Research Journal of Applied Sciences, Engineering and Technology 8(13): 1558-1562, 2014
DOI:10.19026/rjaset.8.1133
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: June 08, 2014 Accepted: July 19, 2014 Published: October 05, 2014

Research Article

Reduction Waste by Combining Lean Manufacturing and Six Sigma in an Electronics Industry

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Abstract: Nowadays organizations are involved in a complex environment with continues changing, that should impels the innovations looking for increase production performance, quality improvement, customer satisfaction and create a competitive advantage. Lean manufacturing provides an approach to identify and eliminate waste and all non value added activities through continuous improvement. The use of lean manufacturing as a set of "tools" that assist in waste identification and besides linked to DMAIC stages from six sigma could result in a systematic approach toward increasing value through production flow, statistical capability from the process and customer satisfaction; synergizing company efforts. An application case in an electronic industry from this integration is presented where sigma level from process was raised to 4.625 (99.91% efficiency), postulating VSM (Value Stream Map) and DMAIC stages as an essential first step from lean and six sigma respectively. The emerging integration that is already used in many industries is referred as Lean Six Sigma.

Keywords: DMAIC, lean manufacturing, lean-six sigma, six sigma, VSM

INTRODUCTION

In order to compete and survive in the globalization market, industries must adopt new tools and techniques, facing the challenge for delivering their products quickly at low cost and good quality (Kumar and Abuthakeer, 2012). Maintaining high productivity levels in their process, increasing the quality of the Products, increasing the customer satisfaction and decreasing the organization expenses are the main objectives for the organization (Nourbakhsh *et al*., 2013).

Two promising methods for addressing this issue are both the application of lean manufacturing (principles and techniques) and six sigma principles. These principles produced an emerging philosophy named "Lean-six sigma" that implies the knowledge of the foundation from lean manufacturing and six sigma principles.

Lean manufacturing was originally developed by Toyota Company to improve and optimize production process looking for minimize wastes (Padilla, 2010), and could be applied on any companies' size. Lean can be considered as a production strategy, which main purpose is helping to eliminate all operations with non value added to the product and processes, reducing or eliminating all waste and looking for improvement process operations (Silva, 2008), by pulling the product flow from customer needs in pursuit of perfection (Kumar and Abuthakeer, 2012). Therefore, a lean manufacturing implementation is associated with productivity increase, quality improvement, reduction of lead time and cost (Marudhamuthu and Krishnaswamy, 2011) by using the company assets as systematic approach to eliminating waste in the production process (Anvari *et al*., 2011).

Lean manufacturing should be considered not just a set of tools and techniques, even that involves a large set of them, but a working philosophy that adopted by the company can make significant improvements in terms of their operational performance (Marudhamuthu and Krishnaswamy, 2011). The advance in company competitiveness comes from thousands of employees solving problems, enabling processes to flow on line with customer's demand and focusing on cost reduction by eliminating non-value added activities (Puvanasvaran *et al*., 2008). Some of the main tools and techniques from lean manufacturing are: value stream mapping, 5S, TPM (Kumar and Abuthakeer, 2012); other techniques are kanban, kaizen, Single-Minute Exchange of Die (SMED) and Poka-yoke (Sabaghi *et al*., 2012): also Just in time, teamwork, Total Quality Control (TQC), visual control and many others (Salimi *et al*., 2012); that requires a comprehensible framework by managers and employees to avoid failing initiatives (Salimi *et al*., 2012).

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On the other hand, Six Sigma is the philosophy of constant process improvement, achieving customer satisfaction by focusing on the statistical deviation, process capability and preventing errors happen (Nourbakhsh *et al*., 2013).

Six sigma projects seeks to find and eliminate both process errors and defects causes, focusing in designed process by customer needs (Zu *et al*., 2006); Also these projects require team collaboration with aligned efforts toward the clear purpose and goals (Cariño, 2002). Successful implementation is conditioned by manager support, not taking individual projects as a single initiative related with cost reduction but a strategic measure supported by company staff (Eckes, 2002).

