INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br *v. 10, n. 6, November - December 2019*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

LEAN SIX SIGMA: IMPLEMENTATION OF IMPROVEMENTS TO THE INDUSTRIAL COST MANAGEMENT

Rodrigo Subirá Conceição
State University of Maringá, Brazil, Brazil
E-mail: rsubira7@gmail.com

Maria Carolina Pariz
Federal University of Technology of Paraná, Brazil, Brazil
E-mail: Mariac_pariz@hotmail.com

Vander Luiz da Silva
Federal University of Technology of Paraná, Brazil, Brazil
E-mail: luizvnder@gmail.com

Daiane Maria de Genaro Chiroli
Federal University of Technology of Paraná, Brazil, Brazil
E-mail: daianechiroli@utfpr.edu.br

Franciely Velozo Aragão
Federal University of Technology of Paraná, Brazil, Brazil
E-mail: fvaragao2@uem.br

Submission: 1/28/2019
Accept: 3/13/2019

ABSTRACT

In practice, with the aim of achieving competitiveness, the industrial sector has the primary function of looking for ways to increase productive performance, improve the quality of products and processes, and reduce waste and production costs. An alternative to these strategies is the deployment of improvement projects, following the DMAIC structure of the Six Sigma approach. This study aimed to present the results of Lean Six Sigma implementation oriented to cost management. A case study was carried out in an agro-industrial cooperative, specifically, in the grain receipts department. The tools applied in the case study were: Requirements Tree; Charts Pareto and Stratification; Cause and Effect Diagram; Failure Mode and Effect Analysis; Statistical Process Control, and; Control Array, respectively. These tools are widely used in quality management and continuous improvement of industrial processes, mainly.

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

As result, it was possible to apply all the tools proposed by the methodology and achieve a satisfactory result of cost improvements. The improvements obtained in the department's cost management system, as well as the increase in the capacity of the process, were both significant.

Keywords: Six Sigma; Industrial management; Cost reduction; Cost management

1. INTRODUCTION

With the growing competitiveness in the global market, industries have a newfound need for maintaining a continuous evolution process, related to the aspects of production, quality, costs, among others (AWAJ et al., 2013).

In practice, the industrial sector has the primary function of looking for ways to increase productive performance, improve the quality of products and processes, and reduce waste and production costs, with the aim of achieving competitiveness. According to Cho and Pucik (2005), in enterprises, controlling the quality of products and processes and reducing costs are the main ways of achieving competitive advantages.

An alternative to these strategies is the deployment of improvement projects, Lean Six Sigma. The Lean Six Sigma incorporate concepts of quality engineering, statistical quality control, total quality management and offline quality control (MAST; LOKKERBOL, 2012). Both methodologies work to improve processes and reduce waste (ZHANG et al., 2012), including improvements in productivity, growth of the enterprise's participation in the market, reduced lead time, reduction of cost and continuous quality improvements (JADHAV et al., 2015).

This study aimed to present the results of Lean Six Sigma implementation oriented to cost management, following the Six Sigma's DMAIC method (Define, Measure, Analyze, Improve and Control stages, respectively).

A case study was carried out in an agro-industrial cooperative, specifically, in the grain receipts department. A number of Quality Management tools have been applied benefiting the industry under study, as well as the results presented can provide subsidies to other industries and managers.

Firstly, the research is contextualized and its goal is presented. Then, in the second section, the theoretical approach, which encompasses concepts of quality

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

management and the DMAIC methodology, is described. In the third and fourth sections, the research methodology and the results are presented, respectively. In the fifth section, the conclusions are presented.

2. QUALITY MANAGEMENT

To achieve the ideals of quality in an enterprise, its concept needs to be brought into the organizational framework, giving way to the need for the Quality Management.

Juran (2009) establishes three universal processes for quality management aiming at the satisfaction of the customers' needs: quality planning, quality control and quality improvement.

Based on Quality Management concepts, enterprises evolve to the vision of Total Quality Control, starting from the 1950s, and later, in the mid-1980s, the concept of Total Quality management is spread (PALADINI, 2008).

Total Quality Management (TQM) is a management philosophy that seeks to integrate all functions of an organization, with a focus on the customers' requirements and organizational objectives (HASHMI, 2016). For Oakland (1994), TQM is an approach that allows increasing an enterprise's competitiveness, providing greater efficacy and efficiency to its processes, in addition to, according to Gharakhani et al. (2013), improving the organization's performance in terms of quality, productivity, customer satisfaction and profitability.

For achieving organizational objectives such as better product quality, cost reduction and lead time, among others, enterprises in general begin applying the Lean Six Sigma principles.

2.1. Lean Six Sigma

Lean management was originated at Toyota, in Japan, and then implemented by American enterprises (ARNHEITER; MALEYEFF, 2015). According to Werkema (2006), with the Lean approach it becomes possible to reduce the lead time, wastes and increase the speed of the process.

The Six Sigma approach it was originated at Motorola in 1987. A year later, the enterprise received the Malcolm Baldrige National Quality Award, and Six Sigma became recognized worldwide (DROHOMERETSKIA et al., 2014). In the Six Sigma,

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

the solution of problems based on statistical quality tools is emphasized (WERKEMA, 2006).

Given the ascertained Lean and Six Sigma management and deployment capacity of leading enterprises, the George Group was the first to integrate and popularize the two methodologies, resulting in the Lean Six Sigma program (SALAH et al., 2010). From the perspectives of Zhang et al. (2012), Lean and Six Sigma are approaches of reduction of waste and processes improvement.

The Lean Six Sigma refers to a methodology geared towards variations of processes, reduction of waste, improvement of organizational quality, among others (FURTERER; ELSHENNAWY, 2005; SALAH et al., 2010).

The Lean Six Sigma implementation is based on DMAIC Methodology (nomenclature represents the sequence of stages), represents a cycle to develop projects, for improving quality, both in relation to the reduction of defects and to the increase in productivity or reduction of costs.

3. METHODOLOGY

This study was carried out in the grains receiving department of an agro-industrial cooperative located in the state of Paraná, Brazil.

Based on the Lean Six Sigma strategy, the project grounds itself on the DMAIC method for its elaboration.

3.1. Define

The first stage of the project should be defining its scope and goal, in accordance with the enterprise’s business case (WERKEMA, 2006).

For the elaboration of the Six Sigma project of cost reduction in the grains receiving department, during the Define stage, the Project Charter was developed, based on a standard model proposed by Domenech (2016). According to Werkema (2006), the Project Charter is intended to align the design team with the enterprise’s strategy, from the definition of the project’s scope and goals.

Tools were also applied, such as: Requirements Tree - VOC/VOB, and; Pareto Charts and Stratification of Costs (Ys), respectively.

