Analysis of the Quality Indicator of the Paint Process of a Metal mechanical Industry

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Abstract

To ensure survival in a highly demanding scenario, it is critical that organizations return their efforts to the proper execution of the internal processes that make up their productive chains. From this perspective, the understanding that quality products and processes are reflected in the company's productivity, especially in customer satisfaction, as way of guaranteeing a competitive position in the growing market. The objective present work aims to analyze the causes of the main problem of the painting process that impacts the quality indicator, through the use of the problem solving method and the application of quality tools. The data was first collected and organized in a way that facilitated problem analysis and decision making. A brainstorming meeting with the representatives of the sectors directly related to the process was carried out, in order to discuss the causes of the high index of the problem related to the ink layer and to delimit the actions necessary to seek the decrease of occurrences. After the actions were carried out, it was possible to observe a gradual increase in the indicator over the months, which reached the goal established by the organizationt.

Keywords: Productive systems. Quality Indicator. Quality tools. PDCA

1. Introduction

With increasing customer demand, as organizations have experienced many changes without the definition of quality and productivity standards, their strategies for analysis and production of productive systems. In this context, the current scenario requires companies to be committed to the continuous improvement of their products and processes.

Quality is no longer a difference and has become a process for pursuing continuous improvement and satisfaction of internal and external customers. In this way, a competitive advantage of organizations is often the selling price. Thus, for a company to deliver value to the customer, it must necessarily reduce losses and reevaluate costs.

According to Lobo e Silva (2014), Quality is a management philosophy that seeks to integrate all departments of the company, in a culture that demands quality in the aspects of each operation, so that all activities are carried out correctly the first time, reducing losses and meeting customer needs and organizational goals. According to Tubino (2015), as long as the quality of the product is preserved, a company must seek the lowest possible price, and consequently increase sales volume.

Quality management provides for the elimination or reduction of processes that do not add value to the product, generating costs unnecessary for the organization, such as losses, failures and rework. These problems of production, when measured, verified and monitored, enable us to analyze the organization in terms of efficiency and effectiveness of its processes.

The company where the research was carried out works in the production of road implements. Currently, it has two units and approximately 600 employees, constituting a portfolio of twelve products, in addition to the manufacture of spare parts.

This study aims to analyze the paint process of the tipping road implement and provide the subsidies for management to eliminate the causes of the main problem that impacts on the industry indicator - the low ink layer - seeking to reduce the occurrence index and, consequently, perfecting the process. For that, we analyzed the indicators of this process since the year 2016, as well as its main characteristics.

The results were obtained following the iterative four-step management method known as PDCA, widely used tool to maintain and improve results in process control. Figure 1 presents concepts of the PDCA cycle recommended for improvements, constituting as a means of solving problems that characterizes extremely important aspects within the concepts of Total Quality Control (TQC). Also known in Japan for QC Story. (Campos, 2014), these concepts seek to contemplate costs and reliability, aiming at zero defects, with a systemic focus on the production process, not enough to inspect and eliminate failures, but going beyond, implementing an integrated work structure to any organization , methodical and documented, to ensure customer satisfaction and more competitive costs. (LOBO, SILVA, 2014).

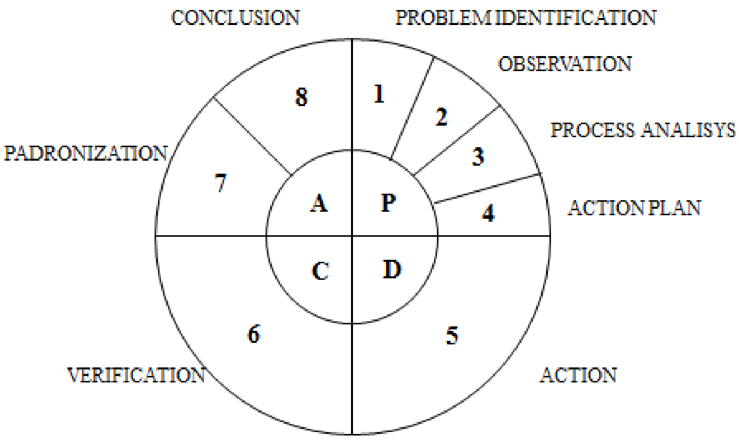

Figure 1 – PDCA Cycle for Improvements (QC Story)
Source: Campos (2014, p. 69)

The PDCA is a cycle that begins in the planning phase aims to establish goals, and procedures, processes and control guidelines that should be executed on the means for which the goal can be reached. This is the most complex stage of PDCA improvement, where the more information associated with planning, the greater the likelihood that the goal will be achieved.

According to Werkema (2011), at the end of the planning phase, a plan of action, commonly known as 5W1H, must be set to block the root causes of a problem, 5W1H are the initials of: what will be done, when will be done, why it will be done, who will do it, where it will be done and how it will be done.

The second stage concerns the execution of processes as defined in the planning phase, including also the collection of data required for the next step. (CAMPOS, 2014)

After completing all the steps, it is necessary to verify if the data collected are in accordance with the planned goal and if the blocking actions adopted were effective. At the end, Corrective Actions are performed for the detected nonconformities, so that they do not occur again. In this sense, it is important to emphasize the difference between the words "method" and "tool", where the method is defined as the sequence that will be used to achieve a proposed goal, on the other hand, the tool will be the resource to develop and apply the method. (CAMPOS, 2014).

With the intention of encouraging the reduction of the occurrence index of the problems, and consequent improvement of the process, data and images regarding the thickness of the layers of ink were analyzed since 2016.

2. Methodological Procedures

The process control and increase of errors that permeate the painting stage were evaluated and revised through the PDCA methodology. The information sheets for the application of the auxiliary tools to the methodology were collected from the checking sheets, internal documents to identify problems, their causative areas and detailed descriptions. Figure 2 presents the description of the PDCA Cycle, based on the Japanese method called QC Story, brought by Campos (2014), used to obtain the results.