In statistic science, the standard deviation is used to describe the variability, showing the deviation of each operation from the average measurement of the process. So standard deviation is always related with the quality and in this philosophy is the target that should be continuously reduced in manufacturing products, by eliminating errors in products and processes.

So sigma quality levels should be constantly enhanced looking for a process that be less likely to create defects, with a better product reliability, thus a sigma level of six involve that no more than 3.4 defects are present per million opportunities. Sigma level indicate the defect proportion of the production process; in order to determine it, the DPMO index (Defects per million opportunities) should be calculated and translated using tables related with the underline area of a two tailed normal distribution area; like "sigma capability conversion table" presented by Pande and Holpp (2002).

According with Leduc (2008), after a review of several articles related with Lean Manufacturing and Six Sigma, published by the Society of Manufacturing Engineering (SME), Six Sigma was identified as a quality program with a focus on reducing process variation also Lean Manufacturing as a program focused on eliminating waste and improving flow. While Six Sigma uses DMAIC phases as the core tool for reducing variation, Lean Manufacturing primary attention is a process mapping looking to promote production flow and eliminate wastes (Al-Muhareb and Jasper, 2012); thus Lean Manufacturing essential basement is in process mapping trough Value Stream Mapping (VSM) who according with Marudhamuthu and Krishnaswamy (2011), should be the first step toward identify wastes of the process; also Al-Tahat (2010) gives preponderance to VSM as a helpful tool for process improvement in the value stream and eliminating wastes.

For Lean Manufacturing, the seven wastes are transportation cost, waiting cost, overproduction cost, defects cost, inventory cost, movement cost and excess processing cost stream (Sabaghi *et al*., 2012), than could be located by VSM. That is a collection of activities and actions required to bring resources and to show the main flows of value added to activities, besides identifying and taking actions related the value stream (Al-Tahat, 2010).

Combining both methodologies, efforts related to cost reduction and productivity enhancement are synergized. Since Six Sigma is focused to reduce variation through error prevention and Lean manufacturing targets in reduce waste and performance improvement. Thus the emerging Lean six sigma objectives are creating more value at lower costs (Al-Muhareb and Jasper, 2012).

METHODOLOGY

This lean-six sigma project is based in the integration of six sigma and lean manufacturing; taking tools and techniques from both; in order to achieve the proposed goals. The central structure of the method is based in the DMAIC sequence; who represent a problem-solving method which objective is process improvement, ensuring that the implementation be systematic and in a proper way (Deros *et al*., 2011). DMAIC is based on five stages for solving a problem, which are Define, Measure, Analyze, Improve and Control.

First stage of DMAIC is Definition stage, where a whole image of the project would be submitted (scope, reasons, benefits, goals, objectives, team members, defining interactions, delimiting project). A process stream trough VSM is useful in this stage to identify internal and external factors that influence process performance.

Second stage is Measurement where information related to actual situation was collected, and related with process performance and problematic areas; also, if is necessary generate quantitative data who allows make a diagnostic from current status to establish metrics goals.

In the third stage of analysis, the causes for deviation were identified. Besides, there were determined the effective and non-effective activities on deviations. During the fourth stage which is called improvement, process changes were implemented. Trough the last stage which is called Control, process changes were documented looking to be sure that changes in the process were maintained and integrated in the production process (Hwang, 2006).

This Project was realized in an electronic company installed in Mexicali, B.C., Mexico, in AC CAPS area for all production process of AC capacitors. The goal was to reduce and gain control over waste level, assuring material resource optimization over this area. AC CAPS has 5 production steps involving different activities: A1-Coiled, A11-Metallic, A2-Electrical Test, A3-Assemble, AR-Visual inspection and packaging.

To know the current situation related with waste rates from AC CAPS area, historical data from last year was collected. The ratio between entering material cost of production process and outgoing material cost from the process was calculated. Resulting a waste level rank between 1.04 and 2.37%.

