, decided to take the issue of quality seriously.

Later, in 1996, the American company General Electric (GE) proposed the challenge of reaching level 6 sigma in all its processes, from the manufacturing project to the services. GE's case was the most famous and successful in the application of Six Sigma and this is due in large part to the constant support of the then CEO, Jack Welch.

The Six Sigma program redefines quality as the added value of a productive effort and seeks to ensure that the company achieves its strategic objectives. Every time an error occurs, the company wastes time and money to correct it, that is to say, by designing and manufacturing products almost without defects, or preventing the possibility of errors, it is containing expenses.

The main objective of this work is to show the efficiency of the application of the Six Sigma methodology for the reduction of losses in the cutting area of an industry that produces car covers. In an eight-month period, we aim to achieve a 10% reduction in fabric waste by starting and anjou type by 5%, and an annual savings of 119K €. As a secondary objective is the development of capacities in the participants of the process, being able to transform them into Green Belts and motivate them through a career boost.

Although the company under study is a subsidiary of a large multinational and already uses the Six Sigma methodology not only in the manufacturing process, but also in other areas of the organization, the scope of the work will be only the cutting area of the Corte & Costura factory, located in the north of Portugal. The process under study is the first case of application of the methodology in this factory.

WHAT IS SIX SIGMA?

A strategy and a systemic approach, Six Sigma leads to a profitability benefit through product / service efficiency, customer loyalty and productivity. The main objective of this strategy can be defined in a simple way to achieve zero errors in all management performance in the company. The idea is to obtain a minimum level, close to zero, at the level of production failures. The Six Sigma methodology consists of drastically reducing variability to a level of 3.4 ppm (6 standard deviations) from the mean to the upper or lower specification.

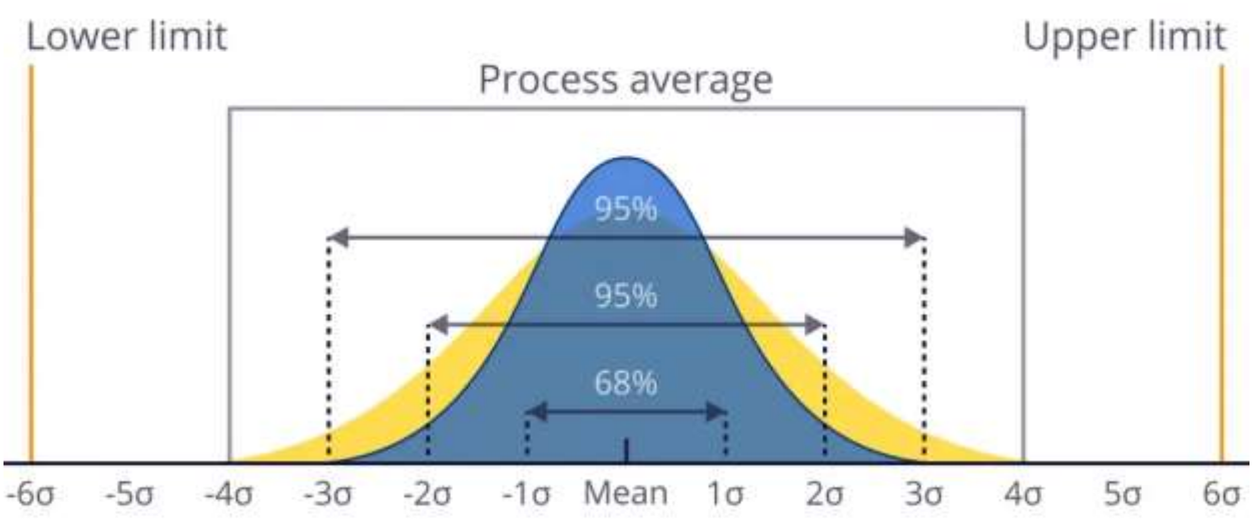

Illustration 1: Visualization of the original process Source: Internet.

EFFICIENT APPLICATION OF THE SIX SIGMA PROGRAM

The idea of applying the six sigma method was developed by Motorola in 1980 and the goal was to minimize the amount of defects to as low as 3.4 parts per million opportunities, i.e. to eliminate production costs, for example: costs of not doing the correct thing for the first time , costs of not satisfying consumer demands, etc. After Motorola, other firms, such as Texas Instruments, Allied Signal, Kodak, General Eletric, Sony, etc., reported that they had made substantial savings in executing the six sigma programs.

Six Sigma consists of the use of mathematics to solve issues, the usage of methods and strategies in a methodological and structured manner to gain information, which contributes to the development of changes with a significant effect on the outcomes.

While the initial goal of Six Sigma was to concentrate on the production phase, nowadays Promotion, Ordering and Invoicing are tasks that are now part of the Six Sigma approach with the intention of fully reducing shortcomings in operational processes.

Six Sigma and its fundamentals

Six Sigma has various meanings and meanings by different individuals. Formal and disciplined approach is used to describe, calculate, assess, develop and monitor processes. According to Hoerl (1998), the basic concept behind Six Sigma 's theory is to constantly reduce procedure variations and to remove flaws or faults in all goods, systems and transactional processes.

Six Sigma can be described in two terms: market and statistics. In terms of company, Six Sigma strengthens the market technique used to maximize performance, eliminate risks, decrease production costs and enhance the reliability and productivity of all processes that match or surpass requirements of consumers. (Antony & Banuelas, 2001). In mathematical terminology, the metric is a concept that corresponds to 3.4 defects per million opportunities (DPMOs) where sigma is a word used to describe the mechanism of average variance.

