LEAN SIX SIGMA: DMAIC -THE GERMANE PHASE DEFINE, A PRACTICAL STUDY

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Abstract

Companies no longer compete with each other only on the final price of their product and or service. Technology allows the search for continuous improvement in processes in all organizations. So a focus for this condition is the practice of lean methodologies, six sigma, and the whole set of tools and techniques. In this sense, this article seeks to investigate how lean six sigma and especially the DMAIC methodology, especially the Define phase, contribute to six sigma practice. It is a practical case study of a lighting company, its assembly line, and its non-conforming finished products. In this way, data collection took place, and the sub-steps of the Define step were developed. The correct execution of each sub-step contributes positively so that the other stages of the DMAIC can be correctly structured, thus providing subsidies for six sigma and lean to be developed and prosperous in organizations.

Key-Words: Lean; Six Sigma; DMAIC Methodology; Define Phase

1. Introduction

This paper presents a case study undertaken by implementing DMAIC Methodology, specifically phase Define, into a Brazilian medium-sized lightning company located at Parana State to reduce the defects on the finished product manufactured. The not conforme finished products were a issue, due fact they were escondendo outros problemas na linha de produção. The organization's goal was to reduce the defects on the assembly line on the finished product, and secondly, work-in-process inventory, scrap, and rework costs. The management realized the importance of removing operational inefficiencies and wastes to salve cash flow and retain customers.

Today LSS is a business process improvement strategy. LSS offers reduced waste and increased value. However, the approach employs the DMAIC cycle as the key driver in the implementation process, using LSS.

The LSS will empower the fulfillment of defects reduction, eliminating non-value-adding activities from the production line, and has been developed with the integration of DMAIC tools and techniques.

In terms of methodology, this is applied research; data collection took place in the lighting company, an uncontrolled environment, without controlled manipulation of variables.Concerning the objective, it is descriptive. The data is sourced from the company's database, forming the context for analyses that are part of the phase Define and other guidelines. As a research problem, this article aims to develop reflections on how applying the defined phase of the DMAIC methodology can contribute to the Six Sigma process?

2. Literature review

The main theoretical concepts that make up the article's scope are presented in this topic. The papers and classic literature with their relevant analyses and contributions are its sources.

2.1 Lean Six sigma

Due to the market conditions as customers, pressure, and competition increment for reach more excellent value based on quality, faster delivery, lower cost, manufacturing and service companies should follow either Six Sigma or Lean Manufacturing. Six Sigma helps to have a better process and problem-solving approach, and Lean Manufacturing cooperates on management strategy to increase market share and expand profit. The Lean production core works to create an updated system that produces products with little or no waste, as per customer demand. On the other side, the Lean strategy brings tools and techniques to reduce inventories, set up times, lead times, scrap, rework, and other essential aspects (KUMAR et al, 2006).

However, to achieve the positive results from these methodologies, some prerequisites should be observed as management commitment, good communication between all levels of culture, training, and education of employees. Using the comprehensive set of tools mentioned above can help reduce all kinds of waste (rework, overproduction, waiting, material, human skills, transportation, and unnecessary movement) from the organization (KUMAR et al, 2006).

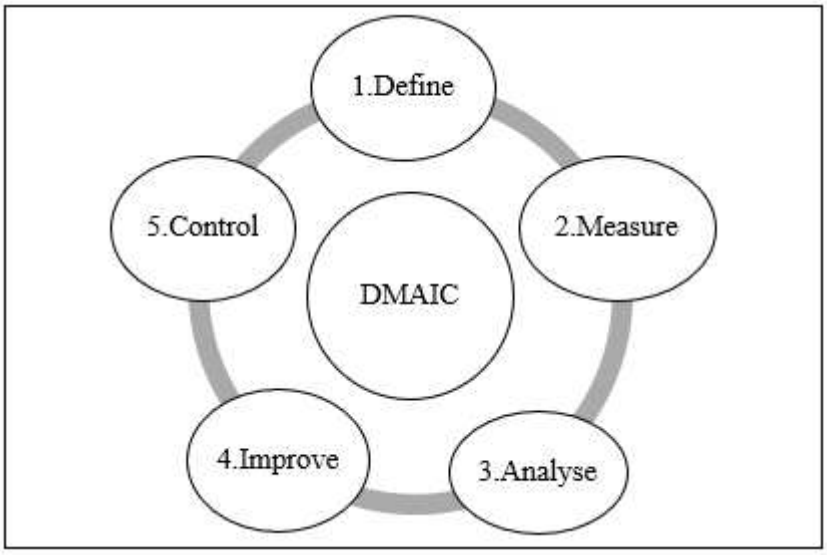
As a historical chronological sequence for six sigma, in 1987, Motorola developed the six-sigma methodology and defined a goal of 3.4 parts per million (ppm) defects (STEWART, SPENCER, 2006; KADRY, 2018).