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

In the department studied, the variables Safety, Quality, Cost and Process were analyzed through the Requirements Tree. Domenech (2016) reports that the Requirements Tree allows so that project leaders may become aware about the needs of customers, converting them into measurable variables. Of the variables analyzed, Cost was the one prioritized in this study, given the need for its improvement.

Then, from the analysis of historical data relating to costs generated by the grains receiving department, Pareto Charts were applied to prioritize macro costs (apportionment, work force, tax and technical expenditures). These costs were properly stratified. For Domenech (2016), the stratification of costs (Ys) assists in the detection of the causes of the process' problems, though it does not allow the identification of the root causes.

3.2. Measure

The purpose of this stage is to understand and document the current process, which will be improved through the project. The costumer's voice must be heard in more detail and the reliability of the current process' measures must be verified (FURTERER, 2009).

The Cause and Effect Diagram was elaborated in the measure stage, and allowed presenting the possible causes of increased costs in the industry. These causes were identified through the stratification of costs and through the analysis of the process. The Cause and Effect Array was then elaborated to prioritize the causes identified earlier.

3.3. Analyze

In the Analyze stage, the fundamental causes for the problems identified are determined, the reasons why the problems occurred will be explained considering the project's goals (WERKEMA, 2006).

In this stage, the Failure Mode and Effect Analysis (FMEA) methodology was applied, for analyzing the criticality of the costs and failure modes present in them.

3.4. Improve

The Improve stage begins with the generation of ideas to solve, minimize or eliminate the fundamental causes of the problems detected in the previous step. For this, appropriate tools are used to support the project's team in the generation and selection of solutions (WERKEMA, 2006).

Then, in the Improve stage, the possible solutions to the failure modes identified in the FMEA were generated by the project team, and a plan for improvements containing eight procedures was elaborated.

3.5. Control

The control aims to maintain the improvements made and determine the capacity of the current process (DOMENECH, 2016). In this study, the Control stage was performed by applying two statistical tools, the Statistical Process Control and the Control Array, respectively.

4. RESULTS AND DISCUSSION

The Table 1 presents the Project Charter that was constructed.

Table 1: Project Charter.

Six Sigma Project: Reducing Costs in the grains receiving department			
Service	Grains receiving	Project's revenue	R$ 880,000.00
Belt Leader	Strategic Management	Department	Grains receiving
Sponsor	Operations Superintendent	Representative of the process	Manager of the grains receiving department
Champion	Master Manager	Start date	03-01-2016
		End date	12-16-2016
Information	***Explanation***	***Description***	
1. Business case	Connection of the project with the enterprise's strategy	The project is related to strategic High Efficiency management, which aims to achieve the result with the least possible loss of resources.	
2. Opportunity	What are the project's opportunities?	In 2014, 1.2 million tons of products were received, totaling R$ 7,500 million; in 2015, 1,160,000 tons were received, totaling R$ 8,300 million, i.e., there was a decrease in the receiving of products and an increase in cost. In addition, in the last 3 years, the values achieved were, on average, 34% higher than the budgeted values. In 2015, the value achieved (R$7.15/Ton) was 27% greater than the budgeted value (R$ 5.64/Ton). For 2016, there will be the opportunity to reduce the value achieved in 2015.	
3. Goal	What is the project's goal?	Meeting the budget set for 2016, i.e., maintaining a total expenditure of R$ 6,45/Ton, which represents a R$ 880,000.00.	
4. Project's scope	Processes that will be affected by the project. Beginning and end of the fundamental process	All processes carried out in the department, from classification to expedition, including support processes such as maintenance, logistics and hiring of a temporary work force.	

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

5 Team members	Name, department, function and dedication of the participants	Black Belt Leader (Strategic Management). Dedication: 30%
		Green Belt (Trainee). Dedication: 100%
		Green Belt Administrative Assistant (Grains Industry) 50%
		Yellow Belt: Manager (Grains Industry) 20%
		Yellow Belt: maintenance manager 20%
		Expert: finances analyst
6. Benefits to external clients	Mention the final customers and the key indicators and benefits	Reducing of the expenses of the grains industry, alignment with the cooperative's High Efficiency strategy and improvements in cost management.
7. Agenda	DMAIC Stages	Planned start date
	Define	03/01/2016
	Measure	03/21/2016
	Analyze	05/02/2016
	Improve	08/01/2016
	Control	10/03/2016
8. Required resources	Are any skills, among other required?	Modification in the systems with the purpose of improving the costs issue.

The goal of the project was defined as meeting the budget for 2016, seeing as in all previous years for which data had been raised, the industry had blown the budget by about 30%.

The project's Requirements Tree, presented in Figure 1, was created for listening to the costumers' accounts. In this tool, the highlights for the achievement of improvements, as well as for the existing restrictions, which may not be changed or extrapolated, were identified.

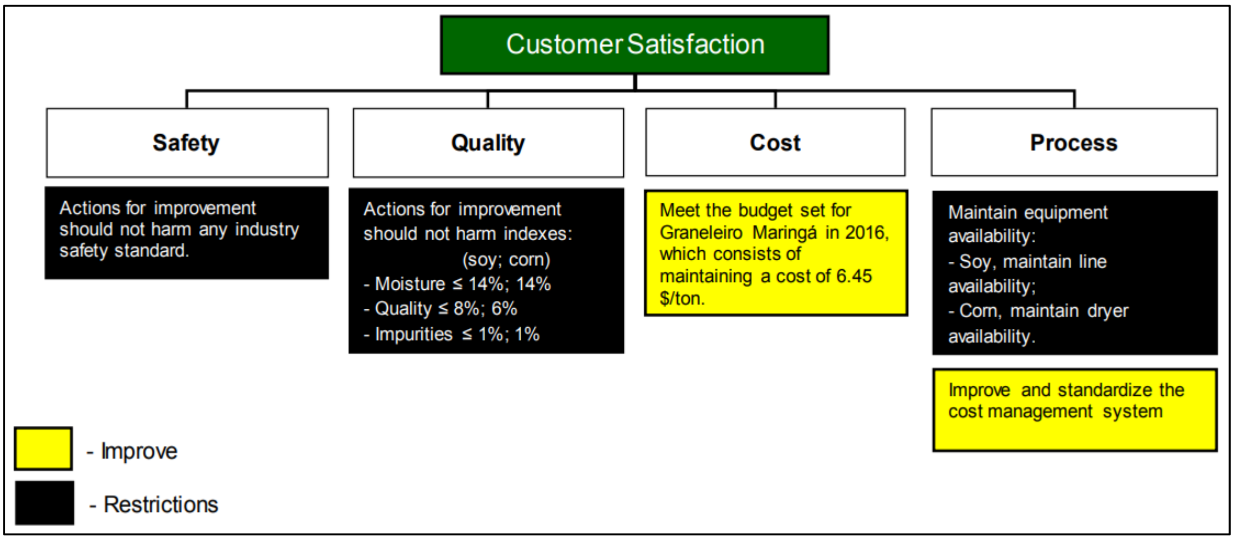

Figure 1: Requirements Tree.
Souce: Authors (2018).

