https://dx.doi.org/10.22161/ijaers.6.6.44 ISSN: 2349-6495(P) | 2456-1908(O)

Optimization of the Production Process Layout of a Small Clothing Company

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Abstract *— Companies seek improvement of results through the use of process analysis tools. The aim of this study was to analyze and structure the production process of a clothing manufacturing company, using methodologies such as PDCA and quality tools that aided in decision making, proposing changes to optimize the main indicators of the feasibility of each proposal with its cost-benefit.*

Keywords *—* ***Process for making clothing, PDCA, Quality tools, Productivity indicator, Process layout.***

I. INTRODUCTION

The production process models used today are influenced by several factors, among them the volume of demand and the variety of items to be produced, there may be hybrid models to serve different types of processes and causing companies to seek more and more by innovations to ensure competitiveness through the guarantee of quality and flexibility of its products.

Within the clothing industry, when analyzing the production process model historically, it can be assimilated to other branches, which began with artisan processes, producing by order and demand, evolving to linear processes of production, to meet high demands of the market, currently works with hybrid models, as exemplified by [1], in their studies aimed at structuring a productive process of a military garment manufacturing company, where a mixed physical arrangement was applied that depended on the stages of each process.

In order to analyze the process of the company in question, the PDCA methodology was used to better understand the production process, to prioritize the main causes and effects that are generating low index in the indicators and, finally, to define the action plan that will generate the best results for the company. The quality tools used in this methodology have the objective of bringing clarity to the work that is carried out in the process, helping in making decisions based on facts and data.

Regarding each study and analysis performed, one can better understand the process flow and decide which best model can be deployed on the factory floor, as well as the improvements needed to ensure high productivity and production performance. According to [2], the positioning of facilities, machinery, equipment and production personnel are very important for the performance of a productive operation, whether in manufacturing, storage, service or office operations. In addition, the location of these items directly affects the ability of a company to compete 12wewithin the market.

II. BIBLIOGRAPHIC REFERENCES

The manufacturing industry requires a low level of technology and because its machinery is easy to handle, it is formed by medium and small companies, where these factories produce low value products in large scale and with cheap labor, where often, this branch can provide gains of scale in the stages of the productive process [3].

The company studied works specifically with the production of hospital clothes, where it seeks growth within the local market and in the state of Amazonas. Within its internal process, the company buys all the necessary inputs for the manufacture only of the process of cutting and sewing. That is, buy the fabric ready for the final product, and the same is responsible for the sales plan and storage of the same.

In this way, we can better understand the flowchart of the production process that begins with the receipt of the inputs, which is allocated in a separate stock for them, soon after the cuts are made in the materials and separation of the products that are defined through the plan of production generated by the management of the

https://dx.doi.org/10.22161/ijaers.6.6.44 *ISSN: 2349-6495(P) | 2456-1908(O)*

company, after which all cut material is separated and passed on to the sewing and packaging process, and finally, the products are stocked waiting to be sold to the store. All this procedure is done in a handmade way and the company has 15 diversified sewing machines, 2 ironing boards and a cutting table as machinery, plus 6 seamstresses, two sewing aids and a cutter as an operational level collaborator.

2.1 PDCA Methodology

Before approaching the importance of the productive system model and process layout for the productivity results of the company in question, one must understand the steps used in the analysis and production solution (MASP) methodology and connect them to the PDCA cycle, to be able to understand their influence in the decision making made during the study. According to [4], any kind of decision is made in order to solve problems and avoid their recurrence, so these decisions must be based on data collected in the process, and analyzed by the sequence of the problem solving method. The following eight steps of MASP are described below according to each acronym in the PDCA cycle:

P - Plan

1) Identification of the problem. that through analysis of the process as a whole, where we will see not only the current situation or the bottleneck of the process, but also work on the prevention of possible incidents in the future.

2) Analysis of the Phenomenon, where through the generation of indicators we can see the real effect of what is happening in the process, understanding this effect, we can better understand the root cause and move towards a more assertive action plan (facilitate decision making by part of the board).

3) Critical Process Review that is in Failure. We will prioritize the bottlenecks to be treated trying to dismember it to arrive at the fundamental solution

4) Create a short-term action plan that has a large-scale effect.

D - Do

5) Execution of the action plan generated.

C - Check

6) Verification of the results obtained.

7) On top of these results we will check if the effect is sufficient or not, if a reanalysis is needed, we will include more actions in the plan

A - Act

8) And finally, when we arrive in a satisfactory state in relation to the expectations of the board, we will work in a process of standardization of all the processes to avoid that the effect happens again or to continue with the process of improvement.

2.2 Production Balancing

Production balancing is used to level the steps of a process as to its available resources, whether they are machines, people or inputs used, through the time, methods and volumes of each step. According to [6], balancing helps in defining all the activities that will be executed during the process to ensure that the execution time between the stations is the same. Balancing the production line is to define the set of activities that will be executed in order to guarantee an approximately equal processing time between the workstations [7]. The production line balancing is one of the techniques applied to improve the process and simplify the management [8]. In this way, through time analysis and availability calculations, resources can be used more efficiently within the process.