PDCA	FLOW	STAGE	OBJETCTIVE	TOOLS
P	1	Problem Identification	Accurate identification of problems and their seriousness	Check Sheet
	2	Obsevation	Problems Characteristics as different perspectives.	Pareto Charts / Control Charts
	3	Analisys	Identify all possibles causes of problems.	Ishikawa Diagram
	4	Action Plan	Develop actions plans to cancel the causes of problems.	5W1H
D	5	Action	Cancel fundamental causes.	-
C	6	Verification	Verify effective attainment of canceling causes.	Grafics
	?	(Is it Workin ?)	Assess and testing.	-
A	7	Padronization	Prevent the recurrence of problems.	-
	8	Conclusion	Review of all processes of problems to aftermost works.	-

Figure 2 – Troubleshooting method – QC Story
Source: Adapted from Campos (2014)

Thus, following the steps, were performed:

a. Planning: (1) The problem identified by the management of the plant is related to the component of TQC "Product Quality", related to the company's painting process, as one of the fundamental processes in the manufacture of road implements and high value aggregate to the final customer, since it matches the appearance and aesthetics of the product. To identify it, historical data were collected from 2016 to May 2017, recorded from the quality inspectors' point of view through the check sheet (2). In order to raise the characteristics of the problem, the Pareto Chart was used, in order to stratify the data of the problems that most impacted the process and prioritize the direction of the actions. Control charts for analysis of the main problem affecting the indicator were generated, as well as those observed in the regions of greatest occurrence of problems in the main product manufactured by the Tipping implement. (3) A brainstorming meeting was held in June 2017 to analyze the problem, where the team involved used the Ishikawa Diagram to analyze the most probable causes, in order to avoid their recurrence, seeking to favor ideas in the construction of the diagram. (4) In the final phase of planning, the action plan was constructed, filling the table with the definitions of 5W1H.

b. Action: In addition to the proposals in the action plan, carried out by the responsible ones according to the established deadlines, other actions of monitoring the sector's indicator for employee awareness were established.

c. Verification: In the verification step, new data were collected after blocking actions and compared to the initial results of the process. It was observed that the blockages were effective, in this way, the final stages were given continuity.

d. Standardization and Conclusion: Finally, the new methods implemented were standardized from the revision of work instructions available in the sector and the employees were trained in the new documentation. At the conclusion of the problem solving process and application of the PDCA for improvements, those involved recapitulated the steps and made suggestions for analysis of future problems.

Through the execution of all the steps of the proposed method, it was tried to reduce the index of the main problem that affects the indicator of quality of the process of painting of road implements.

3. Results

For an understanding of the case studies, there is a need to have a process, since the finished products are supplied from two industrial sectors: the first is responsible for the installation of the vehicle and the traction and the second for products such as trailers, semitrailers, buckets and bodies, known as road implements. In this way, implements can perform their load transport functions. Figure 3 shows the interrelationship between the three processes of manufacture of road implements, in addition to the parts manufacturing sector.

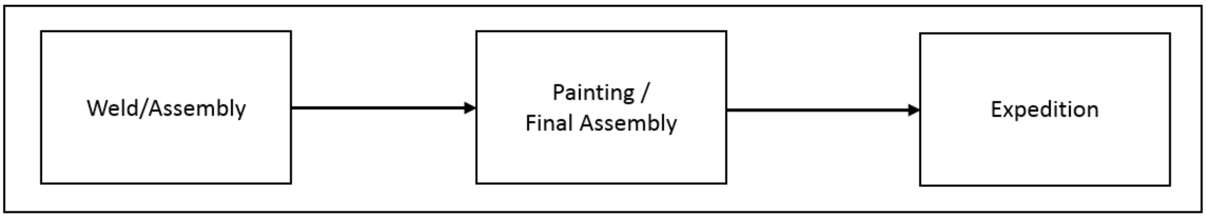

Figure 3 – Process of manufacture of road implements.
Source: Authors

- Welding / Assembly: It refers to the structural assembly production lines of the implement using steel sheets as its main raw material. Welding is the process of joining the materials (particularly metals), which ensures the continuity of the physical and chemical properties of the material.
- Finishing: It is composed of the jet line, where the paint surface is prepared and the paint layer is applied in the color requested by the customer. After being painted, the finishing line still covers the assembly of aesthetic, electrical and pneumatic components. At the end, the product goes to the stock and waits for the billing.
- Shipment: When invoiced, the product goes to the shipment where the final tests are carried out and also the last adjustments to be delivered to the customer.

At the end of each stage, quality inspections and controls are performed to ensure that the product meets the organization's requirements for the next process. The inspector has the authority to release or disapprove the product, if it is not compliant, it records the rework that will be necessary for the release, including the time that will be spent.

For each product, there is an inspection criterion defined by the company that is used by the quality inspector. Figure 4 shows the example of the Tipping product, the main implement produced in the unit studied.

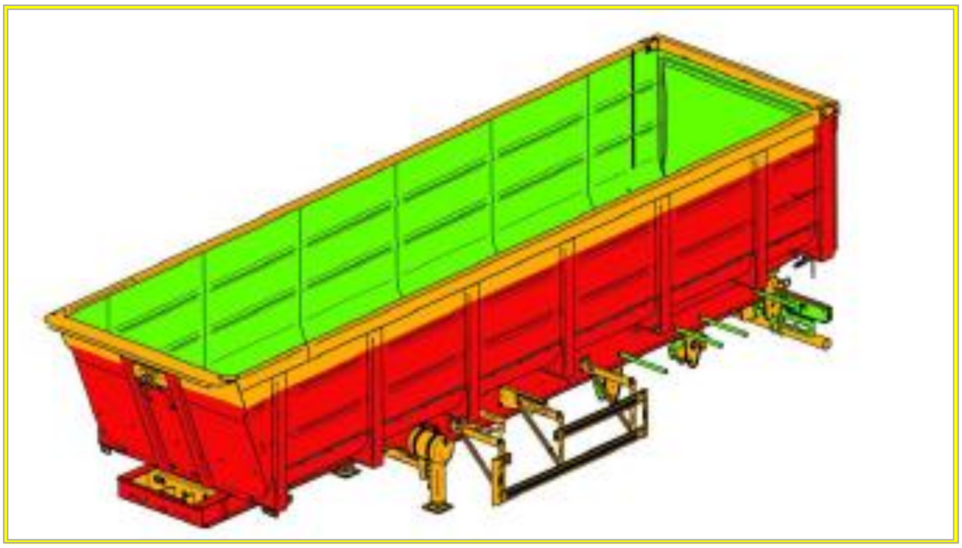

Figure 4 – Paint Acceptability Standard (Implement: Tilting).
Source: Company's stock.