Initially, the only need for improvement identified was related to the reduction of costs in the enterprise. Subsequently, an external consultant hired by the enterprise carried out an analysis to identify which of the project's actions should be evaluated in

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

a sustainable manner, resulting in the reduction of the costs currently generated by the department, and in the improvement of the management of future costs.

The customers' needs and the constraints imposed by the business having been identified through the Requirements Tree, analyses of the historical data on costs were carried out and Pareto charts elaborated to stratify the project's scope.

The first analysis to be carried out concerned the total expenditure in the period, classifying costs at the macro level, as shown in Figure 2.

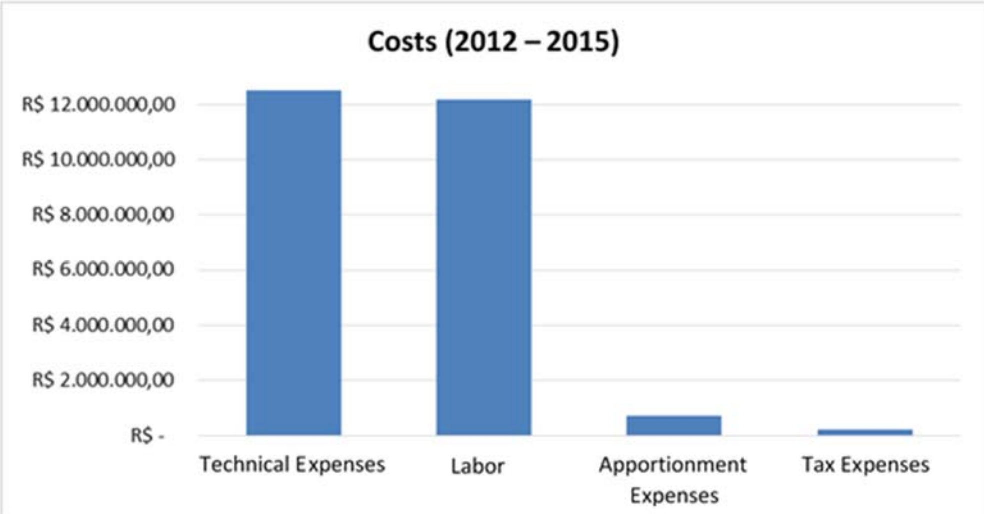

Figure 2: Cost categories at the macro level.
Souce: Authors (2018).

Based on the cost analysis at the macro level, the two main cost categories (work force and technical expenses) were explored, as presented in Figures 3 and 4, respectively.

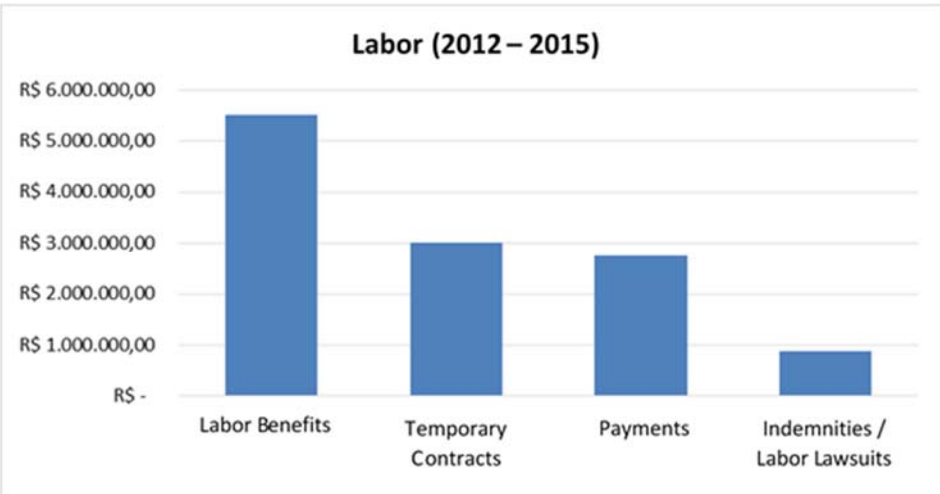

Figure 3: Subcategories of costs associated with the work force.
Souce: Authors (2018).

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

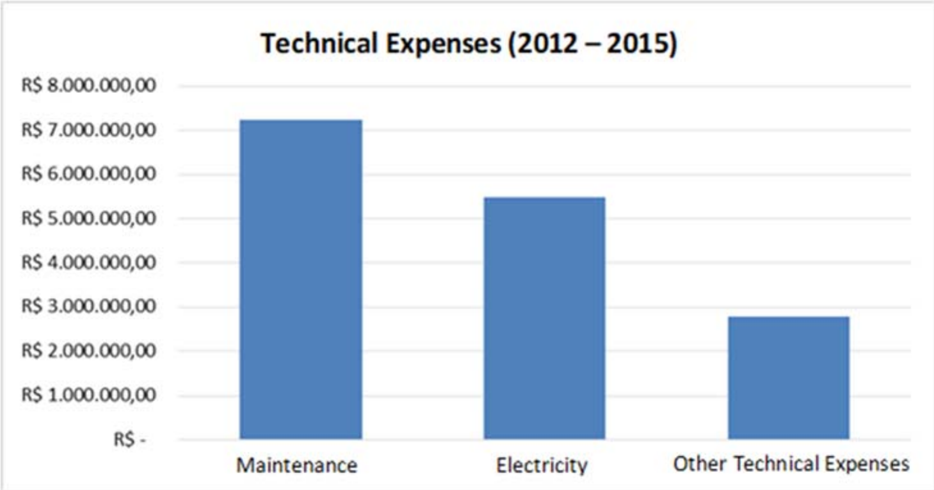

Figure 4: Subcategories of costs associated with technical expenses.
Souce: Authors (2018).

Considering this information, the stratification of costs (Y) was carried out, having been schematized in Figure 5.