Sigma level was calculated to evaluate the defect proportion from production process, using data of initial diagnostic. Each production unit could have 23 chances to be defective (quantity of defects that could be founded in one unit); so a sampling data shows that during two month period for 5163 produced units, 176 were found defectives; DPMO = (found defectives) / (quantity of defects that could be found in one unit×produced units) ×1,000,000 = 176/ (23×5169) ×1,000,000 = 1,480.39. Applying the "sigma capability conversion table" (Pande and Holpp, 2002); results in a Sigma level value of 4.375 σ. This metric could be used to evaluate the improvements of the area, also to focus in defect contribution and machine usage.

The collected data was analyzed in order to identify major contributing factors of waste and to determine which of the five production process in AC CAPS area, produces most waste. Finding that, A1-Coiled process generates the most waste, contributing with 57.75% of the total waste. Turning this situation, into a course action for team members to ensure activities that impact the waste level of the area.

After, it was realized a brainstorming for a Fishbone chart (cause-effect diagram), finding the reasons and causes of wastes in production area. A countermeasure activity were related with each sub cause so they were categorized according to the "spines" or "backbones" from the fishbone realized previously, knowing as the six Ms: Manpower, Method, Machines, Material, Measurement and Environment (Mother Nature).

The 28 countermeasure activities show a wide range of aspects that could affect waste in the production process such as "proper use and handling of the raw material in their area as well as the material in process" or "replace damaged and worn out tools, for others in good condition". To figure out the importance and impact of each countermeasure activities, a variable indicator was defined to check the incidence and impact in waste for each one.

Countermeasures like "correct assignment of codes according to waste origin", "empower capability for detecting and reporting unusual situations" as "material segregation by critical points of quality, emphasizing returns to vendor" will give results with high incidence and impact.

Trough the last stage called "Control", improvement activities were validated, verified and monitored in the sigma level; besides, changes were made in procedures in order to assure the follow up of the new or modified process.

RESULTS FROM LEAN SIX SIGMA IMPLEMENTATION

Seven subgoals were realized during these projects, everyone was developed in a specific DMAIC stage using a variety of lean six sigma tool. Table 1 shows in detail this process.

Table 2 shows the annual percentage of waste during 2010 to 2012, this was collected by a monthly analysis after implementing corrective activities. At the beginning, the study area had a percentage of waste between 1.04 and 2.37%, taking as an average in 2010 of 1.65%. While in 2011 a percentage of waste between 0.82 and 1.82% (average 1.33%), and 2012 had a level between 0.78 and 1.26 and 0.90% in average, respectively.

The tendency of waste index during 2011 and 2012 is showed in Fig. 1. Also, it can be observed that waste was continuously diminished up to reach the planned goal of 1%.

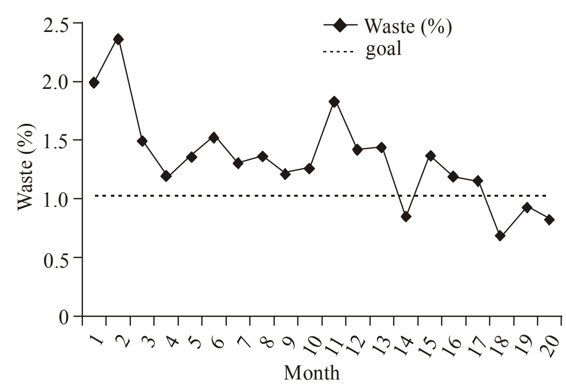

Fig. 1: Behavior of waste percentage reduction in A1 coiled process area during 2011-2012 period of improvement implementation

Table 1: Subgoals from proposal activities, DMAIC stage and lean six sigma tool used