The inspection criterion is followed by the colors of the image:

- Red Zone: Has greater visual exposure, inspection criterion considered critical.
- Orange zone: It has less visual exposure. The inspection criterion is considered as not critical.
- Green zone: It has no visual exposure, internal area of the implement. The inspection criterion is considered irrelevant.

It is worth mentioning that the inspection of the quality related to the painting is performed only in the external area of the product. In the inner area only a coating painting is done to avoid oxidation until delivery of the implement, which with the use of the product is lost due to the friction of the flow of the cargo transported through the structure.

The quality of the three processes is measured by the indicator generated from the inspectors' records, called Percentage of Approved Products, characterized by a target of 80% indicator, meaning that every 100 products, 80 of them must reach the inspector in perfect state, without the need for rework.

As the main object of this study, the quality indicator of the Finishing process will be analyzed, which is characterized as the main obstacle to be improved. From the data collection obtained through the check sheet, the graphs of Figures 5 and 6, which illustrate the reality of the Finishing process, were made, including the sub-processes of painting and final assembly of the components.

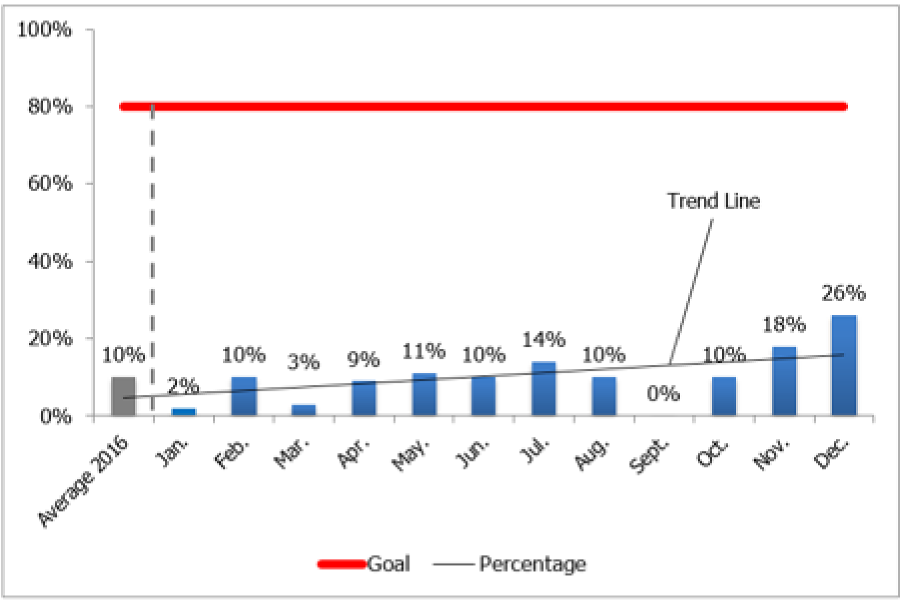

Figure 5 – Percentage of approved products - Completion - 2016

Source: Authors

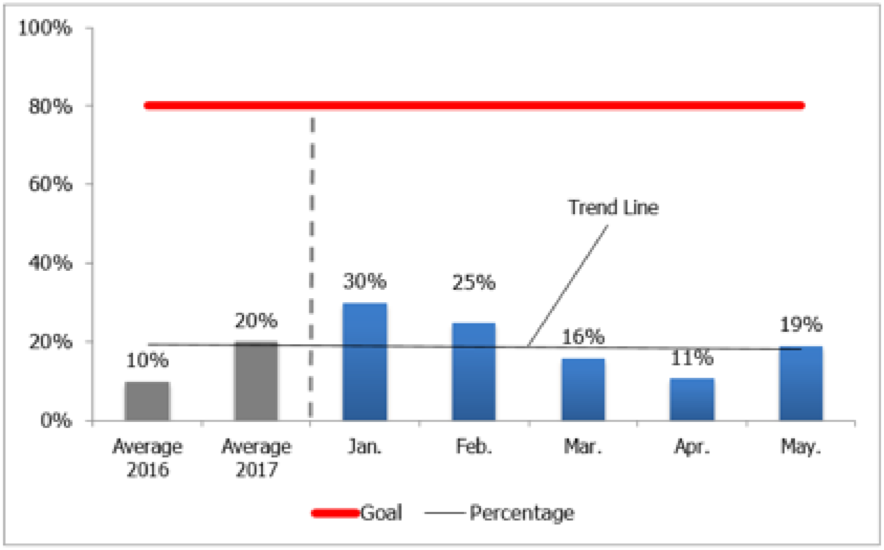

Figure 6 – Percentage of approved products (Finishing - January to May 2017)

Source: Authors

The average for 2016 shows that only 10 of every 100 manufactured products meet customer requirements without doing any kind of repair or rework, 90% of the implements that were produced went through some form of rework before being released to the Expedition.

The trend is repeated during the year 2017, Figure 5, but with an increase, since the average of the period from January to May presented the result of 20%. Since its inception, the indicator (Percentage of Approved Products) is analyzed in a general way, including the painting and assembly lines of the components. It is empirically agreed, from the data in Figures 7 and 8, that the greatest amount of problems to be reworked comes from the painting process, as it is verified through the Pareto Charts.

