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Lean-Six Sigma approach put into practice in an empirical study

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Abstract Manufacturing process improvement using Lean principles, tools and techniques has been highlighted as one of the most effective approaches since its main goal is to eliminate waste and inefficiencies by creating more value with fewer resources. This approach has been extended worldwide, especially in the manufacturing sector. Nevertheless, to deepen the development of advanced stages of Lean, such as pull and demand-oriented production, it is necessary to reduce variability in processes. For this purpose, the integration of Six Sigma-DMAIC could be a useful approach in order to develop advanced lean stages. This paper presents the Six Sigma and Lean effectiveness integration via an action research case study carried out in a domestic appliance manufacturing facility.

Keywords: Six Sigma, DMAIC, Lean, variability, case study

1.1 Introduction

Customers want reduced costs and, at the same time, they require higher levels of quality and value. This notorious phenomenon results in a race for survival and profitability as companies attempt to meet these customer needs. In today's environment, in an effort to please customers, businesses often will employ different approaches such as Lean and Six Sigma.

Lean is a philosophy that incorporates a collection of tools and techniques into the business processes to optimize time, human resources, assets, and productivity while improving the quality level of products and services for customers.

Six Sigma is recognised as meticulous approach to reduce a variation in all critical business processes towards performance improvements that can generate

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financial savings in an organisation (Antony et al., 2006). Moreover, is a discipline that helps to identify the root causes of variation in processes (manufacturing, service or transactional) using factual data and a rigorous methodology, rather than experience, abstract data or assumptions.

The Lean production and Six Sigma approaches have gained importance in recent years. Many companies have reported on their implementation of practices commonly associated with a Lean production system and the positive impact those practices have on manufacturing performance. However, Lean principles of waste reduction do not completely address the costs associated with inconsistency in terms of either quality or the time performance of activities or processes (Mena et al., 2002). Thus, Lean production and Six Sigma principles have significant overlap, although there are unique aspects to each.

The purpose of this paper is to demonstrate the advantages of applying Six Sigma with a DMAIC methodology approach in order to make progress in a Lean improvement program. DMAIC is a top down approach that allows an enhanced Lean process to be achieved. For this purpose Lean techniques are not very appropriate for reducing variability, whereas DMAIC and associated techniques could aid in improving manufacturing processes in order to get a continuous flow in the third stage of the Lean thinking methodology "make the activities flow". To demonstrate the effectiveness of the proposed techniques, the researchers have been involved in a case study of a company engaged in the manufacture and sale of components for central heating, domestic hot water, water heating and domestic appliances.

1.2 Literature review

1.2.1 Lean thinking

Over the last twenty years, small and large businesses have intensively applied the Lean approach. This methodology is sometimes called lean manufacturing or the Toyota Production System (TPS), among other names. The origins of lean manufacturing can be attributed to the TPS, which is a Japanese method focused on the 3M's. These Ms are: *muda*, the Japanese word for waste, *mura*, the Japanese word for inconsistency, and *muri*, the Japanese word for unreasonableness. *Muda* specifically focuses on activities that should be eliminated. Within manufacturing, there are categories of waste.

Taiichi Ohno identified seven common forms of waste, which is defined as activities that add cost but no value: production of goods not yet ordered; waiting; rectification of mistakes; excess processing; excess movement; excess transport; and excess stock (Ohno, 1988; Monden, 1993, Japan Management Association, 1985). It is common to find that in a factory less that 5 per cent of activities actually add value, 35 per cent are necessary non-value-adding activities and 60 per cent add no value at all (Womack, 1994; Womack, 1996). It is easy to see the steps that add value, but it is much more difficult to see all the waste that exists in a factory because *muda* is everywhere.

Fortunately, there is an effective methodology for eliminating *muda*: lean thinking. It provides a way to specify value, line up value-creation actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more with less (less human effort, less equipment, less time, and less space) while coming closer and closer to providing customers with exactly what they want. Moreover, lean thinking also provides a way to make work more satisfying by providing immediate feedback on efforts to convert *muda* into value. And, in striking contrast with the recent craze for process reengineering, it provides a way to create new work rather than simply destroying jobs in the name of efficiency (Womack, 2005).

In order to eliminate the existing waste during the manufacture flow of a product or family of products, the value-creating steps must be distinguished from those not creating value. Frequently, lean's focus is manifested in an emphasis on flow. Lean manufacturing has evolved into the lean thinking principles whose implementation methodology can be resumed as (Womack, 2005): identify which features create value, identify the sequence of activities that make up the value stream, make the activities flow, let the customer pull the product or service through the process and perfect the process.

1.2.1 Six Sigma

Even though Lean thinking is a powerful approach based primarily on the elimination of *muda*, there is another approach that is more focused on the elimination of *mura,* or process variation. Six Sigma has been used all over the world and many companies have testified to its important role in their success (Hutchins, 2000).