One of the keys to the success of the Six Sigma program is the step-by-step or roadmap approach, using definition, measurement, analysis, improvement and control. It is the DMAIC methodology. The definition phase consists of defining the problem and defining the critical quality characteristics, the most important for the customer. In the measure phase, the most appropriate outputs of the qualitative characteristics to be improved are selected and the unacceptable performance or defects for each characteristic are established. In addition, preliminary data must be collected to evolve current process performance and capacity.

In the research process, root causes of faults or failures (Xs or input variables) need to be evaluated. In the enhancement process, it is important to reduce the rate of defect or the amount of defects by utilizing basic yet effective statistical tools / techniques.

For some processes, it takes several turns to achieve the desired improvement in the performance or capacity process. In the control phase, it is necessary to sustain the improvement that has been achieved since the improvement phase.

2.2 Real benefits of Six Sigma

The Six Sigma method stresses the financial return on the balance sheet of the company. It has been effective in a variety of organizations where efficiency is enhanced above what might be accomplished through any methods. The main advantages gained by Motorola and GE from the use of the instrument are as follows:

Motorola (1987-1994):

- ✓ Defects in the processes reduced to a factor of 200;
- ✓ Manufacturing costs reduced by $ 1.4 billion;
- ✓ Shareholder quota increased fourfold.

General Electric (1995-1998):

- ✓ The company saved more than 1 billion.

2.3 Key ingredients of the Six Sigma program: An overview

It is necessary to define the main control variables that affect the outputs, in order to monitor and optimise the process outputs. The main component of Six Sigma performs the same function as the output variables for every operation. From now on, the main components required to incorporate the Six Sigma software will be disclosed shortly.

The relative weighting of crucial success factors (CSFs) can allow citizens to consider what are the important ingredients for the effective application of the Six Sigma process and what are the non-essential ingredients for performance. In addition to helping citizens develop a greater understanding of the Six Sigma method of execution.

Several scholars, such as Antony and Banuelas (2002), Henderson and Evans (2000), have analysed the main success factors for the adoption of Six Sigma. Antony and Banuelas (2002), Henderson and Evans (2000) and Goh (2002) consider the following main performance factors to be more important:

Commitment of top management, moving down in the organisation, as long as this tends to control and restructure the company of the enterprise and the internal adjustment of the individual mindset of the workers towards quality within a short time of implementation;

Extensive preparation and preparation in Six Sigma, project management and method qualification culminating in Green Belts, Purple Belts and Professional Black Belts;

Appropriate shift of behaviour and corporate layout, project-oriented and shift of coordination of strategies and networks, encouraging leaders to tackle opposition and informing senior management, staff and clients on the advantages of Six Sigma; Description Assess performance in financial terms as long as it encourages the approval of workers and allows them to make financial progress from the outcomes of the Six Sigma initiative.

Other considerations, not less significant, are: attention on business policy, emphasis on consistency and product requirements, human resource management and the interaction between consumer and supplier, emphasis on Six Sigma performance standards, consistent success indicators with the goal of preserving a Six Sigma focused approach and the extension of human resources management and organisational processes (Chakrab).

Fryer (2007) extends the list and presents thirteen main performance factors: managerial engagement, consumer service, provider management , quality results, evaluation and reporting, job staff, connectivity, process management, constant review, tracking and assistance, recruitment and preparation, staff participation, community management as a target, product design and organisational structure.

The following are best exemplified the CSFs identified from the literature and considered most important in the author's view:

Management participation and commitment

Any good programme needs adequate support and preparation to be involved and given (Halliday, 2001). The concepts behind Six Sigma should be discussed with the senior management of the company.

Jack Welch, GE's Chief Operating Officer, was affected profoundly and contributed to the organisational transformation of Six Sigma (Henderson & Evans 2000). The true value of the project will be put into doubt and the momentum behind it would be undermined without the quality of encouragement and engagement of the top management (Pande et al., 2000).

Shift of society

In order to effectively adopt and execute Six Sigma, we need to shift the mindset of the company and improve employees ' attitudes. Employees should be inspired and react to their own job results. It is also important to remember that workers first encountered Six Sigma and think that they might have to study statistics when they were introduced at GE. This is because of Six Sigma's misunderstanding that numbers are essentially used.

Six Sigma is the way workers will do their jobs every day in GE and this is nothing more but the attitude of individuals whose overall purpose is to 'please do the correct thing.' The Six Sigma project demands a right mentality and behaviour, regardless of the rank, of people employed in the organisation.

People in the organisation ought to realise the need for improvement and be aware of it. Companies who have achieved in handling transformation have demonstrated who improved and continued contact, inspiration and preparation are the strongest approaches to overcome opposition to transformation.

There are two specific fears of the technological transformation in the organisation: fear of transformation and fear of the modern norms. The individuals concerned need to understand the desire for improvement in order to resolve the apprehension of improvement in every manufacturing climate. THE Business ideally, the engagement framework will be established that discusses the significance of Six Sigma and how the Six Sigma approach functions in the enterprise (Hendricks and Kelbaugh, 1998).

The findings should be publicated once the experiment is carried out, but should not only be reported in good cases but the blockages should also be accepted and shared. It will allow several initiatives to stop and benefit about the same errors.

Facilities for organizations

Besides top management, an efficient operational framework is often required to facilitate the operation and growth of the project. Six Sigma operators in the business are typically well qualified and have been extensively educated by reports and lead teams in project recognition, execution and management.