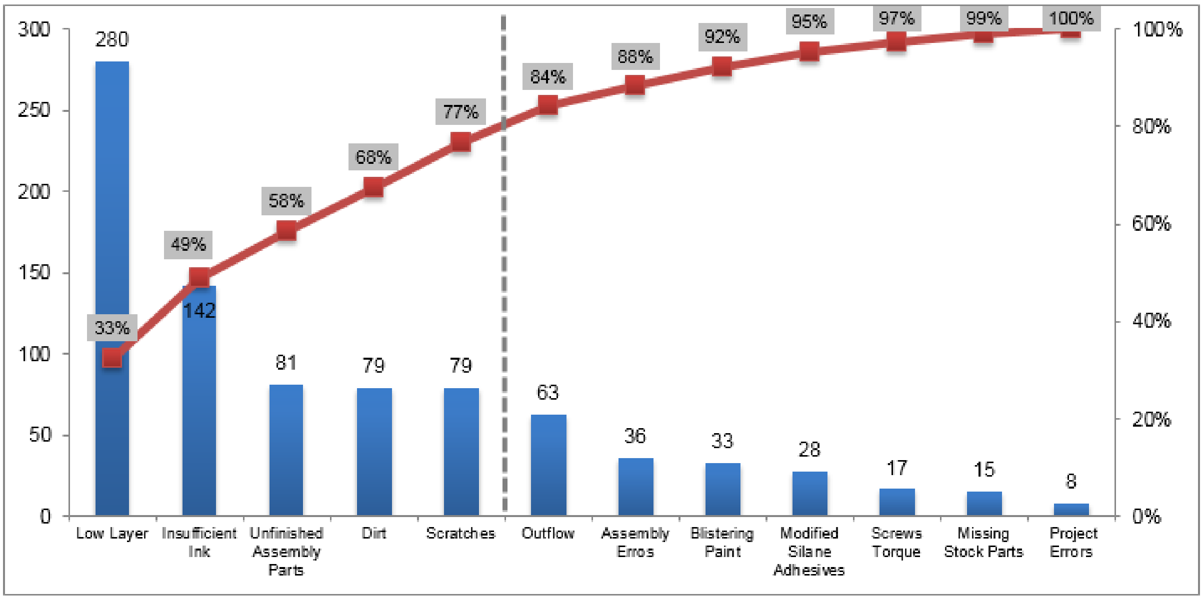

Figure 7 – Main problems evidenced in the quality inspection in the Finishing indicator - Period: January to May 2017

Source: Authors

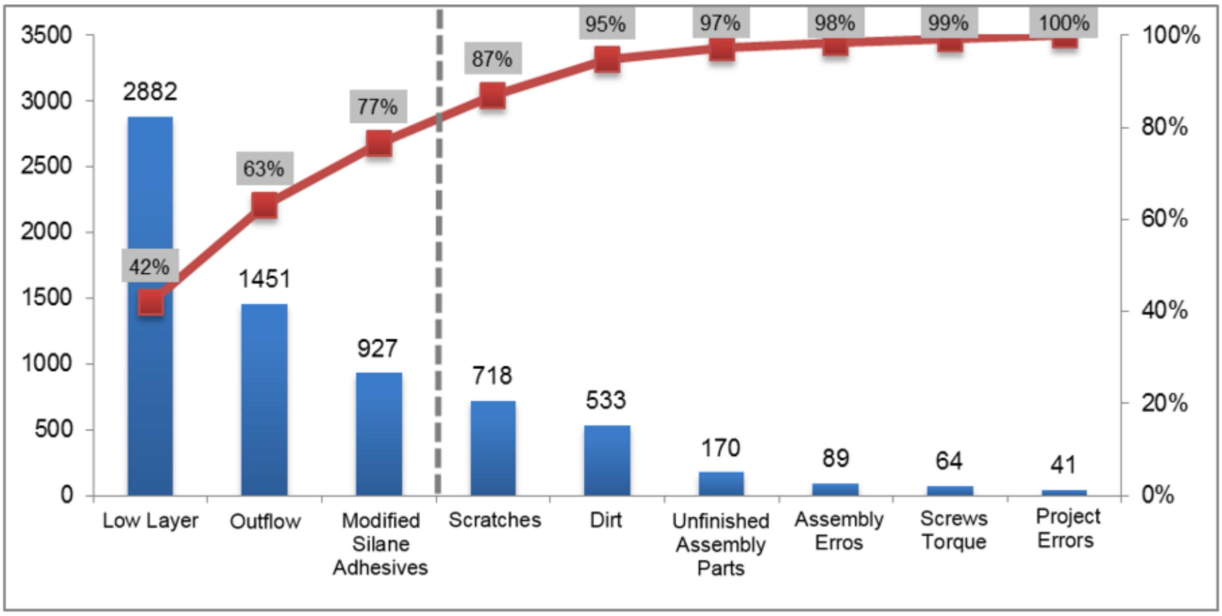

Figure 8 – Main problems evidenced in the quality inspection in the Finishing indicator - Period: January to December 2016

Source: Authors

Through the graphs it is observed that the biggest problem of the process is the "Low Layer", which occurs when there is not enough surface coverage by the paint to maintain a pattern. Still referring to the characterization of the problem, we also analyzed the main points of the product Tipper in which the largest occurrences of the problem are verified.

