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Implementation Of Methodologies In The Automatic Insertion Of Components For Optimization In The SMT Process: Applying The DMAIC Method

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Abstract:
Background*: The automatic insertion of SMT components is a process used in the electronics industry that has faced challenges related to the disorganization of assembly machines. This results in low productivity, disorganized feeders and delays in getting ready to change models. In this context, this study aims to implement lean production principles to improve the assembly process and identify the root causes of existing problems.*
Materials and methods*: In this study, lean production tools and methodologies were applied to analyze and improve the process of automatic insertion of SMT components. Data were collected on the different models and configurations used, in addition to information on the particularities of the process. The analysis was performed using graphs and tables to present the results obtained.*
Results*: The results required by the application of lean production methodologies brought significant improvements to the process of automatic insertion of SMT components. It was possible to identify and solve the root causes of problems related to disorganization of assembly machines. Comparative data across different models and configurations provides valuable insights to improve process efficiency and productivity.*
Conclusion*: Based on the results obtained, it can be concluded that the application of lean production tools and methodologies is effective in improving the process of automatic insertion of SMT components. The identification of the root causes of the problems and the implementation of improvement proposals resulted in greater organization, increased productivity and reduced preparation times for changing models. These results indicate that the methodologies used in this study can be replicated in other areas of the industry to obtain similar improvements.*
Key Word*:SMT; SMD; Processes; Optimization; IAC.*

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I. Introduction

Companies are increasingly using robots to automate their production processes, which increases efficiency in productivity and quality. Electronics companies are not out of this reality, as they have machines that automatically insert semiconductor components, with cutting-edge technology and high performance for assembling printed circuit boards (PCBs). The mounted boards are part of various electrical equipment such as: televisions, computers, cars and several other products that depend on electronic circuits.

There are six advantages to implementing automation in the industrial process: increased productivity, reduced installation costs, quality optimization, increased process and worker safety, possibility of remote monitoring and obtaining competitive advantages [1].

The purpose of this article is to carry out studies in production processes to reduce the assembly time of automatic insertion, increase the use of SMT machines (Surface Mount Technology) and optimize operational processes, applying the Six Sigma tool and DMAIC and finally, the results obtained from the implementations should be presented, which will be described in the conclusion in general.

Justification of the article

The challenges of electronics manufacturing organizations, which have automatic assembly of components, are increasing with frequent technological innovations, mainly in continuous process improvements. This scenario generates instability in the market due to the fact that products and services have a decreasing life cycle and consumers are more demanding. Therefore, when observing the need for improvement in the process of an electronics company, it was proposed to carry out a study and application project that will make changes possible.

The research study focused on analyzing the performance of the production processes of the lines, only in the sector of automatic assembly of electronic boards, more specifically in activities involving surface mounting technology or Surface Mounting Technology (SMT). In general, many scientific works are being developed with the aim of improving processes in the manufacture of SMT electronic components and in the way their application is carried out during the assembly process. This work could contribute scientifically by applying it to other SMT assembly companies to obtain production results and cost reductions.

Assembly process

SMT Assembly Process

Industrial automation is an alternative that currently meets the need in industries that seek to produce their products on a large scale. With industrial and technological development, the industry has undergone a huge transformation over the years, especially those that have an area of operation in electronics, where large products have been transformed into small, practically portable equipment[2]. All this is possible due to the technology embedded in these equipment, which enables flexibility and miniaturization.

The surface mounting process is a more recent technology, as it mounts the semiconductors on the surface of the rigid PCB (Printed Circuit Board) of modern devices, in miniature form, with the components directly glued and soldered on the board. It is necessary to use the machines for assembly and ensure the reliability of this SMT technology. In short, SMT technology offers better performance, they are manufactured for use in mechanized assembly processes, which guarantees uniformity and reliability and enables technological evolution in industrial automation, reducing its size and processes, as the tendency is to reduce each the amount of insertion more and more.