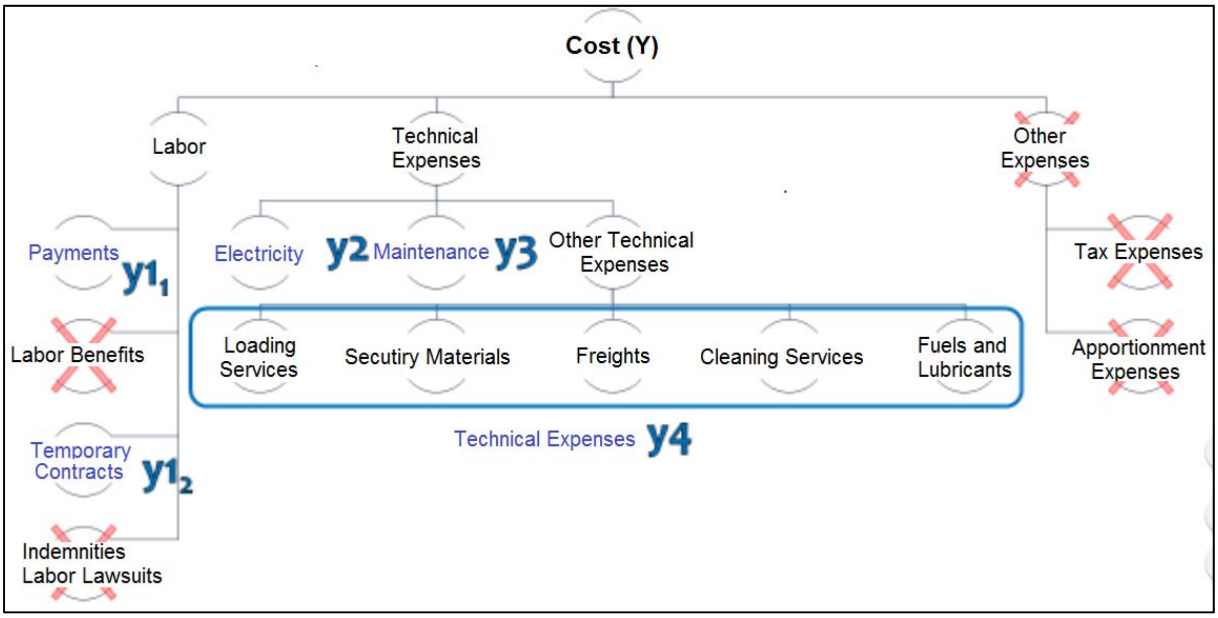

Figure 5: Stratification of Y.
Souce: Authors (2018).

To achieve the objective proposed in the project, namely cost reduction (Y) in the grains receiving department, costs were divided into four groups, Work Force (y1), Electricity (y2), Maintenance (y3) and Technical Costs (y4). Y4 relates to other technical expenses, except for electricity and maintenance that correspond to separate groups. Y1 has a division between permanent work force (y11) and temporary work force for each harvest (y12).

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

The charges were removed from the scope of the project, seeing as they are directly related to the permanent work force, and thus the improvements performed in this group would directly affect them.

A cause-and-effect diagram was created to identify and represent the possible causes of increased costs in the industry, as shown in Figure 6.

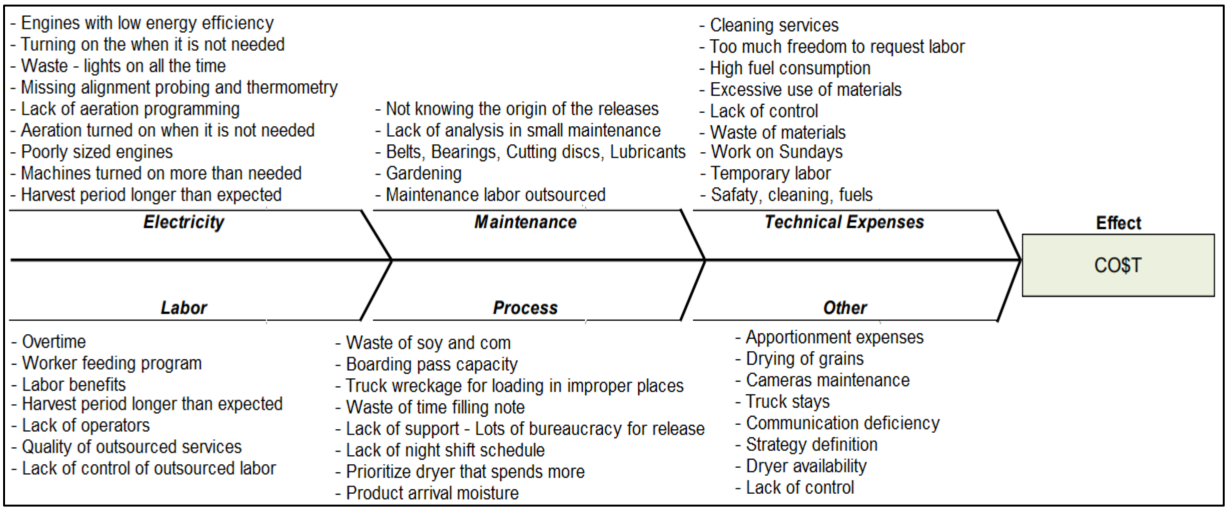

Figure 6: Causes that promote the increase in costs.
Souce: Authors (2018).

The four Ys stratified in the Define stage were used as the diagram's primary axes (Work Force, Electricity, Maintenance and Technical Expenses), with costs associated with the process and other expenses not encompassed by any of the previous divisions.

As result of the application of the Cause-and-Effect diagram, 53 potential causes for the increased costs in the studied enterprise's grains receiving department were identified.

To prioritize the 53 potential causes for increased costs identified in the Cause-and-Effect diagram, the Cause-and-Effect array was structured, as shown in Table 2.

Table 2: Prioritization of causes that promote the increase in costs.

									To be continued
Process: Grains receiving **Project:** Reducing costs in the grains receiving department			**Member of the project's team**						
Cost category	***X_n***	***Variable***	***A***	***B***	***C***	***D***	***E***	***F***	***Total***
Electrical energy	X_1	Motors with low energy efficiency							
	X_2	Turning the industrial dryer on when not needed							
	X_3	Lights on at all times							
Electrical energy	X_4	Lack of alignment between drilling and thermometry							

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

	X_5	Not programming aeration							
	X_6	Turning aeration on when not needed							
	X_7	Poorly designed engines							
	X_8	Leaving machines turned on for longer than needed							
	X_9	Harvest period (duration > expected)							
Maintenance	X_{10}	Not knowing the source of the releases							
	X_{11}	Lack of cost analysis in minor maintenance works							
	X_{12}	Replacement of belts, bearings, cutting discs							
	X_{13}	Gardening services							
	X_{14}	Maintenance operations							
	X_{15}	Outsourced work force							
Technical costs	X_{16}	Cleaning services							
	X_{17}	High fuel consumption							
	X_{18}	Excessive consumption of materials							
	X_{19}	Lack of control of expenditures							
	X_{20}	Waste of materials							
Permanent work force	X_{21}	Overtime							
	X_{22}	Employee supplying program							
	X_{23}	Charges							
Temporary work force	X_{24}	Harvest period (duration > expected)							
	X_{25}	Absence of temporary employees							
	X_{26}	Records of absence of employees							
	X_{27}	Quality of outsourced services							
	X_{28}	Lack of controls on the part of the outsourced enterprise							
Process	X_{29}	Waste of grains (corn and soy)							
	X_{30}	Shipping box capacity							
	X_{31}	Bureaucratization of operations							
	X_{32}	Lack of programming of the night shift							
	X_{33}	Product's moisture level at arrival							
Others	X_{34}	Apportionment expenses received							
	X_{35}	Grain drying							
	X_{36}	Parking/storing of trucks							
	X_{37}	Communication failures							

To facilitate the analysis, the priority causes were organized hierarchically and characterized according to the groups to which they belong, such as electricity, maintenance, among others, as shown in Table 3.