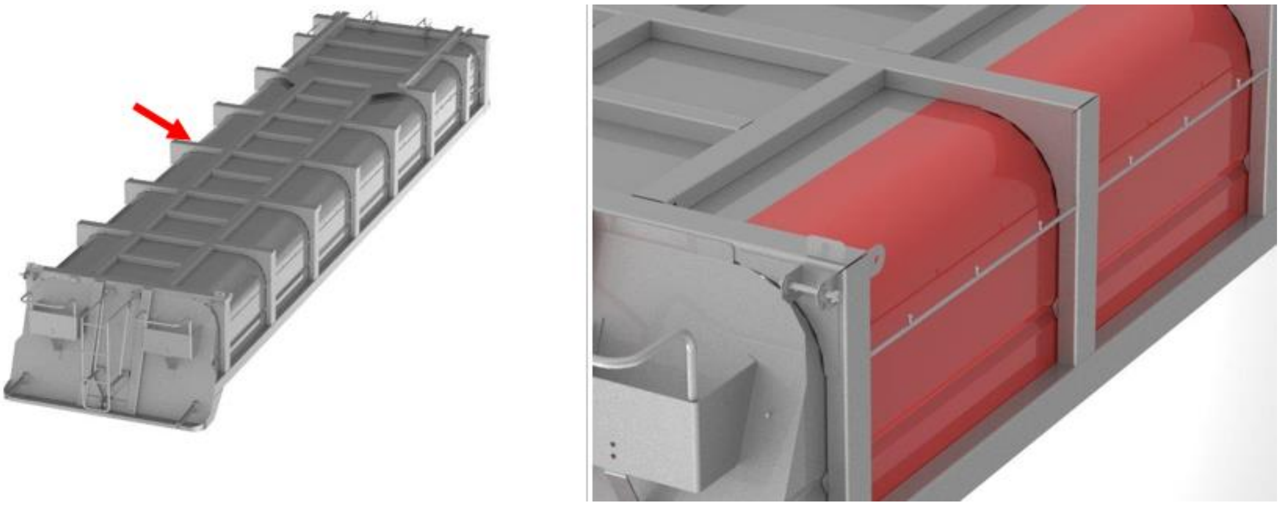

Figure 9 – Critical point of occurrence of the low ink layer - Tipping Box
Source: Adapted from the company's collection.

According to Figure 9 it is possible to observe that the critical point is located in the radius of the fold, between the floor and the side of the load box of the Rocker. Still referring to the low layer problem, the data of the layer measurements, of the Tipper implement, were carried out, carried out by the quality inspector of the month of May of 2017 and organized in a control chart for better visualization. A sample of 125 measurements was used since 10 inspections are done on each product and approximately 100 products are manufactured in the month. The company adopts as ideal values that have a minimum of 70µm layer thickness as Lower Specified Limit (LSL).

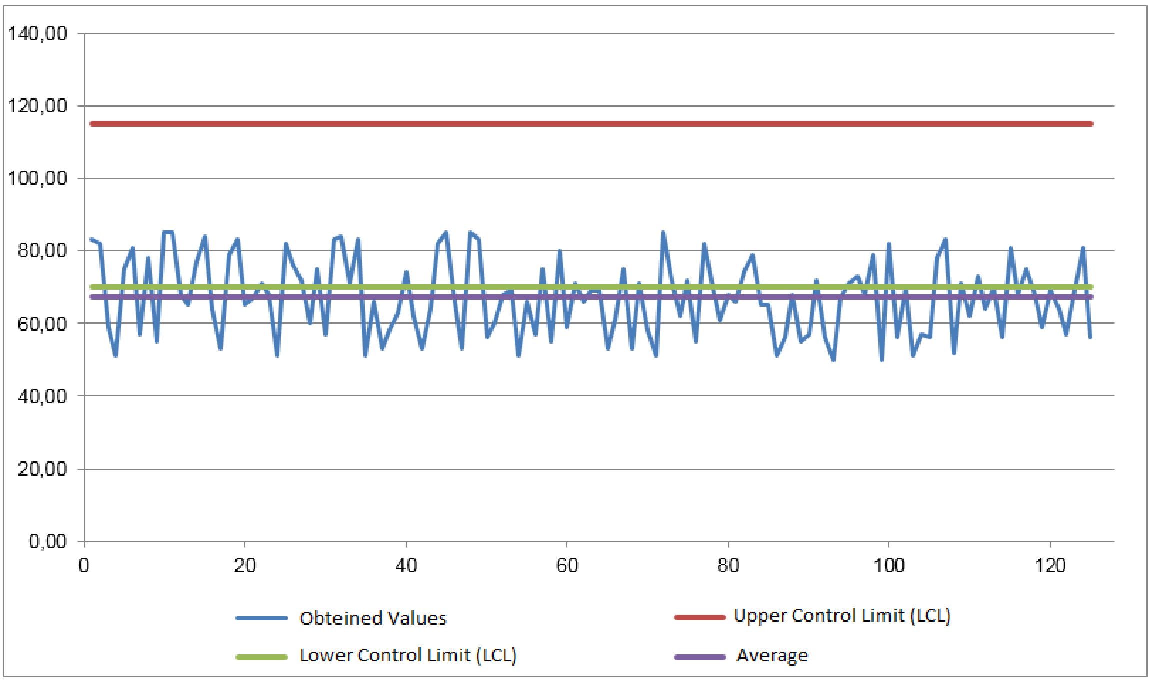

Figure 10 – Control chart showing variation of ink layer measurements (May 2017)
Source: Authors

Control limits are able to define whether a process is under control. When the points collected are located between the Specified Upper Limit (SUL) and the Lower Specified Limit (LSL), it means that the process is under control; however, if the points are outside these limits, it will be evidence that a study of the causes of this variation and, later, corrective actions.

From the graph of Figure 10, it is observed that the process is unstable, since there is a lot of variation between the measures considered low and satisfactory measures, with many values below 70µm, according to the specification.

After analyzing the data stratification, we sought to know which factors would be attributed to the causes of the low ink layer in a brainstorm, using the knowledge of the people involved. Among these, were those responsible for the Process Engineering, Quality Management and Coordination departments and representatives of the Finishing Line.

In order to investigate the fundamental causes, the members used the Ishikawa Diagram in the original configuration, analyzing material, labor, working methods, machines, environment and measurements. Figure 11 shows the result of the analysis.

