

Lean Manufacturing Application on Balancing of Mounting Line in a Company of the Two-Wheeled Pole of Manaus-Amazon Industrial Pole

Eloisa da Silva e Silva¹, Marden Eufrazio dos Santos², David Barbosa de Alencar³

^{1,2}Academic department, University Center FAMETRO, Manaus-AM, Brazil

³Research Department, Institute of Technology and Education Galileo of Amazon (ITEGAM), Brazil

Abstract— In an assembly line system, raw material enters and progressively moves through a series of workstations while being transformed into the desired product. The production line balancing aims through effective activities and actions to ensure a continuous and level production, providing maximum productivity and efficiency while maintaining the proper work rhythm of the production process and avoiding wastage. Apply the balancing method in the processes that indicate difficulties to be accomplished, eliminate bottlenecks in the assembly line; increase the productivity indexes of the motorcycle production sector; measure the time of activities performed on the production line; analyze different methods, theoretical and practical balancing assembly production continuous model; improvements in Lean Manufacturing. The data collection was done through observation and documentation of the times of each job, in order to generate data to analyze productivity losses due to movements that do not add value or process poorly distributed. From these data, it was possible to observe that the poor distribution of the cycle times of some employees was outside the standard time of the assembly line, under such complexity, it was proposed to provide a new balance in the processes. In this way, it is possible to infer that the division of equal activities decreases the production cycle time in the stations and improves the productivity of the line.

Keywords— Process balancing, Lean Manufacturing, Takt time.

I. INTRODUCTION

The Industrial Hub of Manaus stimulated the formation of a productive chain with local, regional and national suppliers, with constant investments in innovative technologies, professional qualification and product development, being considered one of the most modern in Latin America, concentrating the largest Brazil, including Motorcycles [1], [2].

The MH company of Amazônia has 83% market share in the national two-wheeler market, is the largest motorcycle manufacturer in the country and the third largest manufacturer of motorcycles in the world, its activities establish links to the various regions of the country through subsidiary companies and suppliers that in a strategic and indispensable way promote the flow of goods, capital and information, consolidating an integrated space throughout the national and international territory [3].

The severe financial crisis requires companies to improve their performance, efficiency and productivity standards in order to make the best use of their resources and capabilities to survive in the market. From this perspective, the production line balancing (BLP) emerges as an important tool for obtaining improvements in this sector, such as: cycle time; productive capacity; resource utilization rate; degree of idleness of operators; among others [4], [5].

In the Assembly Line II sector of the MH Company of the Amazon, a series of problems that directly affected the production efficiency were evidenced. The failures caused by the poor distribution of processes generated significant disorders pointed out in the main key performance indicators of the sector.

The indicators of production, safety and quality (internal and external rejection) showed how the poor distribution of processes had a negative effect on results. Extremely high quality problems, poorly executed

production plan, fatigued and unmotivated collaborators, ever increasing field defect rate and some employees' cycle time out of standard assembly line time. In view of this, there was a need for a study with a new distribution of processes.

Considering the high productivity, cost reduction and quality maximization in the motorcycle production sector, the present study seeks to apply the balancing method following the Lean Manufacturing approach, as well as eliminate wastes, bottlenecks and stocks in processes that show failures in the motorcycle assembly sector.

II. THEORETICAL FOUNDATION

The theoretical bases are presented as references that served as a basis for the work developed, such as assembly lines, production line balancing and Toyota production system. Some important concepts were researched to develop an efficient implementation of process balancing in Assembly Line II of the company MH of the Amazon.

2.1 Assembly Lines

Assembly lines are production systems, defined as a finite set of manual or automated assembly workstations distributed throughout a drive system, developed for the industrial production of large quantities of products, such products are sequentially launched from station in season by a specific device such as treadmills, undergoing modifications until reaching the last assembly station [6].

The less time spent on tool stops, cleaning, maintenance and material handling, the better the productivity, other characteristics can be attributed to the lines [7], [8]:

According to many sources studied the main points to be raised in an assembly line are: set the cycle time; determine the number of workstations; balance LM and minimize lead time, among others.