Table 3: Prioritization of causes that increase costs, organized hierarchically.

Cost category	X_n	Variable	Total
Electrical energy	X_6	Turning aeration on when not needed	
	X_8	Leaving machines turned on for longer than needed	
	X_1	Motors with low energy efficiency	
	X_7	Poorly designed engines	
	X_3	Lights on at all times	
	X_2	Turning the industrial dryer on when not needed	
	X_{15}	Outsourced work force	
	X_{13}	Gardening services	
	X_{14}	Maintenance operations	

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

	X_{11}	Lack of cost analysis in minor maintenance works	
Technical costs	X_{16}	Cleaning services	
	X_{20}	Waste of materials	
	X_{17}	High fuel consumption	
	X_{19}	Lack of control of expenditures	
Work force	X_{24}	Harvest period (duration > expected)	
	X_{25}	Absence of temporary employees	
	X_{28}	Lack of controls on the part of the outsourced enterprise	
	X_{21}	Overtime	
	X_{27}	Quality of outsourced services	
Process	X_{33}	Product's moisture level at arrival	
	X_{32}	Lack of programming of the night shift	
Others	X_{36}	Parking/storing of trucks	

Souce: Authors (2018).

This step was applied to examine the results identified more critically. The Failure Mode and Effect Analysis (FMEA) methodology was used in this stage.

FMEA was applied to the analyzed cost-generating groups, such as maintenance, electricity, work force, processes, technical expenses and others. For prioritization of the failure modes, that is, the analysis of situations that favor failure, values were assigned to the criticality factors Severity (S), Occurrence (O) and Detection (D), with parameters between 1 and 5, as shown in Figure 7.

Severity		Occurrence		Detection	
1	Insignificant	1	Remote	1	Absolute
2	Low	2	Low	2	High
3	Medium	3	Medium	3	Medium
4	Relevant	4	Relevant	4	Low
5	Very Relevant	5	Always	5	Remote

Figure 7: Factors of criticality analysis of failure modes.
Souce: Authors (2018).

Based on the parameters described in Figure 7, a risk priority number (RPN) was assigned to each failure mode, as shown in Table 4.

Table 4: Application of FMEA for analysis of failure modes.

Continuing

Work front	Group of variables	Failure modes	Effects	Causes	S	O	D	RPN
Maintenance	Accounting	Gardening costs should not be accounted on maintenance	Increased costs	Accounting structure	3	4	1	12
	Structure	Lack of analysis in small maintenance	Increased costs	Deficiency in maintenance structure (lack and connection between	4	3	2	24

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

				planning and execution) Delay in implementation of new maintenance plan due to the lack of definition of on key				
		Maintenance labor outsourced		Focus on core activities	3	5	1	15
Work front	**Group of variables**	**Failure modes**	**Effects**	**Causes**	**S**	**O**	**D**	**RPN**
Electricity	Waste	Aeration turned on when it is not needed	Increased costs	Failure on the Air master system operator failure	4	3	4	48
		Machines turned on more than needed		-	3	1	1	3
		Lights on all the time		i) Lack of awareness, ii) Connected power grid (tunnel and outside), iii) Electric discharge in the bulbs to bum, iv) Location of lamps (inclination for example)	4	4	2	32
	Engines study	Engines with low energy efficiency		i) Moto age (the higher), ii) Rewind (the more), iii) Policy for the purchase of high performance	4	4	3	48
Electricity	Engines study	Poorly sized engines	Increased costs	i) Unavailability of correct motor (for emergency care in the harvest), ii) Do not know the sizing coming from the supplier, iii) Different capacities for the corn and soybean crop	3	3	4	36

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

Work front	Group of variables	Failure modes	Effects	Causes	S	O	D	RPN
Labor	-	Harvest period longer than expected	Increased costs	Only available incumbent is Gilbert study possibility of hiring effective x temporary for the function	5	3	3	45
		Lack of operators – temporary			3	2	2	12
		Quality of temporary outsourced services			3	3	2	18
		Lack of control of outsourced labor			3	4	4	48
		Overtime			3	3	4	36
		Outsourced labor			3	2	3	18
Work front	**Group of variables**	**Failure modes**	**Effects**	**Causes**	**S**	**O**	**D**	**RPN**
Process	-	Product arrival moisture	Increased costs	i) Climatic forecast, ii) Lack of programming in the units, iii) There are more problems in the corn crop, iv) Driver already comes with truck in bad condition, v) Load inappropriate location, vi) Lack of employee training	3	3	3	27
		Noncompliance with the receipt schedule			3	4	4	48
		Truck wreckage due to bad operation on the tipper			2	2	3	12
Technical expenses	-	Cleaning services	Increased costs	i) Costs with removal of buckets, ii) Requests for materials, iii) Already started control and is better, iv) Lack of control that prevents analysis for improvement	2	2	2	8
		Waste of materials			2	2	3	12
		High fuel consumption			2	3	3	18
		Lack of control			1	2	2	4
		All technical expenses			3	2	2	12
Work front	**Group of variables**	**Failure modes**	**Effects**	**Causes**	**S**	**O**	**D**	**RPN**
Other	-	Strategy definition	Increased costs	What makes it difficult is to predict units failure	3	3	3	27
		Cameras maintenance		Study preventive maintenance	2	2	4	16

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

		Truck stays		It is fixed without asking the need at that moment Evaluate impact, see history	2	2	2	8

Souce: Authors (2018).

Based on the NPR results obtained, the main failure modes identified were organized by priority, as shown in Figure 8.

Failure mode	RPN
Aeration turned on when it is not needed	48
Engines with low energy efficiency	48
Lack of control of outsourced labor	48
Noncompliance with the receipt schedule	48
Harvest period longer than expected	45
Poorly sized engines	36
Overtime	36
Lights on all the time	32
Product arrival moisture	27
Strategy definition	27
Lack of analysis in small maintenance	24
Outsourced labor	18
Quality of temporary outsourced services	18
High fuel consumption	18
Cameras maintenance	16
Maintenance Labor outsourced	15
Gardening costs should not be accounted on maintenance	12
Osmarino should not be accounted on maintenance, it is operation	12
Lack of operators - temporary	12
Truck wreckage due to bad operation on the tipper	12
Waste of materials	12
All technical expenses	12
Cleaning services	8
Truck stays	8
Lack of Control	4
Machines turned on more than needed	3

	Electricity
	Maintenance
	Technical Expenses
	Labor
	Process
	Other

Figure 8: Causes prioritization list.
Souce: Authors (2018).