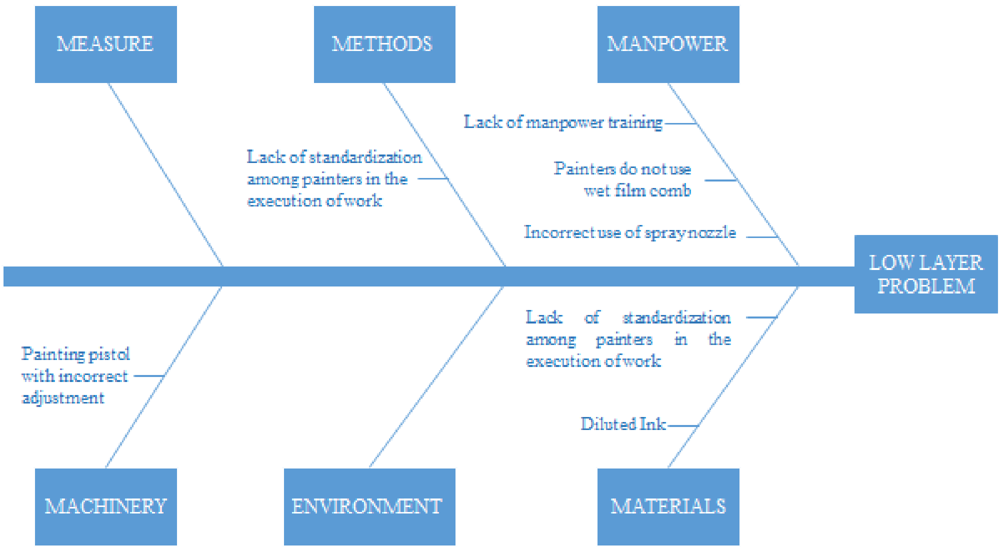

Figure 10 – Analysis of causes from the Ishikawa Diagram.
Source: Authors

After the discussion of the causes, it is observed that the main factor that influences the occurrence of Low Layer relates to the workforce and is directly related to the employees who perform the painting activity. In this way, the action plan based on the 5W1H tool was constructed, according to the reasons.

Table 1 presents, for each case, the actions defined resulting from the analysis of the previous phases, the deadlines and those responsible for reducing the problem index and, consequently, increasing the quality indicator of the process.

Table 1: Action plan.

What?	Who?	When?	Where?	Why?	How?
Setting the paint application sequence according each product.	Process Engeneering	06/2017	Paint Process Line	Lack of standardization among the painters to perform activity.	Informing to employees about the script to paint each product.
Training of recycling information contained in the Instruction of work of the painters and facilitators, referring to the adjustments of the painting machines.	Process Engeneering	06/2017	Paint Room / Paint Process Line	Lack of training painters.	Determining and reviewing all the work instructions necessary to carry out the activities and training groups in the standard procedures.
Elaborating parameters inspection of painting machinery.	Process Engeneering	06/2017	Paint Process Line	Incorrect spray-nozzle adjustment.	Every day the facilitator will inspect setting of the machine and spray-nozzle use
Training methods in painting application.	Provider	06/2017	Paint Room / Paint Process Line	Lack of training painters	Request providers for training recycling regarding the characteristics of the inks and applications.
Regularizing a daily inspection regarding wet film comb use.	Production	06/2017	Paint Process Line	The Painters do not use wet film comb continuously.	The facilitator will inspect wet film comb use for layer measurement each day.
Review the technical conditions of ink supply.	Process Engeneering	08/2017	Document CTF-12	High variability in technical characteristics between colors.	Review of document CTF - 12 and referral to provider.
Inclusion of ink coverage test on quality certificates.	Process Engeneering	08/2017	Providers		Asking the provider to include the results in sent certificates.

Starting auditing program to map individual performance.	Quality Managemen t	07/2017	Paint Process Line	Performance monitoring.	Creating a verification checklist to perform auditing once a week with employees.
Implantation of pre-inspection of employees before sent the product to quality inspector.	Production	06/2017	Paint Process Line	Spread quality culture with the painters, warning them about their mistakes and stimulate them to do the right thing at once.	Before sending product to quality inspector, the employees should review the paint of product and rework it when necessary.
Wareness-raising and indicators monitoring	Production	06/2017	Paint Process Line	Valuing people commitment in evolution process.	Using the "Quality Tuesday" to maintain constant training actions.

Source: Authors

Among the 10 actions established, 7 were defined with the purpose of acting on operational problems, strengthening the relationship with most of the causes discussed, from training, awareness and standardization of the methods of accomplishment of the activity.

As well as the analysis of the process, the actions started in June and, in addition to them, other awareness actions were carried out in parallel to these actions. The company has a communication program promoted by the Quality department weekly responsible for the established directions, named "Quality Tuesday", through the inspectors.

Every Tuesday of the month, during a period of time, the sector indicators and other necessary news related to the process are informed. In this way, the coordinator of the finishing line, together with the person in charge of the Process Engineering sector, initiated a weekly communication to the employees on the follow-up of the actions taken and the indicator.

After analyzing the information and definitions of the actions, it was possible to observe, in Figure 11, the evolution of the results in the indicator of the Finishing process.

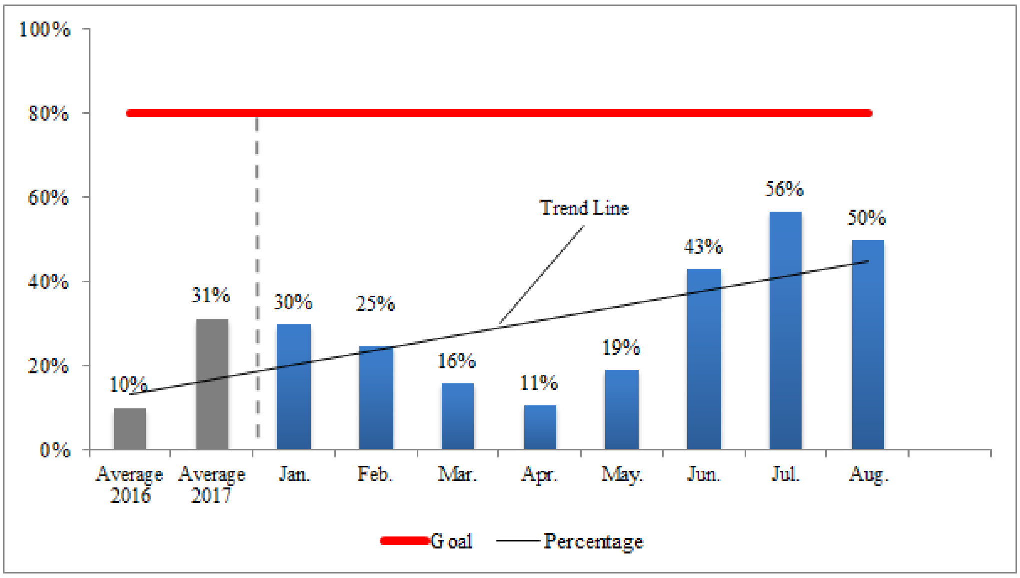

Figure 11 – Percentage of approved products - Finishing - Period: January to August 2017

Source: Authors

As of May, the possibility of increasing gradually and the average of the year 2016, observed the need to restructure the indicator of the finishing process. Therefore, starting in September, it was decided to divide it into "Painting" and "Final Assembly", in order to better structure the information of the problems and facilitate the achievement of the most critical points. The result of the month of September is shown in Figures 12 and 13.