In the company in question, it was analyzed the times of the products that generate the greatest return to the company in search of a balance that could generate better production results.

2.3 Production Performance Indicators

Although the concept of productivity and efficiency are distinct, both are closely associated and can be applied in different branches of industry. For [9], the use of performance indicators is a good performance management practice that can and should be used. According to [10], a performance measurement system consists of a series of measures (or indicators) used to quantify the efficiency or effectiveness of a process.

In the study of [10], a distinction is made between quality and productivity indicators: the quality indicator is related to the measurement of the company's effectiveness in meeting the customers' needs, while the productivity indicator represents the efficiency of the process in obtaining expected results. The diversity in the interpretation between efficiency and productivity is basically the reflection between the various social actors existing within any organization is inserted. Being that, in this work, the concept of productivity is focused on the organization of work in production as the main instrument. Thus, this study was carried out inside the factory floor, where it was made a relation of what was produced with the resources used to produce or availability that had to perform the production [11].

https://dx.doi.org/10.22161/ijaers.6.6.44 *ISSN: 2349-6495(P) | 2456-1908(O)*

Within this context, it had been defined that productivity is the result produced compared to the amount of labor used. The higher the production performed by the same number of employees, the higher the productivity index of the company.

2.4 Physical Arrangement and Process Layout

The physical arrangement of a company is extremely important for its performance indicators, as it will define how the human-machine interface will be in order to improve the flow of processes or impair the distribution of resources causing loss of production time. It is presented by [12], the concepts and classifications of layout and physical arrangement. For [13] the layout or physical arrangement consists of the positioning of the facilities, machines, equipment and operation personnel, in a productive operation, determining the flow of materials, information and customers.

According to [2], defining physical arrangement is deciding where to place the facilities, machinery, equipment and production personnel. This is because they are very important to the performance of a productive operation.

There are four types of physical arrangement [14], positional, product, process, and cellular. The positional layout is that the product is in fixed position and the operations are around the same, usually used in products of great size like ships, bridges and airplanes; the layout by product is defined to allow the linear flow of materials and assemblers in general use this type of physical arrangement, such as automobile production; the process layout is designed to accommodate a wide variety of designs and processing steps, such as in the machining area by lathes; and cell layout machines are grouped into cells that produce a particular family of parts with common features such as specific parts of the car assembly (glass, plastic injection, etc.).

According to [15], in order to define the best type of physical arrangement for the plant, it is necessary to understand the volume of production and the variety of items to be produced, and there may be hybrid models to serve different types of plants.

III. TOOLS AND METHODS

The proposed case study uses the PDCA and MASP methodology with the purpose of obtaining a study focused on the discovery of the main problems and their causes to then generate treatments that can generate results that are close to what was expected. Through these methodologies, several quality tools are used to analyze the process in order to identify the best possible actions to implement improvements in the process.

The first step of the study is to analyze the process to understand how it works, in Table 1, you can identify each step of the process of making the company's clothing and an initial analysis of it.

Table 1. Stages of the production process and initial analysis.

	Process Analysis
Production plan	Passed by the board and still in the initial phase.
Stock of material receipt	Material allocated in deposit and separated by product code.
	Not yet implemented stock control.
	Amount of Material Based on Launch Production Plan.
Fabric Cutting	Uses molds received by the stylist and industrial cutting machine.
	Molds made of wood paper.
	Cutter draws the mold on one side of the fabric, then overlaps the amount of fabric defined in the plane.
	The cut fabrics are separated and identified with a brush, and are allocated in the input cabinet.
Sewing and finishing	3 sewing cells perform the complete sewing process without finishing, which is done by one of the collaborators at the end of production of the product. And an assistant passes the fabric before sewing.
	The cells divide the sewing process between them.
Finished product stock	Finished product is allocated in the room of the leader of production, according to layout presented, waiting to finish works in administration and in the store.

Analyzing the initial survey done by collecting data on visiting the site and understanding how the process works, we verified the need for a 5S in all stages, mainly regarding the sense of use and cleaning. This philosophy helps to keep the process organized, to avoid possible material exchange errors during a production, and to lose material in the process (wasting time). For example, use

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color identification, set fabric storage location that has already been cut and is waiting to enter the sewing process, create stock picking control, set up post cleaning activity (leaving material available to employees), and a number of actions, can help avoid waste. Below are listed some essential elements listed in the analysis for the generation of immediate actions:

A) Stock of material input:

1- The identification of the inputs is being carried out, but only by model. Make stock reorganization by color and model to ensure that the product will not be confused if the order comes with some kind of error.

2- There is a need for material control to work with indicators of material waste, but there is no access to a computer system inside the factory to facilitate the control, so the control needs to be done in a handwritten way.