Kadry (2018) affirms that the sigma means the statistical unit of measurement used to define the standard population deviation. Six sigma is an organized approach to achieving a

committed team and better performance in construction processes (Linderman et al., 2003); and Kadry (2018, p.6) observes that a single sigma improvement in a business process means into about something "about 10% net income improvement, a 20% margin improvement, and a 10 to 30% capital reduction".

According to Pyzdek (2003); and Stewart, Spencer (2006), Harry, Schroeder (2006), Da Silva et al, (2021) six sigma is a systematic procedure constituted by a five-step methodology call DMAIC (fig.1) (Define, Mesure, Analyze, Improve and Control).

Figure 1 Methodology DMAIC



Source: The Authors (2022)

On the most fundamental Six Sigma's tools is DMAIC (see table 1) which consist of five levels. It discerns a routine for the members of the organization follow it to clarify problems and improve processes (DA SILVA, et al, 2021)

Table 1 Lean and Six Sigma Tools and Metrics

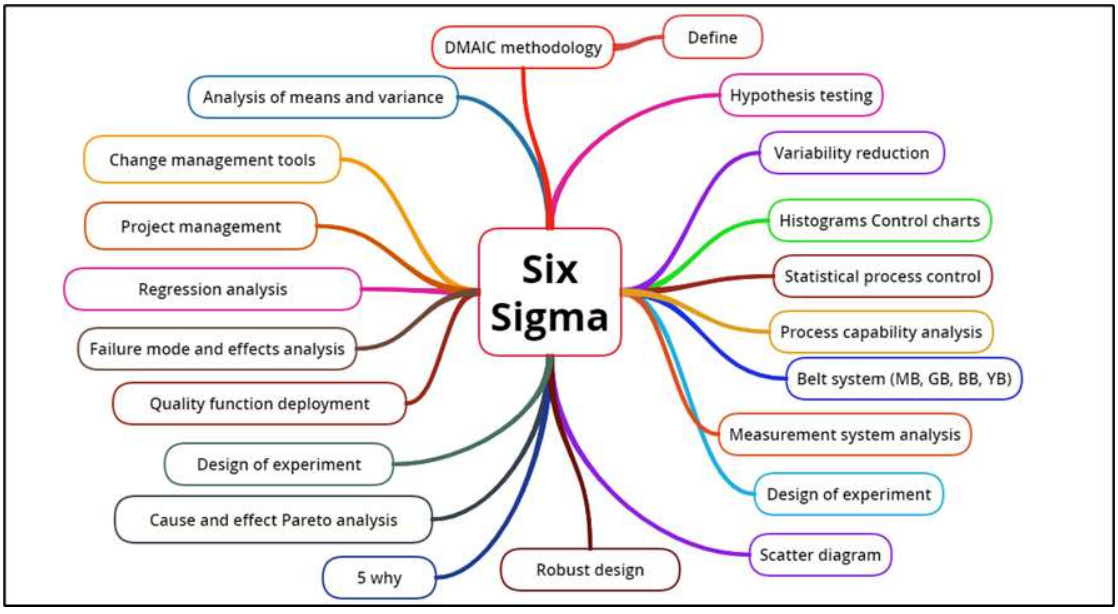
DMAIC Description and Six Sigma Tools	
DMAIC Description	Six Sigma Tools
Define (project definition): define scope, and limits, establish the problem through the customer's need, select champion and team members, establish the impact, aprrove the company's leadership	Project charter, Return on Investment (ROI), Critical to Quality (CTQ), Voice of Customer (VoC)
Measure (pratical problem-process measurement): measure what is being used, draw the process map identifying its inputs and outputs, collect data for	VSM-current, Supplier-Input-Process-Output-Customer (SIPOC), Ishikawa, Pareto, Quality Function Deployement (QFD), Boxplot, kaizen