Of the 26 failure modes prioritized with FMEA, 12 were selected to propose improvement recommendations. The remaining failure modes were already encompassed by some other action for improvement being carried out in parallel within the enterprise, or were outside the scope of the project under study.

In this context, the failure modes considered to be eligible for the proposition of improvement actions were: Turning aeration on when not needed; Motors with low

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

energy efficiency; Poorly designed engines; Lights on at all times; High fuel consumption; Lack of cost analysis in minor maintenance works; Work force of outsourced maintenance; Lack of control of the outsourced enterprise; Overtime; Quality of temporary services; Union, and; Non-compliance with the receiving schedule.

After defining all the project's key points, measuring the relevant data and analyzing all possible causes for increased costs in the grains receiving department, the project's team initiated the Improve stage, with the aim of generating solutions to the causes previously identified.

Based on the results of the FMEA, actions of improvement to the problems identified and analyzed in the previous steps of the project were suggested by the team members. The meeting for generation of ideas was held in a different environment to stimulate the creativity of the members, and the list of ideas generated is shown in Figure 9.

Aeration turned on when it is not needed	Create a pre-aeration analysis routine
	Change the location of the weather station to solve the problem of automatic aeration.
	Analyze the payback of the exchange of engines in the warehouse aeration
	Study the need for a motor as large (100CV) or less for air exchange
Engines with low energy efficiency	Compare old engine (> 30CV) with a new high-efficiency and analyze payback - C.O.MUELLER is conducting the study
	Exchange of low efficiency motors for high efficiency
Poorly sized engines	Do the mapping, taking into account the worst case scenario (soybean), and find out which engines are poorly sized
	Analyze how much is being wasted because of this
	Everything that is done from now on must be done aiming at standardization
Lights on all the time	Analysis of criticality (tunnel x engine room x ...) to decide about the budget of the new installation of the lamps
	Analyze transformer options for lighting to minimize expenses with lamp changes
	Make PLC budget to automate lighting with engine starters
	Install photocell on patio
High fuel consumption	Worksheet for data entry in tractors (to maintain control)
	The acquisition of a vehicle for services that do not require the tractor is under analysis.
Lack of analysis in small maintenance	The database of all bulk carrier equipment on the OnKey is being made
	This will give much more decision power to the maintenance team because it will store all relevant equipment data (inspections and interventions performed, problems encountered, suppliers, etc.)
	In addition, the system will assist in many other aspects of maintenance (eg work orders, work capacity management, and standardization of processes)
Maintenance Labor outsourced	Maintenance work is still outsourced, but the company that provides the services has been changed.
	Now for the same value we have one more electromechanical, and a supervisor who mediates between the PCM and the Maintenance Operational
Lack of control of outsourced labor	Hire employer responsible for supervising temporary employees (team leader); - verify possibility of this action with HR
	Biometric reading
Overtime	Overtime of outsourced labor would be controlled by the leader mentioned in the previous item
	Plan to withdraw from bank hours with the largest banks
	Avoid operations on Sunday
Quality of temporary outsourced services	Assemble general job description to clarify what they are going to do at work to sign at the time of hiring
	Improve employee selection - good list and bad list
	Leader has to have knowledge of the process, and have waist match with staff. It should be clear the alignment with the industry leader
	Bathroom separated and closer to the sector
Quality of outsourced services	Continue requesting only when needed
	Negotiation of contract value
	Do investment analysis on a new claw to lower the demand for union for firewood
	More carts for the warehouse to eliminate the intermediate stock of firewood
Noncompliance with the receipt schedule	Request a specific LSS project for receipt schedule improvements
	Reliability of programming should be the basis for decision making, the responsibility is of programming
	Defray costs related to differences in scheduling and in the performance for units responsible for forecasts

Figure 9: List of ideas generated by the project's team.
Souce: Authors (2018).

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

Based on these ideas, the team held another meeting to assess which of them could be turned into solutions. The following criteria were used: Potential impact on Costs; Complexity/Difficulty of the Solution's Implementation, and; Need for Investment, and scores were assigned to these criteria for each idea, as presented in Table 5.

The ideas concerning maintenance were not evaluated because they were already being addressed in a project developed in parallel by the department's maintenance team, thus the project only helped with the management of costs associated with these actions.

Table 5: List of ideas generated by the project's team.

Solutions selection	Estimated amount - 2016
Aeration turned on when it is not needed	R$ 2.399.529,00
Engines with low energy efficiency	
Poorly sized engines	
Lights on all the time	
High fuel consumption	38.900,00
Lack of control of outsourced labor	932.624,65
Overtime	11.236,20
Quality of temporary outsourced services	932.624,65
Quality of outsourced services	214.000,00
Noncompliance with the receipt schedule	-
Lack of analysis in small maintenance	1.094.000,00
Maintenance labor outsourced	

Souce: Authors (2018).

The solutions were ranked according to the scores received (greater impact, less complexity and lower investment), and six (6) action plans for improvement were prioritized, which will be explained later.

a) *Weekly cost control.* The application of the enterprise's management system accompanies all the costs generated by the department's monthly, and their monthly balance is carried out by an external enterprise. A spreadsheet that compiles the data inserted weekly into the enterprise's system, and creates indicators related to the cost of priority work fronts (Work Force, Electricity, Maintenance and Technical Expenses), was developed as a proposal for improvement.

b) *Standardization of weekly meetings in the department.* Once a week, the manager of the grains receiving department meets with leaders of sub-departments to discuss unresolved matters, update inventory numbers and

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

align actions to be undertaken during the week. However, these meetings used to take place without an agenda, the only constant subject being the control of the stocks. An agenda was developed for the meeting, encompassing the items that used to be treated in a schematized manner, and the monitoring of the indicators generated in the weekly cost control worksheet was also added.

c) *Aeration.* To solve the problem associated with aeration, a model for control of aeration hours was developed. In this context, the filling of this model became the responsibility of the leaders of each sub-department, whenever the aeration system is turned on or off, to reduce the waste of electricity.

d) *Engine efficiency study.* It was found that some engines had low energy efficiency and/or were poorly designed, resulting in waste of electricity. To solve this problem, an enterprise specialized in high-efficiency engines was hired to conduct a study on the engines in question. This study aimed to identify engines with greater energy-saving potential, as shown in Figure 10. Considering the replacement of all engines of the aeration system, the total investment would be R$ 417,934.16, with a potential saving per year of R$ 154,525.61, which generates a payback of 2.7 years, considering 16 hours of work per day and 268 days of operation in the year. This proposal was presented to the board of directors and included in the enterprise's investment plans for 2017/2018.