Six Sigma Tool

Several companies in Brazil develop many projects using Six Sigma in order to increase profits by focusing on reducing waste, improving quality and increasing productivity.

In general, the Six Sigma tool works by setting goals and applying specific projects to achieve these goals. The success of the program will depend on the mobilization and participation of the entire organization[1, 10, 11] . Stillthis methodology consists of eliminating the 7 fundamental wastes present in a company: defects, excess production, intermediate inventories, unnecessary processing, displacements, transport and waiting.

DMAIC method

The DMAIC method (Define / Measure /Analyze / Improve / Control) came up with the task of reducing variations, especially in manufacturing processes. Its functions similar to its predecessors in manufacturing problem solving, such as PDCA (Plan / Do / Check / Act)[3].

DMAIC aims to improve processes through the correct selection of projects that can contribute to continuous improvement. By integrating several tools in the DMAIC phases, it is possible to contribute to structure a systematic and disciplined methodology capable of promoting the reduction of defect and failure rates of products, services and processes in organizations[4, 12].

It is important to emphasize that the use of quality tools may not work if they are applied improperly.

SIPOC process mapping diagram

SIPOC is a tool that makes it possible to assemble a process mapping diagram with the function of grouping the necessary information in order to clearly demonstrate what are the Inputs, Processing and Outputs of a process, identifying its beginning, middle and end of the sequences of activities and those responsible for each one of them.

A SIPOC diagram is usually drawn to map a process at a high-level[5]. However, it can also be used to map a process at increasing levels of detail (macro-processes, but also processes and sub-processes. Mapping the processes will give the organization's manager clear powers to make decisions that allow good results and managerial satisfaction. Knowing who your suppliers, customers, competitors and the power of your products are, gives you an advantage and more guarantee of success.

Ishikawa Diagram

For[6], the Ishikawa Diagram is also known as Diagram Fishbone, Cause and Effect Diagram or 6Ms Diagram. This is a visual tool, in graphic format, created by the engineer Kaoru Ishikawa in 1943 and perfected in the following decades. Its function is to assist in the analyzes of organizations in order to look for the main cause of a problem. Therefore, the Diagram aims to help the team to get to the real causes of the problems that affect the processes, that is, it helps to discover the factors that result in an undesirable situation in the organization.

The use of the Ishikawa Diagram tool is based on the premise that every problem has a specific cause. In this way, eliminating the primary cause means, consequently, eliminating the problem. To discover it, the method suggests testing and analyzing each of the suggestions, carrying out brainstorming, better known as "brainstorming", is a creative technique for groups that serves to try to find a solution to the problem to identify the root cause.

Definition of the 5W1H tool

The 5W1H tool can be defined as an organized document that, through questioning, identifies the actions and responsibilities of those who will execute, being able to guide the various actions that must be implemented and structured to allow a quick identification of the elements necessary for the project implementation[7]. This consists of preparing a measurement table following a response criterion of six questions that will give direction for the measurement to be assertive. The acronym 5W1H is composed of the initials of the words in English, What, When, Who, Where, Why and How[7].

II. Material And Methods

Contextualization

The work was carried out in a manufacturing plant that assembles electronic components on printed circuit boards (PCBs) that currently supplies assembled boards to automotive companies for products such as Cluster (indicator panels) and Car Audio (car stereos). The manufacturing process that was analyzed in the case study is based on an SMT assembly line, observing the processes and assembly lines, it was identified that there were opportunities to make improvements in automation and operational processes. This work began by observing the activities that were being carried out on a daily basis by the operators and movement in the assembly of components on the machines, as the assembly cycle time was longer than planned and for it to be developed, it was necessary to use the Six tool Sigma which, in turn, is important to know that will be defined from the DMAIC methodology (Define / Measure /Analyze / Improve / Control), used to improve an existing process.