the assessment of key points, draw up a cause-and-effect matrix, measure the process variables	
Analyse (statisitical problem-process analysis): identify the root causes, correlate the variables thar are most likely to create distortion in the process, establish plan for the next phase	SM-Future, Failure Mode and Effect Analysis (FMEA), Anova, Priorization Matrix, Repeatability and Reproducibility (R&R)
Improve (statistical solution process improvement implementation): determine the best way to reduce the identified variation in critical inputs, optimize critical outputs, implement the solution, and confirm the process improvement	5W2H, kaizen, Design of Experiments (DoE), Gantt
Control (practical solution process control): establish controls to make sure the probelm has been soved, standardize proposed chanes, implement a control plan, dissemination to other processes	Control Plan, Poka-Yoke (PY), Statistical Process Control (SPC), lessons learned

Source: Da Silva (et al, 2021, p. 1383)

The Six Sigma techniques's and tools are implemented to offer solutions to issues. The architecture of techniques, tools and principles that aggregate and integrated access of Six Sigma is presented in figure 2 (KUMAR et al, 2006).

Figure 2 Six Sigma Architecture



Source: Kumar et al (2006, p. 409) modified

Ray and Das, (2010); Gitlow et al., (2006), higlitinig that Six Sigma is a project approach to process- and productquality. Projects are the path by which Six Sigma remodel quality

advances bottom-line financial benefits (Gulcin and Demet, 2010; Kubiak and Benbow, 2009).

Even though some quality management systems and philosophies are followed carried out by some organizations, the desired standard quality level is not always attained. Without a competent quality cost system in place, measuring the quality improvement is more complex; due to the fact, the product or service quality is not related to the final delivery but the complete business process (Tchidi; He; Li, 2012).

According to Sin et al (2015), the purpose of the Define phase is to determine the project focus, such as project charter and customer critical to quality. For Swarnakar, Vinodh (2016), the Define phase compreendhs problem definition, flow chart, current sate map, project charter and SIPOC chart.

In according with Da Silva (et al 2021) the Lean Six Sigma (LSS) aspects identified were classifed and organized to demonstrate the implementation of the LSS as:

a) customer's focus;
b) value stream mapping (VSM);
c) manage and improve the process;
d) remove value-added waste;
e) manage six sigma;
f) reduce variation;
g) involve commit the team in the process.

These aspects have a direct relation with cost (productivity enhancement); value (based on customers eagerness to pay); quality (important to improve working) and time (to improve working) metrics as presented on table 2 (Da Silva et al, 2021).

Table 2 Lean, Six Sigma Aspects

Lean, Six Sigma Aspects	Metrics			
	Cost	Time	Quality	Value
Assessment: VSM, DMAIC	x	x	x	x
Eliminate: waste, defects	x		x	
Reduce: lead time, variability		x	x	
Customer: added value, satisfaction				x

Disseminate: TPS, TQM	x		x	
Portfolio: aligned with five years	x			x
Project: continous improvement, problem-solving	x			x
Cost: reduction, zero defects	x		x	
Effectiveness: efficiency, quality	x		x	
Emphasis: shop floor, engineering	x		x	

Source: Da Silva (et al, 2021, p. 1361)

The Six Sigma metrics are defects per million opportunities (dpmo), sigma quality level and cost poor quality. The lean metrics are takt time, lead and setup; value, flow and waste. Lean Six Sigma metrics are focus on quality, performance, and availability, ie, OEE, overall equipment and efectiveness. These metrics were arranged follow the parametres: assessment with the review process purpose; continous improvement (*kaizen*) and monitoirng by key performance indicators, as the table 3 presents (Da Silva et al, 2021):