Six Sigma ventures are headed by the CEO or Vice-Chairman of certain organisations. This is accompanied by the development, by the person and particular programmes helping teammates Master Black Belts, Black Belts, Green Belts and other teammates in their region (Harry and Schroeder, 2000).

The programme needs donors to support the Project Team with knowledge, identify and discuss funding and the project 's budget in addition to the Belt Structure.

It is also necessary to select the best time and the organisation's goodwill. The Six Sigma project needs a great deal of capital such as loyalty to staff, the highest level of management, manpower, energy and costs.

The routine

The key is to articulate Six Sigma's 'why' and 'how' as early as possible and to encourage people to develop their degree of comfort by training courses (Hendricks and Kelbaugh, 1998) prior to the arrival of Six Sigma employees.

Typically, there is a hierarchy of competence defined by the 'Belt System.' The Belt structure means that all employees use the same language in the company. The design and delivery of the project in the organisation is also much simpler.

The instruction in the belt method differs between organisations and consultants. For eg, it takes at least a year to learn to become a Black Belt in Motorola. Qualifying as a Black Belt is quite necessary whenever an employee is promoted.

Competencies in project management

Because Six Sigma is a methodology-driven project, it is good practise for team members to possess experience in project management to reach multiple objectives or targets throughout the project (Antony & Banuelas, 2001).

Selection and designation of programs, assessment and tracking

The collection and rating of projects must be appropriate criteria. Badly chosen and poorly described initiatives contribute to performance delays and dissatisfaction.

Three general projection and selection parameters categories are described by Pande et al . (2000). The following are:

1. Criteria for Market Value:

- ✓ Effect on fulfilling the requirements of international customers;
- ✓ The implications for financial services;
- ✓ The repercussions on main abilities.

2. Criterion for effectiveness

- ✓ The remedies Necessary;
- ✓ The reading;
- ✓ Accessible according to technological details.

3. Criterion for operational effect

- ✓ Cross-function benefit;
- ✓ For example, new company skills, clients and systems profit from studying.

The assessment shall take place on a daily basis to direct the effective implementation and termination of the programmes. A project monitoring system is a reasonable practise for recording initiatives, which are requested, approved for execution and completed for consideration.

Six Sigma Approach Awareness

The ideas behind the technique lead to a big part of Six Sigma instruction. Three classes of resources and techniques, separated into changes in procedures, instruments and techniques are learned during preparation.

Simple statistical instruments or consistency resources are usually more than adequate to solve the issue for several Six Sigma programmes. However, certain specialised statistical methods and techniques are needed for more progress in improving business processes.

Furthermore, a consistent collection of indicators must be utilised to assess the systems' output in relation to the expectations of the consumer. The failure rate, low cost efficiency, etc. are examples. Exact details are often essential for an overview of root cause potential and for helping decision-making teams.

Six Sigma link and market strategy

Unable to handle Six Sigma as an individual operation. A holistic framework is needed for the method, not just the use of certain methods and strategies for quality management (Dale, 2000).

The Six Sigma initiative, as it seeks to generate a return, supports the enterprise when addressing variability, contributing to a high scrapping rate, a high rework rate and poor productivity.

In every project, a connation must be established between project goals and strategies.

Six Sigma binds to the client

This desire to communicate with the client is the core aspect of performance for the Six Sigma method. Projects can start with consumer requirements determination (Harry and Schroeder, 2000).

Therefore, two essential steps are required in the Six Sigma interconnection process:

1) Classify important processes, evaluate the main outputs of such processes and describe the key customers represented by the method.
2) Consumer preferences and specifications recognition and description.

The option of core qualitative features (CTQs) is a big challenge. In the initial step of the Six Sigma approach, these CTQs must be quantitatively defined.

The quality feature is a effective strategy for recognising consumer expectations and turning them into specifications for engineering or architecture. Customer requirements are often vague, complex and loosely described in the service sector.

Six Sigma is linked to individuals

Human-resource decisions that facilitate desired conduct and consequences need to be enforced. Some studies indicate, while businesses with low results do not establish this correlation, that 61% of the businesses are connected to their benefits and market strategies (Harry and Schröder, 2000).

Without thorough preparation and a completed Six Sigma project nobody will be advanced in all GE firms. This is an amazing therapeutic strategy in itself (Hendricks and Kelbaugh, 1998). Moreover, Jack Welch from GE needs the Black Belt to operate the project to show the fixation of problems indefinitely.

Six Sigma link to dealers

Many Six Sigma companies find it useful to apply the concept of Six Sigma to the management of their supply chain. You can not create an organisation with Six Sigma without suppliers' involvement in cultural transition.

One method of minimising uncertainty behind the Six Sigma theory is the presence of few practitioners that have large levels of signma of practical capacity.

THREE TRANSITIONS TO SUCCESSFUL IMPLEMENTATION SIX SIGMA

General Eletric, Motorola and other large companies have managed to achieve success and financial gains in the implementation of Six Sigma, however recent literature has revealed the failure of the application of these methodologies in many companies. In this context Devadasan, Goyal and Sadagopan (2005) developed research work in Indian companies to guide and prepare companies for the successful implementation of the Six Sigma program. The authors present three critical transitions that organizations must undergo before implementing the Six Sigma program.