Six Sigma claims that focusing on the reduction of variation will solve process and business problems. By using a set of statistical tools to understand the fluctuation of a process, management can begin to predict the expected outcome of that process. If the outcome is not satisfactory, associated tools can be used to further understand the elements influencing that process. The assumption is that the outcome of the entire process will be improved by reducing the variation of multiple elements.

Moreover, Six Sigma offers many effective tools that provide the controls and assurance needed to achieve the desired levels of quality and control over process variation. Reducing unwanted variation occurs by following a structured problem solving method known as DMAIC, which provides the basis for continuous improvement (Shewart, 1931; Harry and Schroeder 2000).

These DMAIC tools are one of the most effective methods for eliminating product defects and speeding up processes, which translates directly into increased throughput (Lynn Northrup, 2004). However, it is really important that companies determine how to focus and deploy the Six Sigma breakthrough strategy to achieve Six Sigma quality so that key business priorities and strategy issues are addressed. Organizations must embrace some specific elements within the DMAIC model as prerequisites to success in the pursuit of becoming a Six Sigma (Eguren, 2011).

1.2.1 Lean-Six Sigma integration

Considering the fact that the Six Sigma programs adhere strictly to a system's perspective towards quality improvements, it is quite natural to observe the trend of integrating Six Sigma with other business improvement tools and methods such as Lean Manufacturing (Tang, 2007).

It is evident that both Lean and Six Sigma can be characterized in terms of their underlying philosophy and a set of practices, tools/techniques, implementation orientation, units of analysis, and performance measures associated with them. In addition, it is important to underscore the value of management and employee involvement in improving performance, though the nature of involvement differs considerably in the two approaches.

Lean is a bottom up approach where management plays a supportive and facilitating role in engaging shop-floor workers in forming work teams and applying Lean tools. In Six Sigma, in contrast, management plays a more active role, often selecting improvement projects based on financial and strategic goals and championing and monitoring improvement projects.

Hence, the following questions rise:

- Can the Six Sigma-DMAIC methodology be implemented in order to make progress in a Lean improvement program?
- Can Lean and Six Sigma techniques both complement each other in order to reduce process variation and allow the elimination of waste?

1.4 Case study

Yin, in *Case Study Research Design and Methods* (2003), defines case study research as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." According to this author, the single-case research design is useful if the case is a representative and revelatory case.

The researchers have chosen the action research process to develop and refine the DMAIC methodology within a Lean improvement program. Action research is a variation of the case study where the researcher is not an independent observer but a participant in the process (Eguren, 2011; Prybutok and Ramasesh, 2005) (Schein, 2008). Unlike other research methodologies, action research is concerned with creating organizational change and simultaneously studying the process involved (Avison et al., 2001). Therefore, members from the organization under study actively participate in the process.

The study was carried out in a domestic appliance manufacturing facility with a functional organization that is a leader in its sector and has facilities located in different countries. More specifically, the research study was developed in the valve manufacturing section and was focused on the mechanized and assembly stages. When the study began, these sections worked independently with a push functional organization, weekly planning and stock-based management. Through this project, the company wanted to become a lean organization so that the facility worked in a cell with a pull system and customer-based demand.

To better visualize the different states in terms of Lean approach, the researchers have considered useful mapped the processes using value stream mapping (VSM). It is a functional method to help practitioners rearrange manufacturing systems according to a Lean perspective (Rother and Shook, 2003; Womack et al. 2002; Pavnaskar et al. 2003). Besides, according to Pavnaskar et al. (2003), VSM has great potential to improve Lean productive systems. The arguments given are: simplicity and objectivity, the systemic vision provided for each product family reflects manufacturing system inefficiencies, the unification of Lean concepts and techniques in a unique body and the possibility of being the starting point of a strategic improvement plan.

The manufacturing process consists of three stages: stamping, mechanized and assembly. The first stage consists of stamping the valve's body, after which the valve goes to interim storage. In the second stage, based on the weekly planning, valves are taken from the interim storage to be mechanized and then stored again while waiting for assembly. In the final stage, valves are sent on to the assembly stage. The manufacturing process in terms of lead time, inventory, production efficiency and batching are shown.

When mapping the process the researchers realized that there were some barriers to implementing an ideal pull system. The reason is that there were some factors that produced variability. These factors were founded thanks to different used tools, for instance, in the DEFINE phase it could be emphasized, Quality Function Deployment (QFD) where it has been identified the key features highlighting the need for linearizing the process by customer demand, the zero transfers, the zero ergonomic problems and a minimum efficiency level 80%. Moreover, thanks to the SIPOC were viewed the suppliers and the inputs that they generate, the general phases of the process itself, outputs and customers. To conclude the definition phase, the Project Charter was developed which collected in a summary way the problem description, quantitative goals, the impact on the business, the project leader and the team that makes up, resources, restrictions and stakeholders.