In their work, [9] they mention that some terms used in the assembly line must be defined:

- Cycle Time: It is the time of each workstation of an assembly line to complete a set of specific tasks.
- Bottleneck: Machine or equipment that prevents constant performance in a process.
- Lead Time: Critical path of manufacture.
- Setup: elapsed time for an exchange of any running process until the initialization and adjustment of a next process.
- Takt Time: The production rhythm required to meet demand. Or it can be defined as, the maximum time that a unit of product must take to be produced [11].

2.2 Production Line Balancing

Production Line Balancing (BLP) is aimed at restoring continuous flow, eliminating bottlenecks that impede high productivity rates, is a waste reduction tool, especially by reducing operators' downtime [12]. It is the process in which the workload is divided between the operators in a production line so as to meet the time Takt time. A line is ideally balanced when each workstation produces synchronously and in the proper amount, generating a constant and uninterrupted flow in all stations of the line [13].

According to the authors [14], it shows that it is necessary for the production line balancing to analyze exactly or approximately the time of the activities of the collaborators, through this, it will be possible to verify the variation of the activities of the collaborators and to obtain the cycle time of each process within the assembly, the process with the longest cycle of the line directly affects the productivity, the association of the cycle time and the takt time is essential, because if the cycle time is smaller than the takt time the chances of occur excess production are greater, after the survey of the times, it is necessary to analyze the activities that interrupt the flow, which causes the waste.

2.3 Toyota Production System

Toyota found that the key to the operation was flexibility, that is, when you work with smaller lead-times and flexible production lines, you can achieve higher quality, greater customer response, higher productivity and better equipment utilization and space. The Toyota Production System (STP) prioritized the elimination of wasted time and material from each stage of the production process, broke paradigms in search of operational excellence. Before that, production systems were supported by the logic of mass production, following Fordist Production logic [15].

According to [16], "lean" production, or Lean Manufacturing, was the definition or term used to define this production system much more efficient, agile, flexible and innovative than mass production. For a factory to have a lean manufacturing system, it needs to transfer tasks and responsibilities to the workers that add value to the product and must have a system that identifies the defects as soon as they occur and discover the root cause of those defects. It is to promote a harmonious flow of materials and information, between jobs and operators, so that it is produced in the right quantity and at the right time.

The "home" diagram, shown in Figure 1, shows that the basis of Lean Manufacturing is the total elimination of waste, as well as the main characteristics of the

methodology, as well as its two pillars, Just in Time and Jidoka - among other essential components of the system.

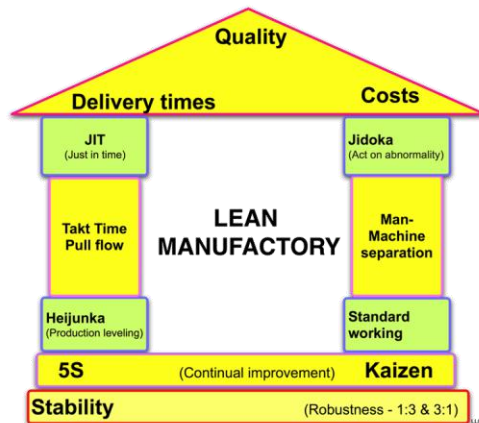


Fig. 1: Illustrative Representation of Lean Manufacturing

According to [18], the fundamental objectives of lean production are:

- Optimization and integration of the manufacturing system;
- Quality;
- Process flexibility;
- Production according to demand;
- Maintain commitment to customers and suppliers;
- Reduction of production cost;

2.3.1 The Seven Losses and Subsystems of the STP.

In his work, [19] presents the basic concepts of these losses.