Table 3 Lean and Six Sigma Tools and Metrics

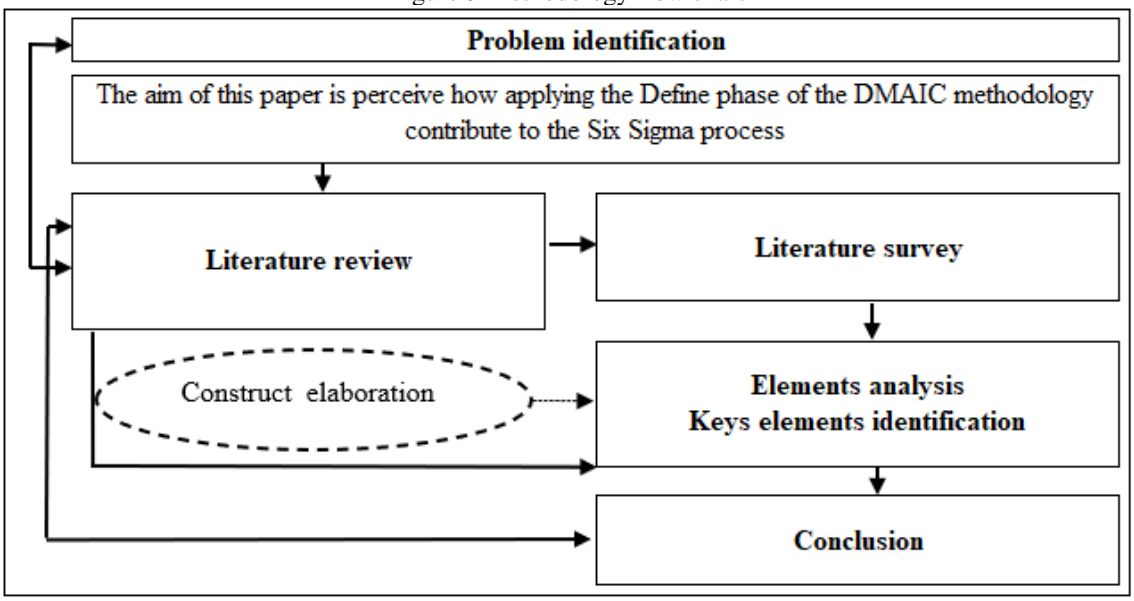
Lean and Six Sigma Tools and Metrics			
	Assessement	Continuous improvement	Monitoring
Lean Tools	Value Stream Mapping (VSM); Just -in-Time (JIT); Toyota Production System (TPS); World Class Manufacturing (WCM)	Poka-Yoke (PY), Total Production Maintenance (TMP); Single Minute Exchange of Die (SMED); Standardized Work (SW), Continous Flow Manufacturing (CFM); 5W2H; 5S; 5Whys	A3-Plan-Do-Check-Act (PDCA); Overall Equipment Effectiveness (OEE) A3-Plan-Do-Check-Act (PDCA); Overall Equipment Effectiveness (OEE)
Six Sigma Tools	Define, Measure, Analyzed, Improvement, Control (DMAIC); Statistical Process Control (SPC);Total Quality Management (TQM); Voice of Customer (VoC); ,Supplier, Input, Processo, Output, Customer (SIPOC); Business Processes Management (BPM); Ishikawa, Pareto, ISO	FMEA; Quality Function Deployement (QFD); Design of Experiments (DOE); Repeatability and Reproductibility	PDCA

Source: Da Silva (et al, 2021, p. 1361)

3. Method

The researchers carried out exploratory and quantitative research. The central idea is to study and comprehend the application of the phase define (D) in the DMAIC methodology. The Web of Science and the Scopus database were extracted to select the papers, and the methodology flow chart is presented in figure 3:

Figure 3 Methodology flow chart



Source: The Authors (2022)

The article research is classified as an applied purpose because it favors scientific development and contributes aspects to research with application to the resolution of specific subjects (GERHARDT and SILVEIRA, 2009; GIL, 2010).

Data collection took place in the lighting company, an uncontrolled environment, without controlled manipulation of variables.

Concerning the objective, it is descriptive, as it brings with it the aim of describing facts and phenomena under certain conditions, or else, the establishment of relationships between variables (Gil, 2010). In terms of nature, it is quantitative because it aims at objectivity, analysis of raw data, collected using standardized instruments (GERHARDT and SILVEIRA, 2009).

4. Analysis and results

The object of study of this article concerns a company that manufactures luminaires, which had problems in the assembly line of the luminaires. The work was carried out throughout 2021, and reference data from 2020 identified 952 RNCs. Every assembly issue identified generates a non-conformance report (RNC).