Meanwhile the MEASURE phase objective is to identify the initial situation. Firstly, the researchers started to develop a series of questions related to the Y's outputs of the process which facilitate the departure diagnosis. Subsequently, the previous questions were responded through data analysis. For this purpose a flow chart was developed detailing for each process stage and the X's factors such as incidences, maintenance issues, changeover times, etc. were identified which affected the Y`s outputs like efficiency, number of manufactured pieces, etc. In addition, using a Pareto diagram, statistical graphics of unit values and capability studies graphics, it has identified the references to analyze, the variability levels of output and the variables that affected the process such as efficiency, changeover times, number of manufactured pieces, lot sizes, lead time, etc.

To conclude, in the ANALYZE phase, which main objective is to identify the vital few X's that affect the process, the researchers developed appropriate hypotheses such as "The efficiency level depends on the incidences of the assembly lines and mechanized". By means of Paret diagram, the incidents were classified where it is important to highlight the stops for reference changeover, breakdowns and minor stoppages. Then, the variability level was seen through capability studies and statistical studies using SPC graphics of unit values. After that, the actions were planned to face the hypothesis and the relevant tests in order to contrast them. All of this, it was defined in detail with statistical criteria. Finally, the experiments were tested and measured the variability, the efficiency level and the number of manufactured pieces in the new process using SPC graphics.

The first stage, which is called the flow stage, consists of synchronizing the assembly and mechanize manufacturing processes, reducing the production lead time and allowing the possibility in the near future to implement a pull demand oriented system once the process variation is reduced. The data showed that process variation remained and it was a barrier to implementing it.

Thus, at this moment is when it is necessary to apply the DMAIC methodology which was carried out by the researchers. Incorporating DMAIC helped with the project's implementation, since it allowed researchers to visualize and manage data quickly and accurately. Due to the DMAIC methodology implementation the facility reached the expected state, that is to say, the flow stage.

1.5 Conclusions

This case study has demonstrated that the integration of Lean-Six Sigma can be an effective and useful approach to eliminating inefficiencies and inconsistencies.

The researchers highlighted a number of questions regarding the implementation of DMAIC such as: define and set project goals, identify key characteristics, the importance of collecting data to monitor the process and convince workers, the use of simulation to test the proposed improvements, the necessity of setting a transition period to validate the improvements and people's resistance to change, the standardization of routines and operative process once the improvements have been demonstrated, the monitoring of indicators and the definition of improving responsibilities for implanting a continuous improvement program.

In addition, the researchers have found that visualizing the current state of a process with VSM techniques allows companies to assess whether the DMAIC-Six Sigma approach could be needed. Moreover, the Table 1.1 is a summary of the phases, goals, tools selected, limitations and learned lessons after using the DMAIC methodology.

At this point, it should be borne in mind that in order to implement a pull system, first all inconsistencies must be eliminated. For this purpose the DMAIC-Six Sigma could be profitable. Nevertheless, in order to apply the pull principles, other techniques such as SMED, TPM and Kanban are necessary.

Table.1.1 Summary table of each phase

Phase	Goal	Tools	Limitations	Learned Lessons
Define (D)	Validate the project rigorously	VOC, SIPOC, Project charter	Selecting and defining an aligned project with the organization strategy specifying the participants	The importance of defining the project objectives and identifying customer critical characteristics
Measure (M)	Identifying the initial situation and making a diagnosis that reflects the environment reality	Flow Diagram, Ishikawa, Pareto, Control graphs, Time graphs, VSM, Histograms and data collection sheets	Identifying the right questions to make a reliable diagnosis. Collecting quality data Working data properly	The importance of defining the right metrics and collecting reliable data thinks to be able to define an initial, real and reliable situation
Analyze (A)	Identifying critical factors that affect in the project objectives	Control graphs, Histograms, Pareto Diagram, Simulations, Data collection sheets, Statistical calculation of the number of tests to confirm the hypothesis, VSM	Being able to test hypotheses and confirm the results Run the simulations properly Involvement of everybody	The importance of validating the hypothesis by testing statistically validated The test execution following some standard methods
Improve (I)	Defining and implementing the solutions which are validated in the hypothesis	Control graphs, time graphs, capacity studies	Being rigorous in implementing the actions The improvements must be accepted by all participants	The importance of defining how to validate the improvement
Control (C)	Standardizing and defining the control system	Control graphs, time series, capacity studies, audit formats, procedure formats to change plans, Pareto diagram	Following the discipline to keep the results over time	The importance of standardizing and implementing the new routines The importance of monitoring the levels of achieved improvement

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