Sector	Number of engines	Investment (R$)	Economy (kWh/year)	Economy (R$/year)	Payback (years)
Warehouse II	6 x 50 CV	89.148,00	118.206,33	39.555,38	2,25
Warehouse JK	6 x 50 CV	66.861,00	88.654,74	29.666,54	2,25
Warehouse JK aerators	6 x 7,5 CV	17.489,16	14.291,53	4.782,37	3,66
Warehouse LM	8 x 75 CV	150.328,00	150.891,37	50.492,78	2,98
Warehouse LM aerators	4 x 3 CV	4.960,00	3.178,64	1.063,67	4,66
Silos JK	8 x 50 CV	89.148,00	86.557,89	28.964,87	3,08
Total	38 engines	417.934,16	461.780,50	154.525,61	2,70

Figure 10. Engine efficiency study.
Souce: Authors (2018).

e) *Mapping of temporary employees.* To solve the external enterprise's lack of control, it being responsible for the hiring of temporary staff during periods of harvest, a specific mapping of the department was developed, which revealed the need of employees by sub-department. That is, for soybean harvesting, for example, the need for employees was as follows: 15 in the SNE department; 27 in the LM department; 14 in Grains Classification; 6 in the Grain Hoppers, 26 in the Bulk Carrier; and 30 in the JK department – a total of 118 temporary employees needed for soybean harvesting.

ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

f) *Awareness on electrical energy waste.* One of the problems identified in the study was the issue of lights remaining on at all times, as well as machines being turned on without need. In this context, posters were hung on strategic locations at the department, educating employees.

g) *Control of overtime hours and compensatory time.* To control excessive spending on overtime hours, a weekly report on the compensatory time balance of each of the permanent employees started being analyzed by the leaders of the sub-departments, to keep the balances near zero. Temporary employees cannot be offered compensatory time, so their overtime hours generate a cost that impacts directly on overtime balance, the daily monitoring of these employees' overtime reports being necessary to avoid compromising the department's budget.

h) *Maintenance.* Maintenance expenditure was identified as one of the most significant in the department and, consequently, was defined as one of the work fronts. Improvement actions were carried out in the management of maintenance, such as the implementation of a management platform for maintenance planning and control through work orders, and also for the registering of separate services in preventive, predictive, reactive and corrective maintenance works, classified as electrical, mechanical, building maintenance, among others. The platform also allows analyzing suppliers regarding parts and services, and regarding the amount of maintenance by equipment, which can be used for possible cost reductions.

All costs associated with any type of maintenance in the department were calculated in a single balance, making the analysis of the concentration of expenses with different types of maintenance impossible. Thus, a model that distributed the expenses in four categories was proposed to analyze and manage them: preventive maintenance of the process (parts/equipment or services contracted to carry out maintenance), maintenance of buildings and patios (facilities of the department or furniture belonging to administration, for example), corrective maintenance of parts and equipment (related to the process) and corrective maintenance.

For process control to structure the *Statistical Process Control (SPC)*, the subtraction of the Budgeted Value from the Achieved Value of the department's weekly

INDEPENDENT JOURNAL OF MANAGEMENT & PRODUCTION (IJM&P)
http://www.ijmp.jor.br *v. 10, n. 6, November - December 2019*
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

costs was used as control variable in the process. The limits were established based on historical costs of the period (2012-2015). With this, measurement system to record the data was defined, using the cooperative's system for this purpose and to generate the indicators presented and the SPC of the department's costs.

The statistical control chart of the process, shown in Figure 11, presents information in R$ by tons received, making it possible to analyze and control all expenditures to make sure they are within the defined threshold.

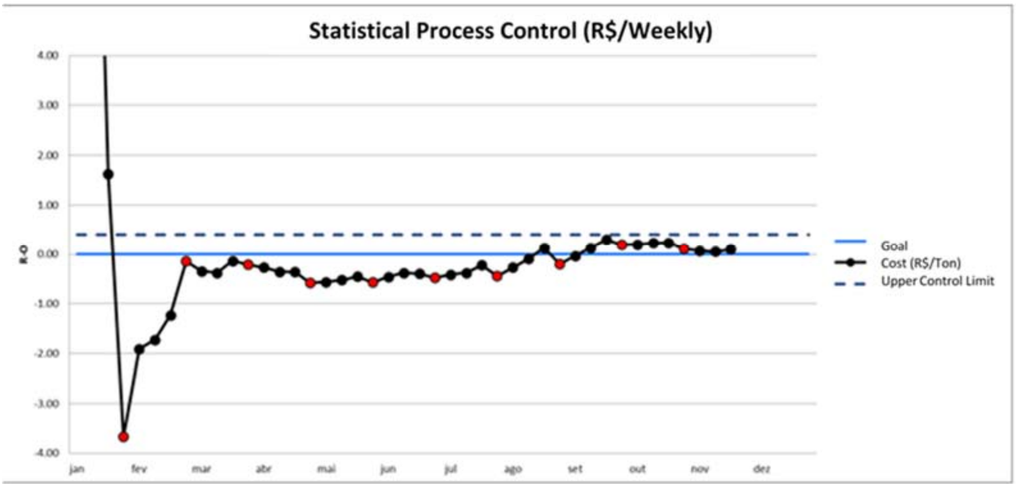

Figure 11: Statistical Control Charts of the Process.
Souce: Authors (2018).

The control array, shown in Figures 12a. and 12b., details in a procedural manner the department's indicators, goal and frequency and those responsible for their monitoring, in addition to the possible investigations and measures to be taken in case of unfavorable situations, and to create a monitoring culture.

Indicators

Front	Indicators	Goal	Frequency	Sponsor
Maintenance	Monthly and Weekly Chart RxB	R-B = 0 USL = 0,30 (General)	Weekly	Maintenance programmer
Technical Expenses	Monthly and Weekly Chart RxB	R-B = 0 USL = 0,30 (General)	Weekly	Administrative supervisor
Electricity	Monthly Chart RxB	R-B = 0 USL = 0,30 (General)	Monthly	Administrative supervisor
Labor	Monthly Chart RxB	R-B = 0 USL = 0,30 (General)	Monthly	Administrative supervisor / Production Supervisor

Figure 12a: Control array of the process.
Souce: Authors (2018).