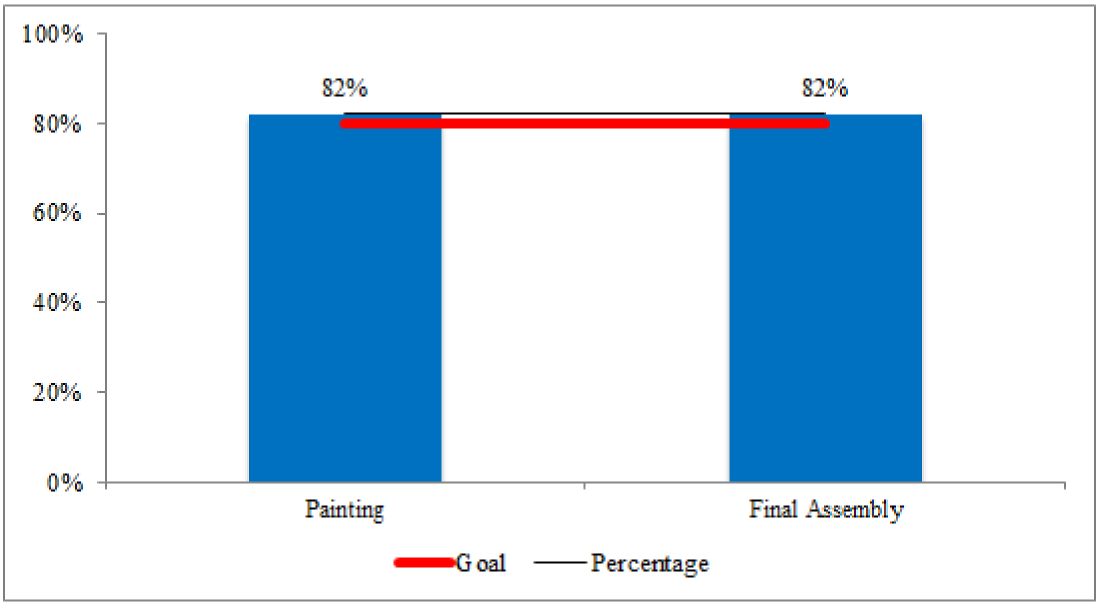

Figure 12: Percentage of approved products - Painting and Final Assembly - September 2017

Source: Authors

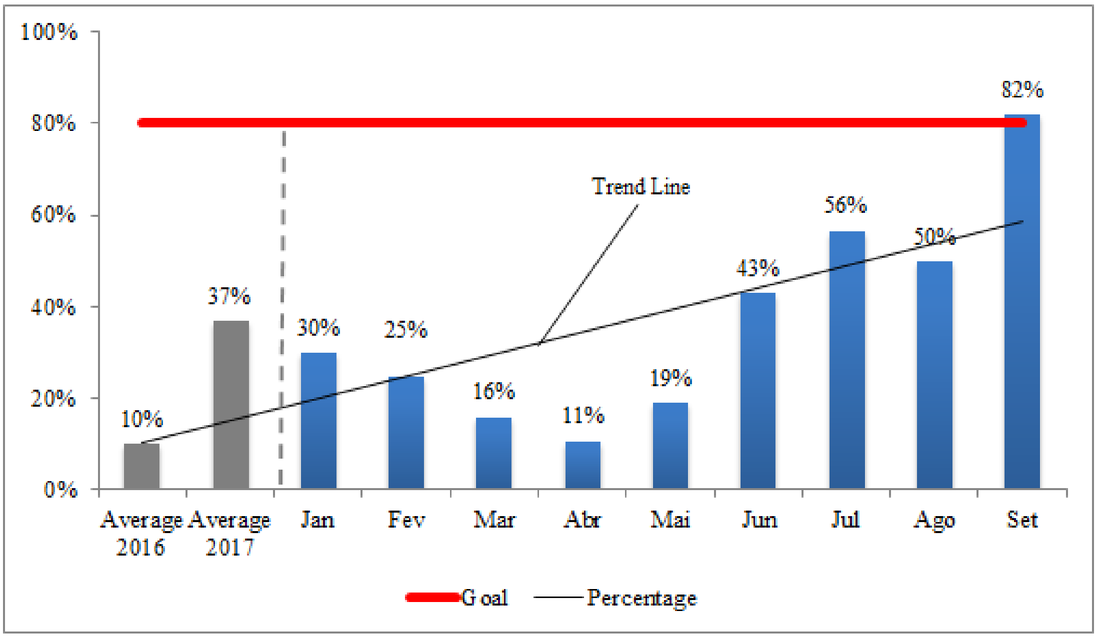

Figure 13: Percentage of approved products - Painting and Final Assembly - 2017
Source: Authors

Both processes have improved significantly, reaching 82% of compliant products and exceeding the target established for the first time since the beginning of the implementation of the program.

The result is consistent with the initial data, where it was clearly observed that the problems regarding the assembly of the components did not contribute to the low quality index. In turn, the painting process that once represented the responsible for inefficiency, is now responsible for raising the indicators.

A total of 125 new samples were collected on the layer measurements carried out by the inspector in the tiltingtruck product, this time in September 2017, and are presented in the Figure 14.