According to Devadasan, Goyal and Sadagopan (2005) the first transition that should occur in a company that intends to achieve success in the implementation of Six Sigma is the physical transition, that is, of people, materials, money and machines. In accordance with this transition requirement, employees selected to participate in the project must meet in a special cell to be developed especially for the realization of the project. The money must be available so that the project owner (who can be the company manager, the Master Black Belt or even another employee chosen for this function) can spend it when and how it is needed. The materials necessary for the development of the project must also be transported to the created cell, as well as the machines, however, in companies where the machines or equipment involved in the project are large and fixed or cannot be transported, they must be marked in some way. form to indicate that they are part of the ongoing project.

The second transition is psychological, managers and employees must be prepared and feel comfortable to carry out the Six Sigma project. The exchange of ideas and knowledge is very important for the project, so managers must make their employees feel comfortable contributing ideas that can help achieve the goal of reducing defects and reaching 3.4 DPMO (defects) per million). A good suggestion is to create an electronic system where employees can collaborate with ideas anonymously, or create a system of financial and / or non-financial rewards that promotes the participation of people with new ideas.

The third transition is linked to mentality. The adoption of statistical principles from the 20th century created a mentality that zero defects is an unattainable reality, this is because the control of statistical quality installed in organizations allows employees to be complacent with defects that are within the level of three sigma, and for this reason, they do not explore how technology and management models should achieve zero defect. Both management and employees must develop a mindset for creating alternative processes that make it possible to achieve 3.4 DPMO.

It is a difficult task to determine the order, type and levels of preparatory activities for transition in organizations that operate at different sigma levels (not all organizations work at the same sigma level of quality). In order to systematize these activities Devadasan, Goyal and Sadagopan (2005) propose some steps to guide organizations in carrying out the three transitions necessary for the success of Six Sigma. These steps are:

• First step: ensure that management is interested in implementing the Six Sigma program.

• Second step: choosing a project that is critical to the performance of organizational quality and measuring its sigma value, if this value is below 3, this will mean that this organization does not take traditional control activities seriously and in this organization the transition will be much more complicated, or it should not even be carried out. If the value is greater than 6, preparatory activities for the transition can be waived. If the measurement result is between 3 and 6, then this organization is the right candidate to apply the program, but will have to carry out the preparatory activities leading to the three transitions

• Third step: after completing the project choice, the current levels of the three transitions must be assessed.

• Fourth step: then, unfinished activities must be carried out in order to complete the three transitions. After that, the critical quality process chosen by managers must be reevaluated until their sigma level is at 6 or more.

The phases for the three transitions required to implement the Six Sigma program were studied at an Indian manufacturing company.

4 SWOT ANALYSIS OF THE SIX SIGMA

Goh et al . (2006) examined the benefits of the Six Sigma popular variant, limitations, openings and risks. Certain scientific and administrative figures are taken into consideration. Thus, 20 years since its inception, a practical methodology and a study of Six Sigma management was carried out.

• Strengths: consumer emphasis, data processing and predictive methods to challenges, senior management encouragement, engagement, well-structured project teams, simple to interpret process for issues, results-based programmes, comprehensive human resource creation and the success of bottleneck production lines.

• Weaknesses: heavy spending, heavy organisational culture vulnerability, standards not embraced universally and transactional procedures at the Sigma stage not checked.

Opportunities: intensely competitive and challenging industries, accelerated digital technology and data creation, increasing concern in safety and engineering efficiency examination and pre-implementation of Six Sigma approval compliance programmes.

• Threats: reform opposition, intensely dynamic labour market and existing circumstances.

Top management engagement and company culture are two main aspects of Six Sigma 's performance. Six Sigmay be a good approach to boost financial performance and market efficiency if senior management is fully dedicated and organisational culture is diverse and open to change. Six Sigma programmes do not have any impact on the operating level if the mathematical principles and resources needed are not successfully implemented; thus, it is important to learn the technological specifics. (Goh, 2006) 2006.

DO IMPROVEMENTS IN QUALITY BRING RESULTS?

Performance is one of the key problems of current research in production processes, according to Chen and Tsou (2005). Bad product consistency decreases consumer loyalty, lowers productivity and raises production costs. In the last two decades several research have been performed on the partnership between quality and manufacturing environment. The connexion between the efficiency life cycle and software output efficiency was explored by Krishnan et al (2000).

Salameh and Jaber (2000) considered that the goods purchased or manufactured were of imperfect standard, a specific case of output and inventory. The connexions between the economy in the productive sector and productivity were studied by Ganeshan et al . (2001) from Taguchi's view of low production. Llore'ns-Montes et al . (2004) analysed the effect on agile development systems of the introduction of the quality assurance mechanism.

Chen and Tsou's (2005) model attempts to determine the expense overall of low production and the financial return on quality enhancement by analysing the Six Sigma DMAIC technique for the manufacturing line for car seats.

The study was carried out at Rica Auto Parts Co. Ltd., a supplier of car seats. This company produces premium quality seat units and seats for secondary vehicles. According to market feedback, customers complain about the noise of the banks. In order to decrease warranty costs and ensure increased customer satisfaction, the production manager was instructed to reduce warranty claims and assess the production cost of his assembly line.

In the defining phase, the seven major manufacturing stages were identified, which are: cap the cushion, mount sliding bands, mount backrest, cover the backrest, functional test, packaging and delivery to the warehouse. After identifying them, all the factors that could affect each stage were listed. At this stage, all root causes of warranty claims were also found, each of which was analyzed and a conclusion was reached that 87% of guarantees were caused by noise from the banks' operation, 10% were caused by misuse and 2 % were from other causes. Based on the 80/20 rule, the noise problem was recognized as the main quality issue.