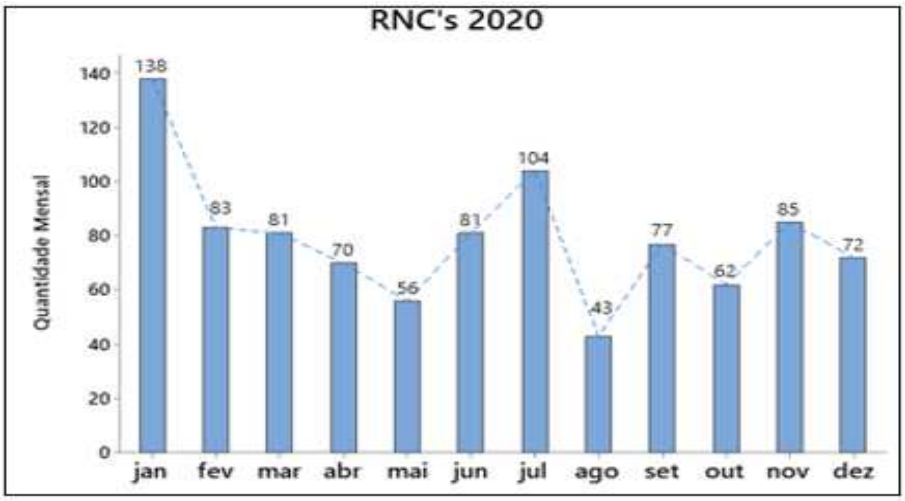
So the first step in the define step was to identify the problem and quantify it accurately. Of this amount of RNC, 6967 lighting fixtures were sent for rework; and 575 luminaires were discarded for not being able to be reconditioned. In addition to representing a loss of time,

labor, supplies, finished product, eventual loss of deadlines with customers, these luminaires added up to approximately R$ 150,000.00 of direct loss and more than R$ 800,000.00 of replacement costs.

The second step was to make sure the data was reliable. The RNCs are documented, cataloged, and classified according to the type of failure; Authentication is also carried out using the internal batch and product verification process.

The third step was to know how the selected data behaved (graph 1); in the 2020 analysis.

Graphic 1 Non-compliance report 2020



The variatic faced since April/2020,

The fourth s ce from 952 to 620 the n 021.

With this planning, the following targets were listed:

a) Cost reduction: direct cost of R$ 50,000.00; and cost with a mark-up of R$ 280,000.00;

b) Quality: customer satisfaction, reduction in delivery time, and increased reliability;

c) Continuous improvement: indicators for efficiency analysis and improvement of the process as a whole.

The penultimate step was to establish the members of the work team, and the last one was the structuring of the SIPOC (figure 4).

Figure 4 SIPOC

Suppliers	Inputs	Process	Outputs	Customers
Warehouse	Components buffers to	Receive the components to assembly line	Products for the pick list	Picl list sector
Pick list sector	Product list	Create assembly kanbans	Kanban needed for each production order	Kit sector production order
Kit sector production order	Production order	Create assembly kit	Assembly kit created	Lighthning assembly line
Lighthning assembly line	Pallet with kit assembly	Pre assemble the plates on the lightnings	Lightning with the plates created	Robot, assembly line
Robot, assembly line	Lightning with the plates parameters/ robot parameters	Mount the wires on the robot/ Mount the wires manually	Lightning with electrical installation	Sector to finished the lightning
Sector to finished the lightning	Lightning electrical installation done	Finished the assembly lightning	Lighting finished	Testing sector
Testing sector	Lighting finished	Batch and product tests	Lighting tested	Packaging sector
Packaging sector	Lighting tested and approved	Packing the product	Product packaging to shipment	Shipment

Source: The Authors (2022)

With these steps performed correctly, the chances of success in the other stages of DMAIC and the practice of six sigma are real.

5.Conclusions

Certain remarks can be made regarding lean, six Sigma, and Define Phase from DMAIC. Lean eliminates waste and non-value-added activities across the organization; using statistical tools and techniques; Six Sigma takes an improved level of process performance and capability. DMAIC is one of the Sis Sigma tools that brings a methodology and practice that allows improvements in a consistent way to the company. Phase Define its fundamental importance in the DMAIC process and the six-sigma methodology. The correct and coherent definition of each step within the Define phase serves as a guide for the next phase, analyses, and actions that need to be carried out. An entire decision-making process and expected results can be compromised if the research problem, the quality of the data, the understanding of the behavior of these data are not clear. Likewise, the definition of improvement targets, the members, and the SIPOC of the process contribute decisively; completing a context of analysis must be done thoughtfully. An entire improvement work using the six-sigma methodology can be compromised, or its objectives can be partially or not achieved. Due to this fact, the elementary of define's phase was not correctly established. All this work requires

the involvement of top executives and communication with the bottom line to develop robust products and processes.

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