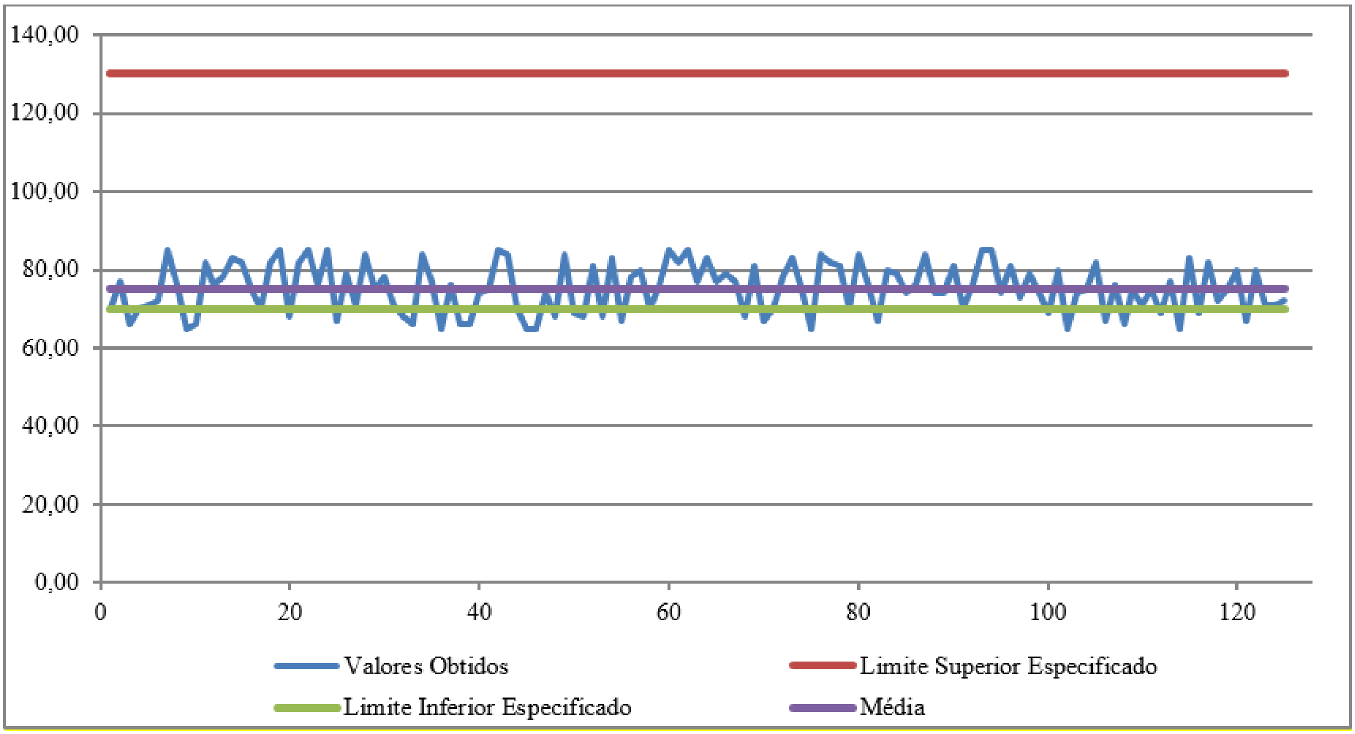

Figure 14: Control chart of ink layer measurements - Period: September 2017
Source: Authors

Contrary to the data obtained in the observation of the problem, the graph of the measurements found in September shows the trend of the process, where most of the measurements are close to the specified value or higher, with few points below 70µm.

The effect is also reflected in the costs that the reworking hours cause, which are calculated by the company's Controllership sector from the times also indicated by the inspector in the check sheet and computed in the ERP system by the Quality Management. According to the evolution of the indicator by the graphs presented, Table 2 lists the number of hours of rework and the costs spent for the rework that gradually decreased.

Table 2: Ratio between rework hours and costs incurred.

Month	Rework Hours	Cost
March	77	R$ 7.184,83
April	87	R$ 9.481,63
May	109	R$ 6.208,93
June	48	R$ 4.004,67
July	28	R$ 2.475,58
Augst	48	R$ 3.878,52
September	18	R$ 1.466,24
	TOTAL	R$ 34.650,40

Source: Authors

As of March, the Comptroller's Office started to request that the reworking hours be registered in the ERP system used to verify the cost of labor. Costs can vary regardless of the number of hours performed due to the individual direct labor of each operator and the materials used.

Self-inspection of employees, as an action, stands out as the main factor of the positive increase of the percentage indicator, due to all the work of study and implementation of the tools, as well as the training done. The methods now standardized were crucial for the realization of new training, which by consequence could raise the degree of skill of the painters in the execution of their tasks.

In the conclusion stage, following the PDCA reasoning, with the return to the beginning of the problem solving process, it is possible to verify an increase in the volume of data for analysis, especially with respect to the materials used in the reworking.

4. Conclusion

The study demonstrated the effectiveness of the method of problem solving brought by Campos (2014), together with the application of quality tools, since the percentage of products approved in the painting process reached the goal sought by the organization in September, resulting in in 82% of products according to the established requirements, without having to rework them.

The differential provided in the application of quality tools is the viability of standardized and organized data that contribute to information and analysis of performance and support decision making at the operational and strategic level. Allied to the PDCA method, they are proven to be efficient instruments in the process of continuous improvement in the production process of painting, because only the results are advanced when graphic techniques and in-depth studies are used, as emphasized in the analysis phase of the problem analysis.

Throughout the presented results it was possible to observe the influence of the training and the realizations of the tools in the human scope, acting on the problems correlated and arranged in the Ishikawa Diagram. The involvement of people who are directly related to the process was of fundamental importance for the success of the proposed method, especially those that perform the painting activity, emphasizing the definition of Lobo e Silva (2014) with regard to quality as being the perfect execution at the origin and understanding that quality is in people.

The costs generated by internal failures are hardly seen, but a significant decrease can be observed, which can be accompanied indirectly in the decrease of materials used for reworking.

Through the success obtained, it is guided by the experience of the reorganizations of the activities related to quality, for the phase of total implantation, with the potentiality of extension to the other processes that need a deep analysis in its unsatisfactory results.

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