In the measure phase, the FMEA quality tool was used to analyze the problem and it was found that the cause of the noise in the seat's operation was the lack of alignment between the left and right side of the seat slip. There was an upper limit (404 mm) and a lower limit (404 mm) for this alignment and when the distance exceeded the specifications the noise was very large. The rework to align the banks cost 1 dollar per unit. In the analysis phase, performance objectives were defined, the main sources of variation were identified and a relationship between them was created.

In the improvement phase, all potential causes of defects were tracked and possible solutions were checked. At this stage it was decided to add a clamp to each mounting pin in order to improve the device and so that the seat does not suffer changes in its structure after assembly. The cost of adding the clips to the device was $ 200.

The mean and standard deviation after improvement are 402.103 mm and 0.43 mm. Process capacity has improved from 0.69 to 1.47 CPK, operating noise has clearly improved, and the process as a whole has reached a level of 4.38 sigma.

In the Control phase, plans were created to control measurements in the future and maintain progress. After identifying the process problems and implementing the improvements, the Tsou and Chen model was applied and it was concluded that for 10 production periods the cost without implementing the improvement was 62,805.5 euros and after the improvement this cost increased to 62,075.8 euros. The study proved that for a standard deviation of 402.103 mm, the investment results in quality gains, but above this value the investment only increases and the quality does not follow the same pattern.

6 METHODS AND TOOLS SIX SIGMA

6.1 The methods

Two main methodologies are included in the Six Sigma: DMAIC and DMADV. For a current phase, DMAIC is used. A new product or method is developed by DMADV. DMADV will typically contribute to a more predictable procedure and eventually a better quality result for new ventures.

DMAIC

The DMAIC comprises five essential phases.

• "D" DEFINE: In this step it is necessary to define precisely:

- The needs and desires of customers;

- Transform customers' needs and desires into process specifications, considering the availability of supply of inputs, the productive capacity and the positioning of the service or product in the market, taking into account the offers of competitors.

• "M" MEASURE: In this step, it is necessary to accurately measure the performance of each step of the process, identifying the critical points that can be improved. Whenever defects occur in the process, additional resources are spent to restore the level of production: inputs, time, labor to carry out the activity. These costs need to be measured.

• "A" ANALYZE: Analyzing the measurement results allows to identify the "gaps", that is, to determine what is missing in the processes to serve and delight customers. The search for the root cause of the problems leads to the development of hypotheses and the formulation of experiments, aiming at the effectiveness of the processes. In order to make improvements in the processes, projects or action plans are prepared, accompanied by schedules, dimensioning of necessary resources, costs and return on investment.

• "I" IMPLEMENT: The success of implementing the improvements is related to the way the plan is sold to people, which must include demonstrating the benefits that the change will bring and, whenever possible, taking advantage of their contributions in the way of operationalizing the strategy.

• "C" CONTROL: The establishment of a permanent evaluation and control system is essential to guarantee the quality achieved and to identify deviations or new problems, which must require corrective actions and standardization of procedures.

DMADV

There are 5 important steps included in the DMADV. Are they:

• "D" DEFINE: In the first point, the specification and priorities must also be consistent with the needs of the consumer and the organisational objectives.

• "M" MEASURE: Four factors ought to be calculated at this point. CTQ 's support quality analysis, flexibility procurement, risk assessments and product flexibility.

• “A” ANALYSIS: Analysis and design methods can be used to build better alternatives to eliminate defects. Their intrinsic capacity to decide whether the concept is the best option or an alternative that can be further produced should be tested for.

• “D” DESIGN DETAILS: A concept must be streamlined in this phase to reach the maximum standard. Furthermore, it can usually be tested in order to refine a template. Since the check is the final phase, each move should be a move into the next stage.

• “V” VERIFICATION: The drawing has to be checked whether it is examined and evaluated. The test typically undertaken is undertaken by a pilot. This can be a step towards full development, as checked by a pilot project.

6.2 The classic tools

Quality tools help companies establish quality improvements, understand and organize processes. The basic tools of quality control are: check sheets, Pareto diagram, cause and effect diagram, histogram, dispersion diagram, flow chart, control chart, brainstorming and 5W1H.

The Six Sigma process effectively implements these tools, which allows most problems to be solved. Each tool has its own use, and there is no adequate recipe for knowing which tool will be used at each stage of the process. This will depend on the problem involved, the information obtained, the historical data available and the knowledge of the process in question at each stage.

6.2.1 Check sheets

These are preplanned ways for simple and succinct collection of data. They document the details of the objects to be checked in order to easily understand the fact and to instantly analyse the circumstance.

6.2.2 Pareto diagram or Pareto chart

The Pareto map is a diagram of the objects and the class in order of the cumulative volume of activities. It enables one to imagine multiple elements of an issue, which helps us to define its priority.

The major trigger on the left side of the diagram is illustrated by falling bars, whereas the small induced ones on the left are displayed down in sequence. Through the addition of each individual to the sum, each bar reflects a reason that indicates the related reason. It is one of the most successful ways of problem-finding.

In this diagram Pareto the nature of issues is graded as "vital few" and "trivial many," indicating that a limited number of causes affect most errors, errors, grievances and costs. If these causes are detected and resolved, near-to all damages may be avoided. This is a goal.

For the "80/20" ratio, the Pareto concept is established. 80% of issues are usually triggered by just around 20% of possible triggers. In other terms, 20% of our issues cause 80% headaches.

6.2.3 Ishikawa diagram

A method to shows the principal triggers for a behaviour, which guide the sub-trigger towards the final outcome, is widely known as the fish graph or cause and effect graph.