- Waiting: Waiting time can be for employees waiting for the equipment, production lines waiting for parts, machines waiting for raw material exchange or waiting for repairs.
- Defect: Occurs due to failures in process, process operation and raw materials, ie if you have two options the part is discarded or it is reworked.
- Transportation: Moving materials more than necessary. Work teams and support teams should be nearby.
- Movement: Caused by poorly drawn layouts, obstacles in the way that cause the operator to divert to reach his destination.
- Stock: The excess of raw materials in the sheds, or areas intended.
- Super Production: It is the biggest waste of companies, also considered as the source of all other waste.
- Super Processing: These are the processes that occur inside the factory but are unnecessary for the good performance of the same.

III. TOOLS AND METHODS

The methodology adopted to carry out the course completion work consisted of a case study. The main focus of the case study is to demonstrate the multiple facts of variables that relate to the activities performed. The case study is a frequently used method for making decision-making or raising questions that aims to deepen knowledge in a particular area, in this way, this tool significantly helps the development of this project.

The case study does not follow a rigid script for its elaboration, but it is possible to establish four phases that show its delineation: a) Delimitation of the unit - case; b) Data collections; c) Selection, analysis and interpretation of data; d) Preparation of the report. [20].

3.1 Field Research Environment

The Assembly Line II sector has a productive capacity of 900 units in a shift, where its functionality establishes in only 1 Administrative shift, containing 79 employees in its production, divided into sub-tread with 40 employees and main treadmill with 39 employees. The main example is the model: K31 ABS.

The choice of this company to carry out this project is justified by the fact that the academic stage of the author of this work of conclusion of course occurred in this company. The research that covers this project was lifted and monitored from December 2018 until March 2019, aiming to collect data for the comparison of results already existing in company documents, giving veracity in the current data or helping in the continuous improvement of the company. The company works with a regular time of equal processes for all workstations, the production is elaborated according to the request of the authorized concessionaires where, through software, it performs an analysis respecting the productive capacity of the line, checking the possibility of generating a date and time for delivery of the product to the customer.

3.2 Tools Used for Time Study

The realization of the time studies had to use common tools in these methods of time collection, for the effectiveness and accuracy of the data found. The tools listed below are the main tools used for this type of research.

- Centesimal hour timer: check the cycle time of each workstation.
- Observation sheet: Carry out the annotation of the data found in the timing;
- Ballpoint pen: Record and record the data.
- Support clipboard: Support the observation sheet and stopwatch.
- Photographic Camera: Record process images in case of doubt.

3.3 Techniques Used for Collecting

The techniques used for data collection were divided in two, the first part in the Cronoanalysis of the data where the methods, tools, installations and materials used in the work were analyzed. This chronoanalysis assists in the execution of activities, through its measurements and evaluations it is possible to find a more reliable and accurate form of the time needed for an operator to perform certain work at a standard pace within a feasible time. In addition, the chronoanalysis evaluates layout, rationalization devices and also cares about ergonomics, providing contributions to the locomotion in the work space, as well as work position and posture suitability so that it does not cause damage to the whole operator's chrono-analysis was carried out through documents found in the company's database, where it detailed the details of the manufacturing process, such as standard time of each process, process cycle, models and several other data that directly contributed to the data collection.

The second technique was the observation and comparison of the data, where each employee's time of operation was rigorously recorded, a survey of each job, and interviews with employees to see their degree of empiricism and to verify where Lean Manufacturing helps with the use of Crono to find out where the process is wasting time or how to reduce process time.

3.4 Planning of the activities to be carried out (PDCA Cycle)

The planning of the case study, according to Figure 2, was organized with the PDCA tool, where the schedule of activities to be carried out was developed.