SMT assembly line

The entire SMT assembly process is focused on automation, with minimal human influence, assembling semiconductors in a few seconds to assemble a board.

Figure 1 defines the layout of the Line for carrying out the project, the studies for optimizing the line were carried out in the Pick & Place machines from the manufacturer JUKI[8], which has three versions of assembly machines with CPH (Component per Hour) indicating the performance of assembly, arranged in sequence, FX-3 (HIGH SPEED) – With CPH 60,000; FX-2 (AVERAGE SPEED) – With CPH 40,000 and KE-3020 (LOW SPEED) - With CPH 20,900, each one has different characteristics and performance that defines the assembly of the components according to the encapsulation of the electronic components.

Figure 1: Line Layout

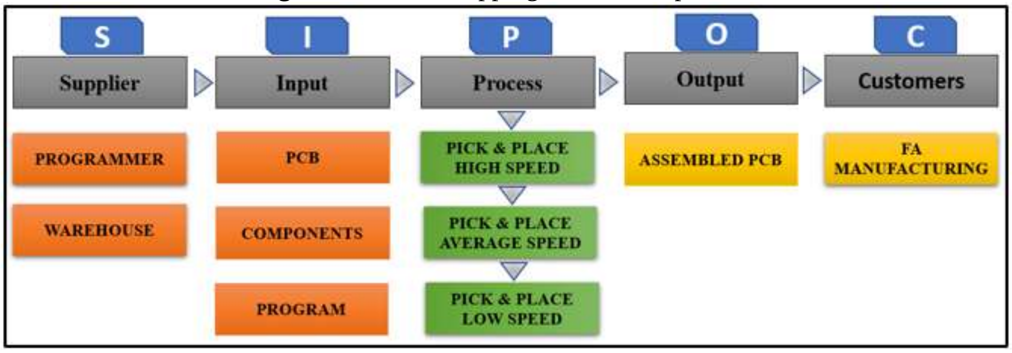
Source: Author's Compilation

To serve an electronics manufacturing company, it is important to know that the equipment was designed by industrial engineering to assemble the plates, in this objective study they are the Pick & Place machines.

DMAIC – Define (Define)

The SIPOC tool was used to understand the process flow, which allowed a clear view of the work activity sequences, as illustrated in Figure 2.

Figure 2: SIPOC mapping in the SMT process



Source: Prepared by the author

Below are the descriptions of the functions performed in the mapping of processes in the SMT:

Supplier (Process suppliers): The programmer develops the machine assembly programs in the IS software (Intelligent Shopfloor Solutions);

Warehouse is the SMT distribution center where the raw materials to be delivered in the process are stored:

Input: The programs are delivered to the process technician to be loaded into the memory of the assembly machines;

Components and PCBs are the raw materials supplied by the Warehouse to be delivered in production and fed into the Pick & Place machines;

Process: In the process there are the Pick & Place machines that will assemble the parts on the PCBs;

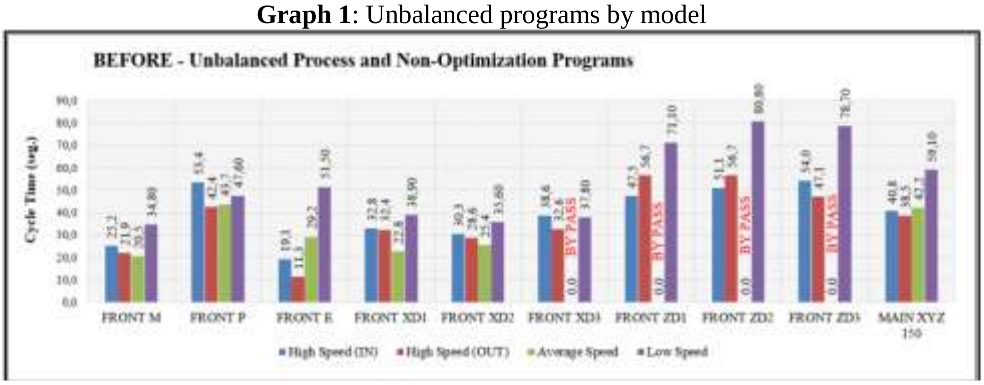
Output: Assembled PCB is the result of each step of the process;

Customers: FA manufacturing (Final Assembly) receives the assembled PCB from the SMT process.