In 1943, Ishikawa of the University of Tokyo invented this instrument. He used this to illustrate how many popular and linked variables might be. Although the diagram itself does not describe the causes of the issue, the diagram serves as a "vehicle to generate the most concentrated practicable, a collection of any known or suspected triggers, which may lead towards the observed impact.".

6.2.4 Histogram

A histogram refers to the frequency distribution of a series of scales, commonly a vertical bar map, consisting of a two-piece rectangle in which each of the bases is equal to the class spectrum and its height correlates to the corresponding frequency.

If the data number grows endlessly and the class spectrum tends to zero, the distribution of frequencies shifts to a distribution of chance. In any analysis, the construction of histograms is a significant predictor of the distribution of data.

6.2.5 Scatter diagram

This diagram allows to identify the existence and the intensity of the relationship between two variables (correlation), one dependent and the other independent. If there are repeated values, you need to circle them as many times as necessary. It can only be said that X and Y have a correlation, but not that X is the cause and that Y is the effect or vice versa.

6.2.6 Control charts / graphs

The control diagrams are configured for process monitoring. This surveillance helps the status of mathematical process regulation to be verified: regulated or unchanged. There are two forms of control diagrams, variables control diagrams, built for circumstances relating to the calculation of attributes and attribute control diagrams, which are supposed to address counting scenarios.

Testing diagrams synthesize a vast number of data by way of mathematical techniques to observe process shifts dependent on results from the study.

It will then tell us, when it is beyond the defined limits, of the conduct of the mechanism and the need for the variance to be examined but not if the variance is to be removed.

6.2.7 Flowchart

It is an illustrative summary of the flow of the various activities and events, phases and decisions of a process. The flowchart allows not only the processes to be called into question, but also the identification of duplications, gaps and dead ends, facilitating the simplification of the processes. It is a fundamental tool, both for the planning (elaboration of the process) and for the improvement (analysis, criticism and changes) of the process.

The flowchart facilitates the visualization of the various steps that make up a given process, allowing to identify those points that deserve special attention on the part of the improvement team. It is basically formed by three modules:

• Start (entry): subject to be considered in planning;

• Process: consists of the determination and interconnection of modules that encompass the subject. All operations that make up the process;

• End (exit): end of the process, where there are no more actions to be considered.

6.2.8 Brainstorming

It is a technique to stimulate creativity of a team, to generate and clarify a series of ideas, problems or questions. It is the most common tool in the collection of verbal data. It helps, for example, in the construction of the cause and effect diagram. Brainstorming's can be:

• Structured: each participant speaks at once, obeying the sequence or;

• Unstructured: everyone speaks when they get an idea.

After the identification of a mediator, the objective of the session is defined and each member presents a single idea at a time. At this stage, one should not criticize or discuss ideas, just register in a way that everyone can see (in a table for example). The more opinions arise, the better.

6.2.9 5W1H

It is a document that identifies through a survey the actions and responsibilities of those who will carry out an improvement project. This tool is able to guide the various actions that must be implemented. The 5W1H must be structured to allow a quick identification of the elements necessary for the implementation of the project.

The elements can be described as:

• WHAT - What will be done (steps);

• HOW - How should each task / step (method) be performed;

• WHY - Why should the task be performed (justification):

• WHERE - Where each step will be performed (local);

• WHEN - When each task must be performed (time);

• WHO - Who will perform the tasks (responsibility).

6.3 The seven new quality tools

These new tools offer the best methods to stimulate thinking, explain cause and effect relationships, organize and systematize information, reveal latent problems or opportunities, process verbal data, stimulate creativity, generate new ideas, allow multidimensional analysis, accompany the implementation of activities.

These tools present a qualitative approach, they appeared to supply the need to evaluate non-numerical data. If data is plentiful, traditional tools are sufficient, but this is usually not the case. In addition, traditional tools do not analyze the consequences of decisions or the relationship of one decision to another.

The new quality tools are: relationship / interrelation diagram, affinity diagram, tree diagram, priority matrix, process decision graph (PDPC), matrix diagram and activity diagram.

6.3.1 Relationship / interrelationship diagram

This tool seeks to visualize the entire set of cause and effect relationships, complex objectives and means by means of arrows in order to solve a problem. The Relationship diagram is very effective for cases involving complex interrelationships.

It is also a tool that requires creativity, the ability to analyze and reflect to define the logical connections that are only implicit in the process. It allows to isolate the few vital elements for the situation under analysis, to identify the different relationships and to make all the personnel involved quickly understand what needs to be done.

Some advantages when using the Relationship Diagram are: to identify the several main points; value adverse comments; identify the interrelationship between various sectors of the company, make solutions faster.

6.3.2 Affinity diagram

Tool that gathers a large amount of qualitative data (ideas, opinions, statements, manifestations, behaviors, etc.) and organizes them in groups, based on the natural relationship between each item, defining groups of items. This tool is applicable in processes where creativity, more than logic, is the fundamental factor in the association of data.

This tool is used whenever it is necessary to clarify important situations or problems, when your initial situation may seem confused or disordered. It is used to clarify the nature, form and extent of problems, grouping ideas or opinions in the form of verbal information (verbal data is collected through brainstorming or interviews), and visually represents data sets that have some affinity.

6.3.3 Tree diagram

It is used to search for the most appropriate and most effective means to solve a given objective. A great advantage of this tool is that it allows the visualization of all tasks and the means to reach the objective, besides forcing people to think in terms of means and objectives.

This tool can be used in several stages of quality control to develop the quality of new product designs, use the cause and effect diagram, develop solutions to internal problems, clarify control and departmental functions and promote increased productivity.