PDCA	FLOW	PHASE	GOAL	TOOLS
P	1	IDENTIFICATION OF THE PROBLEM	DISTRIBUTED PROCESSES	DATA AND HISTORICAL
	2	NOTE	CURRENT SITUATION	RESEARCH AND DATA COLLECTION
	3	ANALYZE	ANALYSIS OF SITUATION AND CAUSES	DIAGRAM OF CAUSES AND EFFECTS
	4	ACTION PLAN	STUDY OF THE CAUSES	BALANCE OF PROCESSES
D	5	EXECUTION	IMPLEMENTATION OF SOLUTIONS	ACTION
C	6	VERIFICATION	ANALYSIS OF RESULTS (BEFORE AND AFTER)	GRAPHIC COMPARISON
A	7	STANDARDIZATION	ACTION, BACKWARD BRAKE	-
	8	CONCLUSION	RESULTS AND BENEFITS	-

Fig. 2: Schedule of activities

The PDCA cycle is a managerial method that aims to guarantee the achievement of the goals necessary for the survival of an organization, taking the information as a factor for directing decisions. The steps that make up this cycle are: Plan (P - Plan), Execution (D - Do), Verification (C - Check) and Corrective Action (A - Action).

3.5 Main idea for conducting field research

The research began with the idea of raising the main negative determinants, which was directly interfering with the company's productive plan, where it was impossible to reach the goals of: quality, production, safety, absenteeism and operational satisfaction. At the outset there was the decision to work on each of these problems in isolation. However, the use of Ishikawa's tool or popularly known as fishbone, Figure 3, showed that it could not treat the conditioners as isolated cases, but rather as a single case that maintained correlation with others and directly influenced the productive goals. Cause and Effect Diagram (Ishikawa) is a technique used to explore and indicate the possible causes of a specific condition or problem.

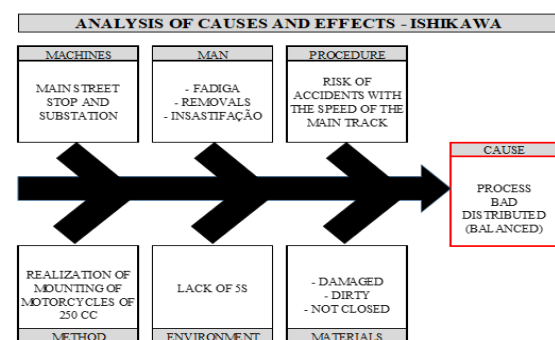


Fig. 3: Analysis of causes and effects (Ishikawa)

The result obtained with the use of the Ishikawa tool evidenced the root cause of the problem, indicating that the method of distribution of productive activities was wrong and needed a new process balancing. In this way, it was defined that the main idea was to balance the processes of Assembly Line II with the approach in Lean Manufacturing.

IV. BALANCING THE PRODUCTION LINE APPLYING LEAN MANUFACTURING

Field research was carried out with the objective of elaborating the balancing of Assembly Line II and defining the action plan to achieve the objectives of this course completion work. Figure 4 shows the steps taken to prepare this research.

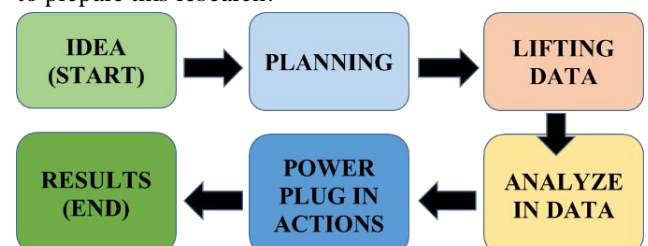


Fig. 4: Flowchart of the steps taken to prepare the field research

Each stage of the process was carried out with the aim of standardizing the research process.

4.1 Data collection.

Initially, the detailed timing of each workstation was generated generating the time and process table and, consequently, the main data, which determine the time and task that each operator was performing at the assembly station.

Subsequently, internal documents provided by the production control sector were verified, to ascertain the status of the indicators, such as: quality indicators; absenteeism; training and satisfaction. Aiming to study their relationships with the current problem of balancing process.

4.2 Analysis of the data.

The analysis of the collected data is the main part of the research, because through a good analysis it achieves great results. The first data collected were collecting and timing to obtain the time each operator performs a certain operation. The workstations, operators and times of each Workstation follow in Tables 1 and 2. Colab. for Collaborator, Lower Limit (L.I), considers (88% of Takt), Meta represents (94% of Takt) and Upper Limit (L.S) (Over 94% of Takt).