Subgoal	DMAIC stage	Lean six sigma tool used
Diagnose and define current situation of waste indicators in process material, using historical data and preliminary studies	Definition stage	Histogram, Pareto chart
Evaluate indicators of waste materials	Measurement stage	Histogram, Pareto chart
Select and build an employee's team from the area who were involved in the project, present and implement improvement proposals	Analysis stage	Cause and effect diagram (Fishbone diagram)
Organize the workplace by encouraging habits of order and cleanliness	Improvement stage	5´s, TPM, visual control, continuous improvement (kaizen)
Improve the factory flow process by relocating production elements, looking for increasing the visual control	Measurement stage	Process mapping (VSM), sigma level calculation, visual control
Improving quality of production processes using quality control	Improvement stage	Continuous improvement (kaizen)
Establish mechanisms for tracking and reviewing the new process methodology, always making sure to maintain and increase the achieved improvement	Control stage	Continuous improvement (kaizen), 5´s, visual control

Table 2: Annual percentage of waste

Year	Min. waste (%)	Max. waste (%)	Avg. waste (%)
2010	1.04	2.37	1.65
2011	0.83	1.82	1.33
2012	0.78	1.26	0.90

Min.: Minimum; Max.: Maximum; Avg.: Average

Table 3: Annual DPMO obtained in A1 coiled process area

Year	Produced quantity (units)	Found defective quantity (units)	Opportunity chances to find defects	DPMO
2011	2070053.00	61004.51	47611219.00	1281.305440
2012	565974.00	15725.99	13017402.00	1208.074294

Table 4: Sigma level per year, in the A1 coiled process area

Year	DPMO	Sigma level (σ)
2010	1480.390000	4.375
2011	1281.305440	4.625
2012	1208.074294	4.625

Sigma level was obtained from yearly data in order to confirm the improvement on waste reduction; at the beginning of the project it was 4.375. Table 3 presents the data necessary to obtain the annual DPMO and Table 4 shows the obtained results.

According to the results shown in Table 4, an increase for the sigma level was observed from 4.375 to 4.625%, representing a rise in efficiency from a 99.79 to 99.91% efficiency, which is a considerable improvement, since all process goal is 6 σ, representing 3.4 DPMO or 99.99966% efficiency, equal to 3.4 defects in a million opportunities which is quite an ambitious but achievable goal.

Besides of the improvements related with waste reduction in the A1 area, the goals impacted also organizing the workplace by encouraging habits of order and cleanliness. 5's tool is the model for achieving and sustaining these habits, also merge with other visual control providing an organized and clean area.

Signals were placed in the area by identifying equipment, delineation of areas, parts in aluminum cans and plastic plugs to ensure the proper dimensions of the coil sections (identified by part number). Areas and places for garbage, non-conforming material and engineering material were designed, among others.

CONCLUSION

Although both methods have a proved effectiveness, their integration in a improvement project of these approaches results synergic; since both methodologies tools complement each other.

The synergic integration of six sigma and lean manufacturing requires defining a guide from both; six sigma provides DMAIC who is a basic methodology for this integration; also lean manufacturing provides VSM that should be the first step toward identifying wastes of the process. As the basement of this integrated philosophy, DMAIC and VSM provide a flexibility approach to any improvement project.

This particular lean six sigma implementation in a midsize industrial company has shown positive results. The full involvement of staff was necessary in this implementation, Lean sigma should be adapted over the circumstances of each case, so in this case tools like 5 s, visual control, production flow, work standardization and waste reduction was used, but defining DMAIC and VSM as core approach for the project.

Also, it is recommended to keep a continuous track on action plans and assigned activities so that not backward in the improvement process.

A plan to reward those who achieve higher performance indicators must be implemented. Promised rewards to employees must be fulfilled, otherwise staff will be de-motivated and company loses credibility with their employees. Bring to their employees attention on solving questions or issues regarding quality, attack problems that affects quality of the product and increase waste generation.

Keep schedule meetings about quality, provide a permanently feedback to staff and continues training to employees.

Materials management and communication with suppliers must be reinforced, ensuring highest quality in raw materials, helping to increase product quality and eliminating wasted time in quality inspections on non conformant material. Also, looking for opportunities to eliminate machines downtime due to lack of material.

ACKNOWLEDGMENT

We would like to thanks CONACyT-Mexico for given support to carry out this study.

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