6.3.4 Priority matrix

This tool provides a method in which the group's attention is focused on the actions that are in fact most relevant, these can be classified according to their ease of implementation in three degrees, represented, for example, by the following symbols: 1-0; 2-X; 3-X. Typically, the list of options to be prioritized corresponds to the implementation tasks of the tree diagram.

6.3.5 Process decision graph (PDPC)

It is used to analyze the development and possible results of the processes, and among these, choose those that provide the desired results, that is, it is a tool that guides us in the face of unknown situations or subject to unforeseen circumstances.

With the PDPC it is possible to prepare preventive and containment actions before the occurrence of unexpected events, thus avoiding undesirable results. The PDPC considers the occurrences over time, therefore, it should be reviewed in the development phase of the activities. The aim is to define alternative actions and plans to be triggered if the speculated problems really appear, with a view to ensuring that all planned steps are accomplished without prejudice to deadlines, quality and the pre-established budget.

PDPC should be used in changing and dynamic activities, in complex processes where unforeseen events mean waste of time and processes where the probability of failures and unforeseen events is really considerable.

6.3.6 Matrix diagram

It stimulates multidimensional thinking by systematically investigating the relationships between two or more sets of verbal data. In addition to indicating the presence, it also shows the intensity of the relationships between the factors analyzed. The most important point in

The use of a matrix is to decide how to combine the sets of phenomena and corresponding factors.

There are several types of Relationship Matrix, which must be chosen according to the number of sets of factors to be analyzed, among which we can highlight:

• Type L - is a basic and widely used matrix that allows to relate two sets of factors. It can be used to associate goals and the means to achieve them, as well as draw conclusions about the relationships between consequences and their causes;

• Type T - is a superposition of two Type L Relationship Matrices. It is a good method of analysis for defect reduction activities;

• Type Y - is a combination of three type L matrices. It shows the relationship between factors A, B and C;

• Type X - is the combination of four type L matrices. However, its use is more restricted.

6.3.7 Activity Diagram

This tool, also known as the arrow diagram, establishes the most suitable daily plan for a project and efficiently tracks its progress. The arrows represent the activities of the project and the combination of them shows the sequence of activities and their interdependent relationships.

The activity diagram has its use indicated in complex projects where a large number of activities must be coordinated simultaneously, projects with a low tolerance for errors and delays, projects where those responsible have great experience and the execution times of each activity are estimated with good precision

PART II - CASE STUDY ANALYSIS

The European automobile industry

According to Donelly, Mellahi and Morris (2002) the car industry in Europe has focused its efforts on the domestic market since the rise of the Japanese car industry and the emergence of the economy in countries such as Malaysia and Korea. The main European producers' response, although late, was to reduce costs, rationalize plants, increase productivity and improve their relationship with suppliers in an attempt to increase efficiency.

The most globalized auto industry in the world is in the USA, Japan and Western Europe triad. These countries employ around 4 million direct workers in their industry, in addition to 10 million who are involved in the indirect production of material and components. When vehicle sales and maintenance are involved, the number of workers directly or indirectly linked to the car industry reaches 20 million (Dicken, 1998, p.316).

In accordance with Fordist techniques, the natural shift in automobile manufacturing known as lean development required EU factories to revisit their methods and systems, if they wanted to contend with other continents. In the implementation of simultary engineering, zero stock, absolute quality management, continuous development and organised work teams, and the usage of Kanban or pulled manufacturing mechanism, Kochan and Lansburry (1995).

It is evident that Europeans are now the poorest and most fragile of the three-way production lines, but the crucial argument is that the struggle and attempts at reforming the automotive sector to reach new markets and develop manufacturing methods are recognized even after a period of time and beginning from a place of comparatively vulnerability. Europe has to contend with so many manufacturing firms, and sooner or later overcapacity, and the opportunity for fusions between firms like GM and Fiat tends to emerge, contributing to complete American acquisition and growing American multinationals' position in Europe.

7.**2 Implementation of Six Sigma at Ford**

Ford has the phrase "Efficiency is the number one job," according to Paton (2008). They launch of new technologies to cut prices and win market share by utilising complete quality control. However, this great car manufacturer has recently made product failures, which have cost its consumers a loss in market share and unhappiness. Ford lagged in overall efficiency behind the archival competitor General Motors, ranking third of the seven largest car manufacturers according to recent surveys. Ford launched the quality review phase a few years back, but the findings are sluggish to be released for a $180 billion distribution business with 345,000 workers worldwide.

Ford CEO Jacques Nasser turned to Six Sigma to reach higher rates of efficiency. At the end of 1999, as the Director of Quality for the global truck company tried innovative strategies for enhancing efficiency, Ford became involved and introduced the Six Sigma approach. In January 2000, Ford officially started the process of Six Sigma. Nasser said that the first step of the Six Sigma effort of Ford was based on consumer loyalty instantly. In order to speed up product development, each of the production lines and related six Sigma programmes have defined the 25 best consumer complaints per vehicle for each of these issues.

Training workers is the secret to the sustainability of the Six Sigma Project for Ford managers. The organisation was the core of the project and established Master Black Belts, Black Belts and Green Belts. Over the first two years of project service, Ford has already educated about 10,000 workers at Six Sigma and is focusing on educating all the personnel in Green Belts until the end of the year.