Tab. 1: Time per process of each employee (1 to 39 Sub Track / 40 to 79 - Main Track)

TIME TABLE OF PROCESSES							
COL.	POST	TIME	L.I	GOAL	L.S	TAKT	%
1	OPER 1	37,47	35,20	37,60	37,61	40	94%
2	OPER 2	36,97	35,20	37,60	37,61	40	92%
3	OPER 3	37,45	35,20	37,60	37,61	40	94%
4	OPER 5	36,80	35,20	37,60	37,61	40	92%
5	OPER 6	37,35	35,20	37,60	37,61	40	93%
6	OPER 8	35,00	35,20	37,60	37,61	40	88%
7	OPER 9	37,42	35,20	37,60	37,61	40	94%
8	OPER 18	37,22	35,20	37,60	37,61	40	93%
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79	OPER 113	30,88	35,20	37,60	37,61	40	77%

Each job was timed in detail to its execution, followed by the annotation of each action performed by the employee, after obtaining the detailed time, the samples were added generating a final result of each job. After the collections were carried out on the assembly conveyors, the process balancing chart was elaborated, Figure 5, a graph that clearly showed the time of each workstation.

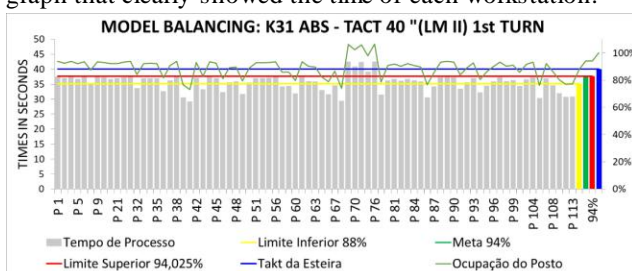


Fig. 5: Process Balancing Chart

With the process balancing chart, it is clear that some processes were experiencing difficulties. Posts 70 and 74 were at or above the takt of 40 seconds, this limit was a risk that should be studied in more detail, because there was a great hypothesis that the employee had signs of overload. At the 69th, 72nd and 76th positions, it was above takt, becoming the production bottleneck, thus, the number of line stops caused by bottleneck was great. In addition, not only did it contribute to the line stops, but also to the employee's ergonomics.

There were 27 jobs in idleness problems (below the lower limit), employees were idle, their cycle time was well below the scheduled takt, this idleness could lead to distractions and forgetfulness in the operational achievements, generating defects that reflected directly in the sectoral quality index. Some employees complained that their posts were causing discomfort and great pain, due to poor distribution of the processes. Finally, the other processes were feasible, but their efficiencies are lower than expected.

4.3 Analysis of the graphs.

In order to understand and understand the problems that occur within the sector of Assembly Line II, the production indicators were studied to identify the contribution that each indicator showed in relation to the non-length of the targets.

Observing the difficulties encountered in the balancing process, it was decided to analyze indicators that maintained a correlation with the production. Among them: general quality chart, sector quality chart; graph of absenteeism and finally a graph of sectorial satisfaction.

4.3.1 General Quality Chart

The first graph analyzed was the general quality chart, this graph is responsible for demonstrating all the quality problems of Assembly Line II. The graph presented in Figure 8 was analyzed in the period from September to November 2018. It was observed that in September there were 61 quality problems, in October 45 problems and finally in November 65.