2.4 DMAIC – Measure (Measure)

In Graph 1, we visualize the cycle times (Cycle Time) of the models it produces on the line, it is distributed by machine. Each model goes through three machines in the assembly process (High Speed, Average Speed and Low Speed). Like Pick & Place High Speed has two assembly modules that make it possible to assemble two boards simultaneously in one machine, this technological process makes the machine efficient in assembling components, in identifying the modules the terminology High Speed (IN) was used in the first module and High Speed (OUT) for the second module, with this definition we can identify the times of each module. Still in Graph 1, the by-pass description was used to illustrate a machine in the process that is not being used, serving only as a PCB transport deducing the efficient line, underusing the assembly of the machine Average Speed, not reaching the production goals programmed by the PCP.

Graph 1: Unbalanced programs by model



Source: Prepared by the author

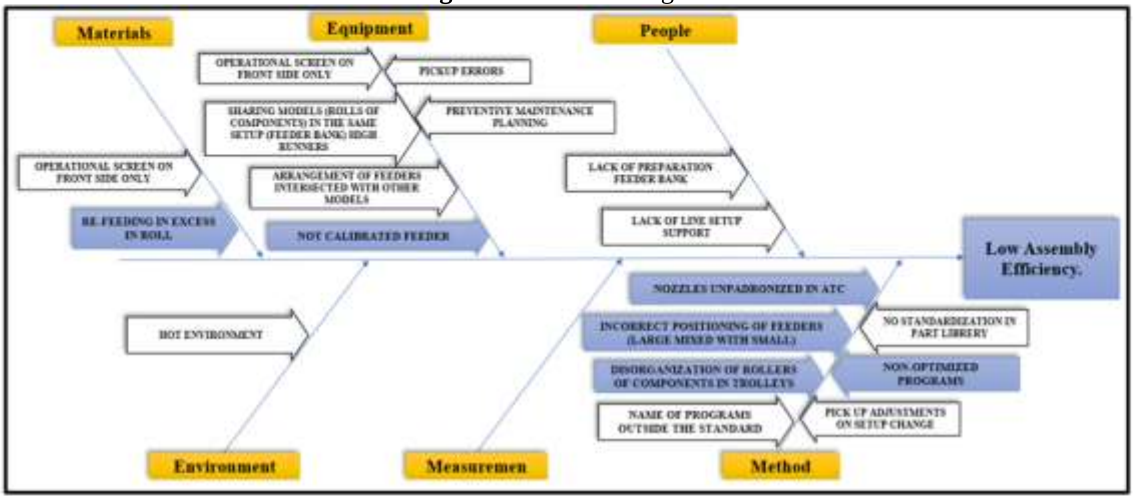
DMAIC – Analyze (Analyze)

Identify the Main Causes of the Problem by the Ishikawa Diagram.

The first action is to identify problems with machines and operational processes. So, the cross-functional team of managers and technicians came together to brainstorm. Through suggestions of ideas, we list the possible causes to identify the problems. We use the cause and effect diagram (Ishikawa), as shown in Figure 3.

Among the different hypotheses raised, the highlighted items can be seen in Figure 3. Six possible causes that are related to the problems were selected, with Low Assembly Efficiency being the main one.

Figure 3: Ishikawa diagram



Source: Prepared by the author

Detailing of Items Selected in the Ishikawa Diagram.