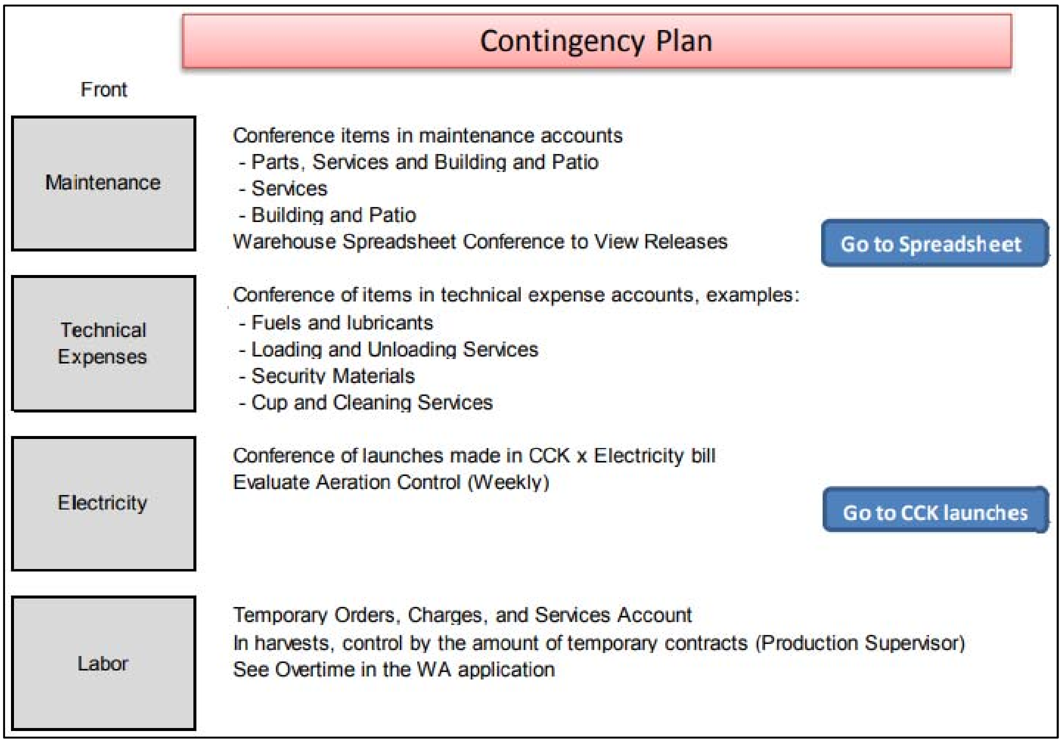

Figure 12b: Control array of the process.
Souce: Authors (2018).

In addition to the development of control tools, tutorials for the monitoring of costs were also created and made available in the system, making it possible for any person who assumes responsibility after the project's conclusion to work in accordance with the control system installed.

Throughout the Control stage, the administrative assistants were trained to control maintenance costs in accordance with the department's budget and to detail and justify the cost indicator in R$ per ton received.

5. CONCLUSION

The tools applied in the case study were: Requirements Tree; Charts Pareto and Stratification; Cause and Effect Diagram; Cause and Effect Array; Failure Mode and Effect Analysis; Statistical Process Control, and; Control Array, respectively. These tools are widely used in quality management and continuous improvement of industrial processes.

We concluded that it was possible to implement all the tools proposed by the methodology and achieve a satisfactory result of improvements. The enterprise's board of directors valued the actions deployed by the project and opened the doors to new projects that may arise as proposals of the project under study in this work.

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

The process' capability had significant gain compared to the full year of 2015. In this year, the Z value, which represents the process' sigma level, was 5.2, while in the months of January to October 2016 it rose to 0.8. The evolution of the team during the project was essential for the success of the improvement actions and for the smooth development of the project. In addition to acceptance within the team itself, collaboration and acceptance within the sector by all employees was also of extreme importance, seeing as they could contribute with ideas for improvements, in addition to accusing many causes that increased costs.

The controls developed by the project also generate the need for those responsible for the management of costs to give it continuity by feeding the database and periodically reviewing the indicators so that the gains provided by the project are maintained and create opportunity for other improvements.

REFERENCES

ARNHEITER, E. D.; MALEYEFF, J. (2015) The integration of lean management and Six Sigma. **The TQM magazine**, v. 17, n. 1, p. 5-18.

AWAJ, Y. M.; SINGH, A. P.; AMEDIE, W. Y. (2013) Quality Improvement using statistical Process Control Tools in Glass Bottles. **Manufacturing Company International Journal for Quality Research**, v. 7, p. 107-126.

CHO, H. J.; PUCIK, V. (2005) Relationship between innovativeness, quality, growth, profitability, and market value. **Strategic Management Journal**, v. 26, n. 6, p. 555-575.

DOMENECH, C. (2016) **Strategic Lean Six Sigma - Tapes: Define, Measure and Analyze**. São Paulo.

DROHOMERETSKI, E.; GOUVEA, S. E. C.; PINHEIRO, E. L.; GARBUIO, P. A. D. R. (2014) Lean, Six Sigma and Lean Six Sigma: an analysis based on operations strategy. **International Journal of Production Research**, v. 52, n. 3, p. 804-824.

FURTERER, S. L. (2009) **Lean Six Sigma in Service: Applications and Case Studies**. New York: Taylor & Francis Group.

FURTERER, S.; ELSHENNAWY, A. (2005) Implementation of TQM and lean Six Sigma tools in local government: a framework and a case study. **Total Quality Management & Business Excellence**, v. 16, n. 10, p. 1179-1191.

GHARAKHANI, D.; RAHMATI, H.; FARROKHI, M. R.; FARAHMANDIAN, A. (2013) Total quality management and organizational performance. **American Journal of Industrial Engineering**, v. 1, n. 3, p. 46-50.

HASHMI, K. (2016) **Introduction and Implementation of Total Quality Management (TQM)**. Available in: <https://www.isixsigma.com>. Acess in: 14 May 2016.

http://www.ijmp.jor.br v. 10, n. 6, November - December 2019
ISSN: 2236-269X
DOI: 10.14807/ijmp.v10i6.996

JADHAV, G. P.; JADHAV, S. B.; BHAGAT, A. (2015) Six Sigma DMAIC Literature Review. **International Journal of Scientific & Engineering Research**, v. 6, p. 117-122.

JURAN, J. M. A. (2009) **Qualidade desde o Projeto: Novos Passos para o Planejamento da Qualidade em Produtos e Serviços**. São Paulo: Cengage Learning.

MAST, J.; LOKKERBOL, J. (2012) An analysis of the Six Sigma DMAIC method from the perspective of problem solving. **International Journal of Production Economics**, v. 139, p. 604-614.

OAKLAND, J. S. (1994) **Gerenciamento da Qualidade Total**. São Paulo: NBL.

PALADINI, E. P. (2008) **Gestão da Qualidade: Teoria e Casos**. São Paulo: Atlas.

SALAH, S.; RAHIM, A.; CARRETERO, J. A. (2010) The integration of Six Sigma and lean management. **International Journal of Lean Six Sigma**, v. 1, n. 3, p. 249-274.

WERKEMA, C. (2006) **Lean Seis Sigma: Introdução às Ferramentas do Lean Manufacturing**. Belo Horizonte.

ZHANG, Q.; IRFAN, M.; KHATTAK, M. A. O.; ZHU, X.; HASSAN, M. (2012) Lean Six Sigma: A literature review. **Interdisciplinary Journal of Contemporary Research in Business**, v. 3, n. 10, p. 599-605.