Paton (2008) suggested that Ford chose six Sigma ventures on three criteria: consumer happiness programmes, a minimum of 70 percent reduction in errors and saving in $250,000 or more. Ford programmes have, on average, surpassed the expectations of cost savings. After defining tasks, Black Belts are still searching for unique observations and continue work on them via the DMAIC cycle and equipment.

In the process of "Defining" Schwarz Belts has the task of distinguishing and recognising the customers concerned. It is really necessary to keep the Black Belts aware of the time period and future financial gains at this point when the team that will engage in the project is established. For this step of the project, the method mapping and the CT matrix are the methods used.

Black Belts create procedures to quantify during the "Quantify" period. At this point they ought to be well aware of how the existing method is working, what the mechanism is, what the inputs and outputs are, which feedback processes impact the consumer and the success may better be accomplished. Method charts, cause and effect graphs, FMEA and graphic techniques are the standard resources for this level.

In the research step, the Black Belts must offer preference to input variables, evaluate the data to find reason for issue and improvement opportunities, creating variance in the process results. They are beginning to look at improvements in process entry and process output at this point. At this point, popular methods include process mapping, modelling strategies, multivariate tests, testing of theories, correlation and regression analysis.

Black Belts can create answers to issues during the "Develop" process and determine how best to manage the root cause. This includes cost-benefit analysis, confirmation of the approach of the issue, creation of an action strategy and communication of the strategy. At this point, popular resources involve visualisation, experiment design, simulation and optimization.

In the final level, defined as "Mission," the aim is to retain the successes achieved during the project execution. At this point, Black Belts needs to complete a control plan, record the initiative, interpret potential for institutionalization in other aspects of the enterprise, create processes and frameworks, and complete a strategy for the audit. Management plans, the statistical control of the operations, the precautionary maintenance and Poka yoke are standard resources at this point.

Paton (2008) notes that no Ford Six Sigma project is declared to be done before the DMAIC period has completed and an evaluation to check the influence on clients and systems has been performed.

Despite the deep determination of Ford Management to Six Sigma, when it agreed to launch the project the organization encountered several obstacles. Six Sigma at Ford faced blockages in resource distribution and data availability like any project in every company. Six Sigma is a project that needs a great deal of knowledge, and Ford increases the exposure to the information that is provided as a by-product of six Sigma, says Ford's Goeser employee, experiencing trouble in accessing the information or not really experiencing registered it.

Ford's Six Sigma investments, particularly with an organization of their magnitude, are not insignificant. The organization spent thousands of hours in preparation, procurement of modern facilities and technological instils, besides $6 million for teaching licenses in "Belts." However, the findings are impressive: Forde's Six Sigma initiative donated 52 million U.S. dollars in 2000 and Ford estimated a donation of 300 million US dollars in 2001 and a two-point rise in consumer loyalty.

CONCLUSIONS

From the study, it was concluded that the Six Sigma methodology focuses on improving quality (reducing waste) by helping organizations to produce better, faster and more economically.

Traditionally, Six Sigma focuses on defect prevention, reducing cycle times and cost savings. Unlike careless cost reductions, which reduce value and quality, Six Sigma identifies and eliminates waste costs. In general, these costs are extremely high in companies that do not use it.

The application of Six Sigma in the Cutting & Sewing industry (practical case) in order to reduce losses in the cutting process proved to be very efficient, as there were quantitative and qualitative gains.

Quantitative gains can be seen through illustrations 29 and 30, with a reduction of more than 10% in the consumption of Starting type fabric and more than 5% in Anjou fabric. The financial gains can be seen in illustration 31, where from July onwards, the saving is 9.8K € per month and follows a positive trend until the month of November. Between the months of January to March, the project's economy stabilizes at around 11.5K € per month. After one year of application of the project, the total saving is 125 thousand euros, a value that exceeded the 119 thousand euros stipulated at the beginning of the project.

There were also qualitative gains, such as the increase in the technical level of those involved in the project, resulting from the training and the increase in the employees' motivation in face of the positive results of the experiment and the possibility of growth and career boost with the training of the Green Belt.

Suggestions for upcoming work

The present study was about understanding the six sigma concept's, its tools and a case based examination of six sigma application. The researchers may consider six sigma application in following functional area of an organization.

• Logistics: the fulfillment of orders without defects, in the quantity and quality requested by the customer is a necessity within organizations and no longer a differential, companies feel obliged to provide services that meet the expectations of their customers.

Many companies have a problem of lack of stock control, that is, the company's physical stock usually differs from the stock registered in the system. Thus, the present work makes a study about the information systems that can assist in the collection, control and manipulation of data related to the company's stock. In turn, the study of stock management is necessary since through this logistical management it is possible to control the level of that asset in order to meet purchase and production orders;

• Sales and Purchasing: Six Sigma can become the essential element to create the pricing strategy in a company. The Six Sigma concepts allow the development of a proactive approach to the strategic determination of prices, enabling improvement in operability. This process avoids lengthy negotiations with no added value and, consequently, price erosion. An important action would be to develop new suppliers for the products purchased by the company, in order to increase the company's bargaining problem.

• Marketing: Six Sigma has evolved from manufacturing to other departments of the company and, although many bosses believe that a statistical method should not work in activities such as Marketing, companies are increasingly using the methodology in the company's transactional areas. Six Sigma in Marketing can assist in a process of checking which of the 4 P's (price, product, promotion and place) is most impacting the company's results.

In addition to testing the usability of the Six Sigma tool in the various departments of the company, the company could also compare the Six Sigma methodology with other methodologies, such as Lean Six Sigma, which seeks to improve processes and products, reduce, or even end up with, activities that do not add value and waste the organization's time and money.

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