Using IS (Intelligent Shopfloor Solutions) programming software, it will be possible to analyze through simulations each process of the Pick & Place machines. The items in the Ishikawa Diagram will be described by hypothesis:

Hypothesis 1: Ishikawa Diagram Method - Non-optimized programs:

It was identified that there are idle spaces (gaps) between the feeders, the gaps cause the movement of the assembly heads to waste time, when picking up the components in the feeders, it travels a greater distance, eliminating the possibility of simultaneous foot printing, items close to the components that is a Pick & Place feature for optimization. Another identified point, the X and Y coordinates of the assembly heads (Head) when picking up the components in the feeders with a lot of movement in the assembly heads.

Hypothesis 2: Ishikawa Diagram Method - Nozzle non-standard in ATC:

In the study, it was identified that the Nozzles are not standardized in the ATC, each change of model or setup on the line, the maintenance reorganizes the Nozzles as defined in the assembly programs, wasting time between 10 and 15 min, affecting the setup time and in the process of assembly.

Hypothesis 3: Ishikawa Diagram Method - Incorrect Positioning of Feeders - Average machine feeders Speed are positioned incorrectly. The operators take the carts to the assemblers and bar code reading the components to check if they are in the correct position and inform the system of their location for confirmation. It is difficult for the operator to page through barcodes, as the large feeders are coupled between the small feeders and vice versa.

Hypothesis 4: Ishikawa Diagram Method - Disorganization of the rolls of components in the Carts - It was evidenced in the Low Speeder machine, they are without partitions to support the rolls in the vertical position, kneading the tapes and damaging the terminals of the components, stopping the machine due to an assembly error. Identified point Operators have difficulties in bar code reading the rolls in the preparation of the setup and in the production processes, the lack of standardization and disorganization of the carts makes the operational process difficult.

Hypothesis 5: Ishikawa Diagram Machine - Non-Calibrated Feeders:

When the head (head) collects the components in the feeders, the ribbon goes to the next component, but the feeders are not calibrated, which causes the components to be in different position. The lack of calibration of the feeders causes errors when picking up components, such as changing feeders, pick-up errors, loss of components (Scrap), low productivity and not performing a simultaneous pick-up.

Hypothesis 6: Ishikawa Diagram Material - Excess Feedback on the Roller:

One of the operators' tasks is to replenish the feeders with semiconductor materials, but when there is an excess of materials, the feeders fail, the ribbons slip to the side, catching in the feeder mechanism.

2.5.3 5W1H action plan

Ishikawa diagram, Table 1 visualizes the 5W1H action plan, for carrying out the activities.

Table 1: Action Plan - 5W1H – Low Assembly Efficiency

	Action plan					
#	What	Why	Where	When	Who	How
1	Machine programs are not optimized.	Optimize programs to reduce the assembly cycle.	Pick & Place machine programs.	Nov/2021 to Jun/22	Programmer	Make new optimized programs.
2	Standardize Nozzles in Pick & Place.	Reduce Assembly Cycle Time.	At the Pick and Place machines at the Nozzle station (ATC).	Nov/2021 to Jun/22	Programmer	By IS Software.
3	Organize the feeders in the optimization of the programs.	Facilitate operator checks and setup changes.	No trolley das Pick & Place	Nov/2021 to Jun/22	Programmer	By IS Software.
4	Arrange rolls of components on feed carts.	To avoid quality problems and facilitate check.	On the Pick & Place trolley.	Nov/2021 to Jun/22	Operators	Implementing trolley partitions between rolls of components.
5	Implement Feeders calibration area.	To adjust feeders and reduce pick-up errors.	On the calibration bench located in the feeder preparation area.	Nov/2021 to Jun/22	Technical	Using calibration equipment. Record maintenance in the IFS System.
6	Define component rolls feedback criterion.	Do not attach component tapes to feeders.	On the feeders that are on the SMT Production Line.	Nov/2021 to Jun/22	Process Engineering.	Recording the procedure and guiding the operators.