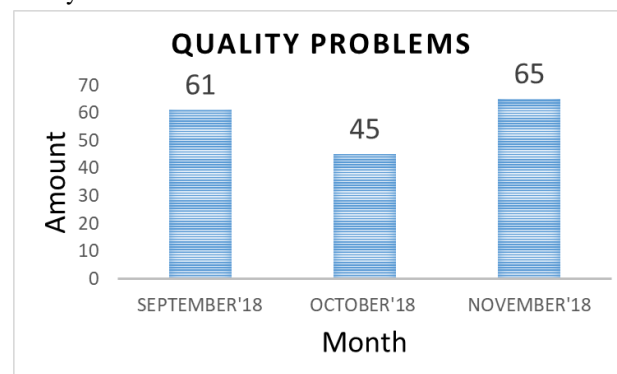


Fig. 6: General Quality Chart

4.3.2 Sector Rejection Chart

The overall quality chart, Figure 7, shows that in September, October and November, there were 171 problems with quality. This amount caught the attention because it contained a very high sectoral rejection rate in its participation. Of these 171 problems it was found that 111 problems were directly directed to Assembly Line II.

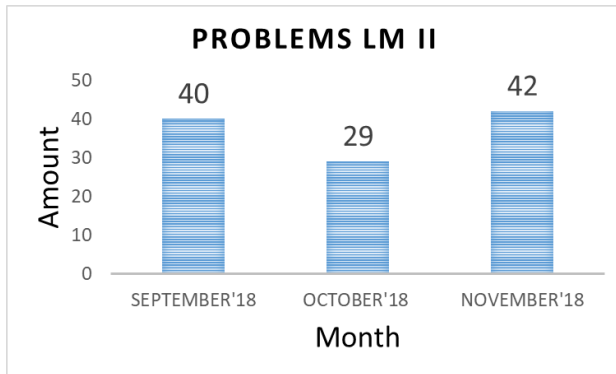


Fig. 7: Sector Rejection Chart

4.3.3 Chart of sector absenteeism

Graph of absenteeism shows the number of employees who were absent from the sector in the period of September, October and November. It is divided into two parts: employees who moved away in relation to the process, examples: right and left shoulder injury, accidents for not performing process correctly, back pain and only by ergonomic conditions and those that have no relation with the process, for example: intestinal pain, headache, parental leave, dentist, and outings for particular subjects.

Because it is related to production, the graph, Figure 8, was analyzed and gained attention to help in understanding the situations that occurred in the Line II sector.

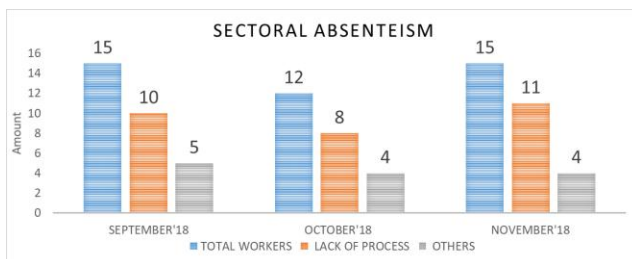


Fig. 8: Sector Absenteeism Chart

4.3.4 Sector Satisfaction Graph

Graph of sector satisfaction, Figure 9, one of the most important graphs of the company, since its function is to demonstrate the employees' satisfaction with the company. There are 3 criteria used for evaluation, the developer chooses which of the options he is most dissatisfied. The reference of the greater, the better (1 to 10) is used.

1st MANAGEMENT: the employee analyzes how the sector's management is being carried out, whether its leaders are listening to employees or whether they are attending in an equal way to all;

2 ° PROCESS: dissatisfaction with the process, being: too fast, in the bottleneck, long time in the same process or fatigued;

3 ° SECTOR: Analysis of the sectoral organization is taking care of and respecting the space of the employee, if the necessary tools for the operations are being offered.

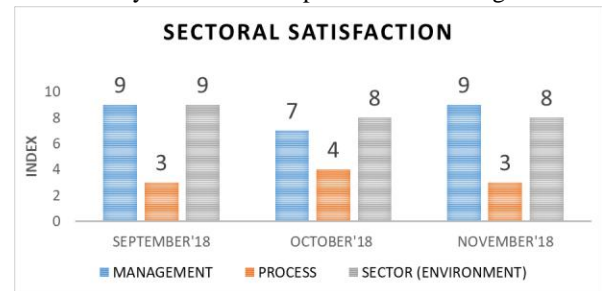


Fig. 9: Sector Satisfaction Graph

4.4 Action Taken

After defining that the most conceptual solution should be the realization of process balancing with approach in the philosophy Lean Manufacturing, took the action of creating a new vision of work in the sector of Assembly Line II. The implementation was carried out in December 2018 and based on the data, the best strategy was set up to obtain a good result in the indicators to be reflected mainly in the first few months of 2019.