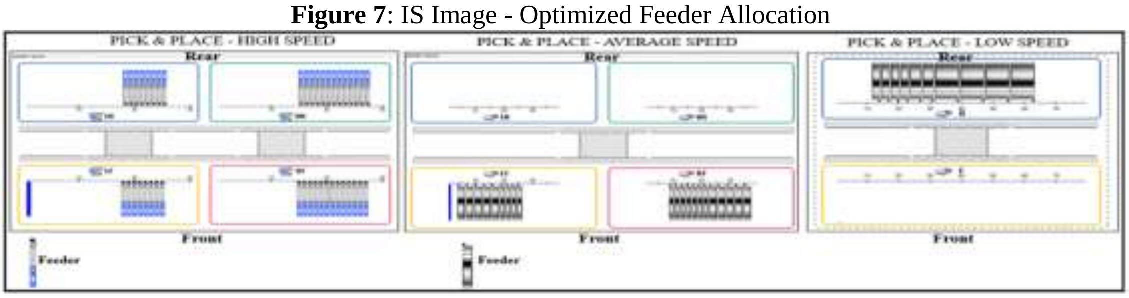
Source: Prepared by the author

III. Result and Discussion

DMAIC – Improve (Improve)

Optimized programs: In Figure 7 it is possible to observe that the feeders were organized to eliminate idle spaces (gaps) between them.

Figure 7: IS Image - Optimized Feeder Allocation



Source: Prepared by the author

Optimization in assemblies is related to the encapsulation formats of components distributed in Pick & Place, actions performed in component distribution:

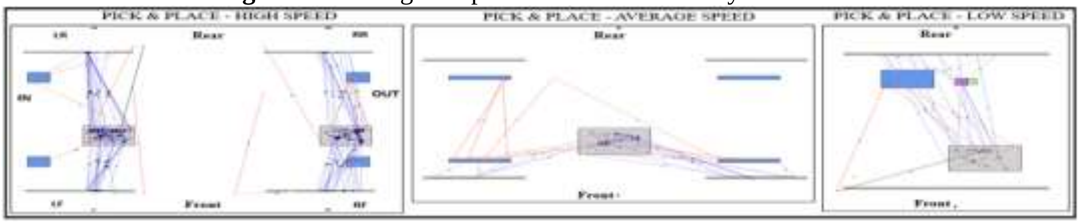
At Pick & Place High Speed – the small components called Chip (resistors, capacitors and inductors) were allocated;

At Pick & Place Average Speed – Chip, SOT (transistors) and LED components were allocated;

In Pick & Place Low Speed – larger and complex components such as Connector, QFP, QFN, SOP fine pitch and others were allocated.

When removing the gaps between the feeders, Figure 8 shows a reduction in the amount of movement of the assembly heads. In the simulation, it was possible to observe the simultaneous pick-up of components, which is a technological characteristic of the Pick & Place from the manufacturer JUKI[9].

Figure 8: IS Image – Optimized Head Assembly Movement

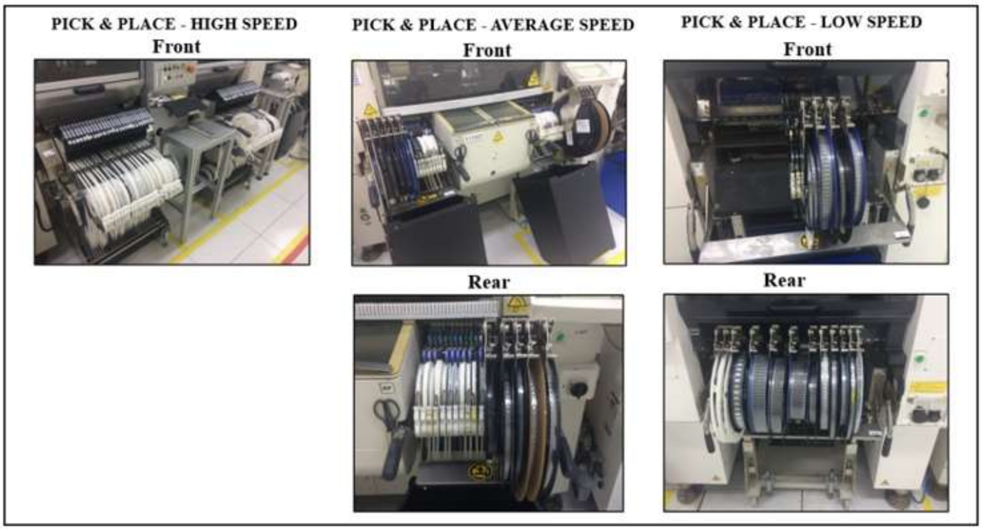


Source: Prepared by the author

The programmer optimized the programs by distributing the components in the feeders with equal amounts of footprints and the components have to be organized by size, the methodology makes the machines perform optimally in the assembly process.

Correct Positioning of Feeders and Organization of Component Rolls on Carts: Figure 9 shows the arrangement of component rolls on carts. Procedures and training were applied for organization, placing partitions so that the rolls did not fall to the side. The order of the feeders was sorted by size, first the small ones, then the big ones, which improved the activities of the operators.

Figure 9: Feeders Organized by Size



Source: Prepared by the author

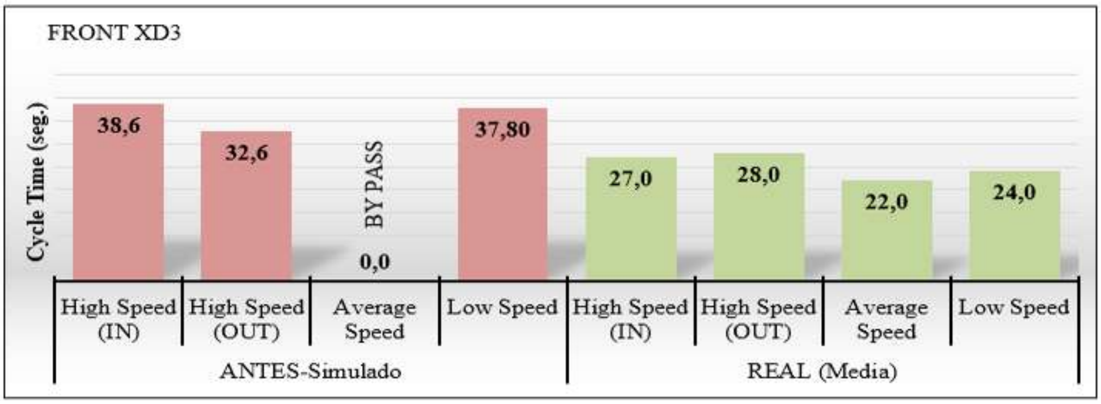
Nozzle in ATC: The Nozzles were optimized so that there is no loss in Setup time, maintaining a standard for all models in the line.
Feeder Calibration: a station was installed to calibrate the feeders, another important point, the technical assistants received training to work at the station and control software was implemented in the maintenance of the feeders.

DMAIC – Control (Control)

Changes in PCB assembly times resulted in the collection of new data, it can be seen through the graphs below comparisons of before improvement and results after improvement. Observing in Graph 2, which represents the Cycle time data of the machines of the Front XD3 model, before the optimization it has bars in red and comparing with what was done represented by the bars in green, the Average Speed machine is in By Pass, indicating that it is not being used for assembly, that is, underusing it. The assembly line was not giving the expected result, low efficiency.

In the optimization of the Front XD3 model program in the bars in green the assembly was distributed among the machines mainly in the Average Speeder, time balancing between the machines.