V. RESULTS

With the applied balancing, the results obtained were excellent, in the production indicators showed that the process balance that was based on lean philosophy, transformed the work environment, giving a new form of execution of the sectoral activities. The results were acquired through much analysis of studies carried out. Colab. for Collaborator, Lower Limit (L.I), considers (88% of Takt), Meta represents (94% of Takt) and Upper Limit (L.S) (Over 94% of Takt). After balancing table 2, it shows the results achieved.

Tab. 2: Time per process of each employee (1 to 39 Sub Track / 40 to 79 - Main Track)

TIME TABLE OF PROCESSES							
COL.	POST	TIME	L.I.	GOAL	L.S.	TAKT	%
1	OPER 1	37,47	35,20	37,60	37,61	40	94%
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5	OPER 6	37,00	35,20	37,60	37,61	40	92%
6	OPER 8	35,25	35,20	37,60	37,61	40	88%
7	OPER 9	36,72	35,20	37,60	37,61	40	92%
8	OPER 18	36,22	35,20	37,60	37,61	40	91%
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79	OPER 113	36,72	35,20	37,60	37,61	40	92%

With the process balancing chart, Figure 10, it is evident that the most critical processes have been adjusted as Lean improvements. Posts 70 and 74 were at or above the takt of 40 seconds because the employee really had signs of overload. At stations 69, 72 and 76, it was above the takt, in which the necessary balancing of the process distribution was performed, removing the production bottleneck at these stations, in this way, the number of line stops caused by the bottleneck decreased significantly. In addition, line stops were no longer occurring in relation to these overloaded stations. Consequently, the ergonomics of employees in these core processes.

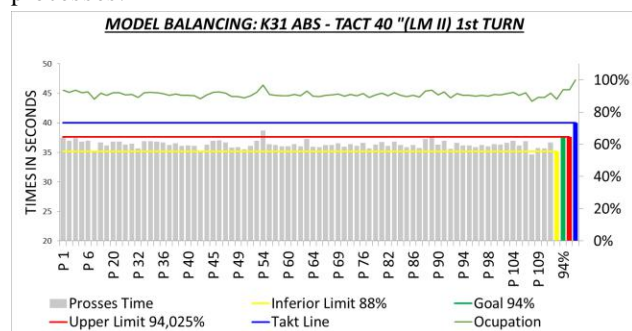


Fig. 10: Process Balancing Chart

5.1 General quality chart

The general quality chart, responsible for being a main indicator in the monitoring of defects occurred inside the factory.

After balancing, we obtained satisfactory results. Where in the month of January the index fell to 10 defects month, in February 12 defects month, and in March were only 9 defects, with this we can see in Figure 11 that there is a relationship of monthly defects with the new process balancing.

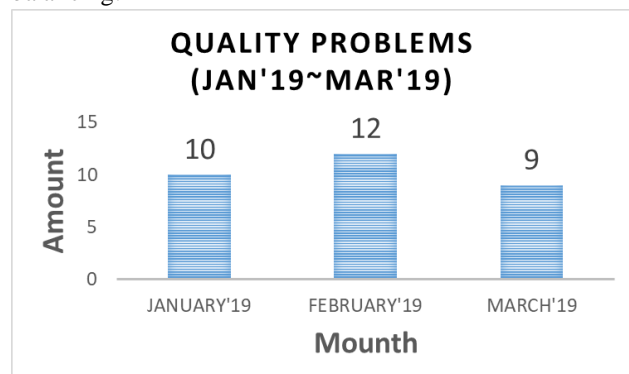


Fig. 11: General Quality Chart

5.2 Sector Rejection Chart.

The sector rejection graph is responsible for indicating the quality problems that occur within the sector of Line II, is extracted from the general quality chart, where its

modality is to analyze in a coherent way how is the sector performance, in the chart below, we can to observe how the application of the balance had a direct effect on the sector, giving a 89% efficiency in the sectorial quality, in relation to the previous one. The results obtained after the balancing were that in January we obtained only 6 defects, in the month of February only 5 defects and in the month of March 6 defects, as shown in Figure 12.

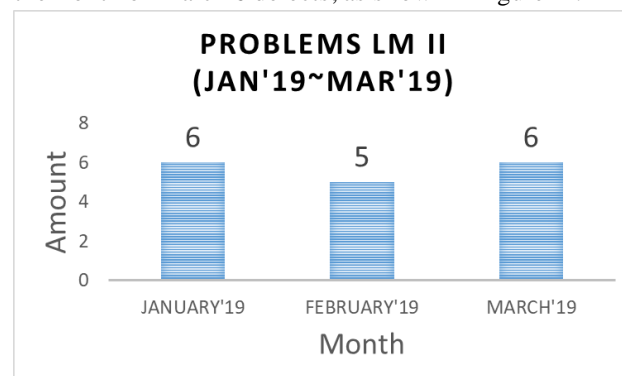


Fig. 12: Sector Rejection Chart

5.3 Chart of absenteeism

Responsible for indicating the employee absence index. With the new process balancing in figure 13, the absences from the process decreased by 89.65% in relation to the previous balance.

The good result is due to the new way of performing the sectorial activities, because the temple cycle employees are in accordance with Takt.

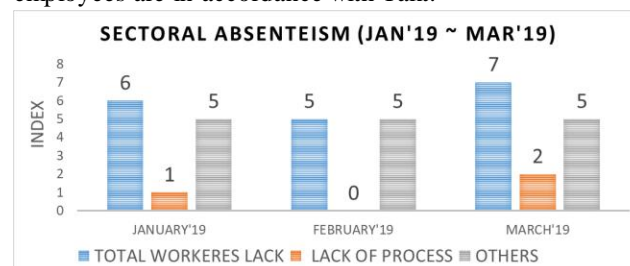


Fig. 13: Absenteeism Chart

5.4 Sector Satisfaction Graph

The sector satisfaction chart in figure 14 is extremely important, since its indicators are aimed at reporting and analyzing the situation of employee satisfaction through management, process and sector management. With application of process balancing based on the lean manufacturing philosophy, the process dissatisfaction index reduced by 89.3%, making it very acceptable for our research, according to Figure 14.



Fig. 14: Sector Satisfaction Graph

The research as an important and delicate subject obtained an expected and acceptable result, the application of the process balance based on the lean manufacturing philosophy showed us how the balance can be adopted as a tool of sectoral leverage. It is evident that the sector achieved good results and great performance after the application of this tool, today it is possible to observe collaborators more satisfied with their processes, where the best result in all the research is to guarantee the productivity of the company and the satisfaction of our employees and customers.

VI. FINAL CONSIDERATIONS

The study developed in this work aimed at the application of the balancing, based on lean manufacturing, in a assembly line of the two wheel segment.

The importance of planning for the implementation of the balancing was presented, analyzing the time of transformation of the product and demonstrating the practices adopted to make improvements within the sector of Assembly Line II. The proposal to achieve higher productivity of the assembly line was to map the processes and collect the cycle times of each employee.

The application of the lean manufacturing approach allowed the transformation of the productive environment, reducing the process cycle, eliminating bottlenecks, waste, separation from injuries, and allowed productivity gains and efficiency, generating a high social prestige for employees.

Lean's approach enabled the company to prevent wasted materials in process and eliminate products that did not add value to the industry. The reduction of waste does not make the end of this tool, a work environment must be in continuous improvements always aiming the well being of its employees and customers.

Main contribution of this course completion work is to demonstrate the path of production balancing by adopting a lean manufacturing philosophy.

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