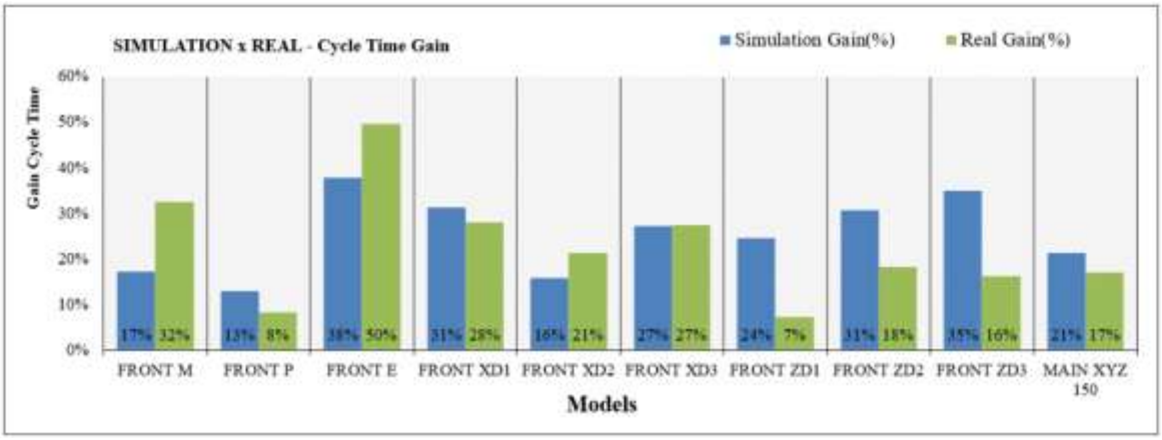
Graph 2: FRONT XD3 - Simulated X Performed Balancing



Source: Prepared by the author

In general, optimizations were made in programs and processes in all models, comparing the simulation bars in Graph 3, which represents the planned with the Actual gain bars, all products had good results in reducing assembly times. It is also noticed that the real gain did not reach the simulated goal, but the Cycle time was reduced for each model, as we can mention the FrontZD1 model, the simulated gain of 24% compared to the real gain of 7%.

Graph 3: Simulated X Real Production Gain



Source: Prepared by the author

IV. Conclusion

This article dealt with a very recurrent theme in companies, showing the problems that directly affect manufacturing processes, such as lack of standardization, lack of controls, unbalanced assembly process. In addition, the use of Lean Six Sigma (LSS) tools and the DMAIC method was shown to improve the efficiency of the assembly operation and the efficiency in the process cycle. From the realization of this study, it was noticed that the application of the Diagram of Cause and Effect tool was effective for the results in the management and taking of decisions, mainly for the development of the strategies for solving the problems, studying in more depth, demonstrating that the method used was of satisfactory use. Computer simulation, using the IS software, proved to be an extremely efficient tool to carry out the simulations. It was evident during the study that it is necessary for the implementation to measure the real times of the processes and compare them with the simulation times and reach the conclusion if it is feasible to make the improvements.

The main challenge in the development of this work was to apply the improvements in the operational process and maintain the work process. In general, the human factor is associated with the idea of error, a mistake made by operators that requires a lot of guidance, dedication and discipline. Even so, it was useful to be able to show, in a simple and detailed way, the technical and operational issues that we had satisfactory results, increasing the productivity of the line, as shown in the graphs and tables.

Through the application of quality tools, it was possible to map the process improvement points. The objective of this study is to define actions to implement them. In general, the result was positive with an average gain of 22.4% in the Actual result the company considers an excellent result for all products, slight reductions occurred, between 7% and 8% in the case of the FRONT ZD1 model and model FRONT P. At the same time, there were reductions of 32% and up to 50%, in the FRONT M and FRONT E models respectively, as can be seen in Graph 3.

It was decided to work with only six aspects identified in the Ishikawa Diagram, but if more actions were contemplated in this work, using the 5W1H Methodology, we would certainly have more results. So here is the suggestion that at other times these actions be mapped and implemented, as well as doing a lateral review on other similar products and processes so that the improvements are replicated.

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