B) Production plan:

1- Creation of double-check (signature of two responsible in the order of production) to ensure that they passed through those responsible for the process and there is no rework or product stopped in stock.

C) Cutting:

1- Creation of copy of all the molds for paper harder, since they are being made in wood paper and already are wearing.

2 - Organization and local identification of storage of cutting inputs, since they are arranged in a disorganized way.

3- Organization and identification of the place of storage of product within the process. Cut fabrics are on all the benches, which can disappear or mix with other models.

D) Sewing and finishing:

1- Creating a place for products that are inside the process, because the products are folded on the table or in random basins.

2- Identification of the product model to be sewn to the show to facilitate when the seamstresses have doubts at some point. The goal is to accelerate the process of learning and solving doubts.

3 - Standardize a Quality Control, removing this responsibility from the production leader and passing to each operator.

4- Creation of management in sight identifying goals on the wall to encourage employees to reach them.

E) Stock finished products:

1- Definition of place of finished product inside the process, the same are arranged directly in the store or in the room of the leader of production.

After understanding the process and its peculiarities, a data survey was made to better understand the phenomena that were causing low index of results. To better analyze these phenomena, it is necessary to understand the expectation of the company that it was to have about a thousand pieces of clothing produced per month with the quota defined by the specialist in the production of clothing in atelier, however, it can be verified that there are a large gap between the expectation and the production realized in its first month of production according to Table 2.

Table 2. Analysis of the Phenomenon: Expectation of production versus actual produced.

Period	Production Expectation	Real Production
Monthly	1000 pcs	120 pcs
Daily	50 pcs	6 pcs
Diary per sewing cell	17 pcs	2 pcs
Production time per piece	30 min	270 min

Considering 9 hours of production per day, and 20 days per month, total of 180 hours per month.

By doing an analysis of production comparing the expectation with the realized, we see that the expectation asks us to perform 50 pieces daily in the plant, and the past period has made only 6 pieces (12% of the planned), and for the production to reach the expected quantity of 1000 pieces per month, she needs to produce one piece every 30 minutes or so, there is a difference of 240 minutes.

The main justification for this result of the first month of production are as follows:

1- Production training due to the refined cut style, where it is necessary to take into account the learning curve of the collaborators;

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2- Adjust the molds and ready-made parts to leave them as requested, considering that they are new products.

3- Employees performing below expectations as they were trained by specialists before entering the process.

Thus, the analysis of the phenomenon makes us identify the actual capacity of the system, in hours, of production, according to Table 3, where: Installed Capacity is the total capacity of the system, Available Capacity is the time that operators have daily work (usually defined by the duration of the shift), Effective Capacity is the time that the operators work by taking the planned stopping hours and the Actual Capacity is the actual production time, considering the planned and unforeseen stops, as well as the pre-planning -defined to produce one piece every 30 minutes.

Table 3. Capacity of the Productive System.

Capacity	Month	Day
Capacity installed	480h	24h
Available Capacity	200h	10h
Effective Capacity	180h	9h
Real Capacity	21.6h	1.08h

With this data, we can calculate the efficiency of the system according to the initial planning of the system to have 1000 pieces produced per month, where we see that the actual capacity is 12% of the effective capacity, that is, the production had 12% efficiency in its first month, which indicates about 8 hours per day of production losses.

The company manufactures 10 different models in different colors and fabrics, and analyzing the production times, it is verified that the process of sewing and refinement of the piece is the most impacting in the productivity of the plant, where most models have the same time of production, differentiating in some smaller parts presented in Table 4. This table also presents the times for production of each piece according to the designer and the production leader.

According to production expectations, we have verified that it is necessary to produce about 1000 pieces per month. Analyzing the current production time only of the male overcoat, it is verified that it would need the 3 existing cells to close the production of 180 needed for the month only of that product, but it would not be possible to fulfill the plan of the other products, that is, the current capacity does not meet the requested monthly plan. Thus, there is a need to insert three topics in the action plan of this study:

1- Production plan: definition of the plan according to the actual production capacity of each part.

2- Sewing process: Redefining the sewing process and finishing in order to increase the productivity of each piece.

3- Standardization of process: Definition of the time of production of each piece, new goals and standardization of the process by product.

Table 4. Time of production of the parts

Model	Production time	Daily production per station	Total daily production
Male Overcoat	**3,5h**	**3**	**9**
Female Overcoat 08	**3,5h**	**3**	**9**
Female Overcoat 09	**3,5h**	**3**	**9**
Female Overcoat 11	**3,5h**	**3**	**9**
Dress	**2h**	**4**	**12**
Female pants	**1h**	**9**	**27**
Female shirt	**0,5h**	**18**	**56**
Skirt	-	-	-
Male pants	-	-	-
Male shirt	-	-	-

Following the analysis of the data of the factory process of the company, we can still identify that the production system defined for the sewing process does not meet the requested capacity, as well as the physical arrangement of the factory shown in Figure 1. The layout of the machines and the warehouses disrupts the movement of employees and also increases the waste of time during production.

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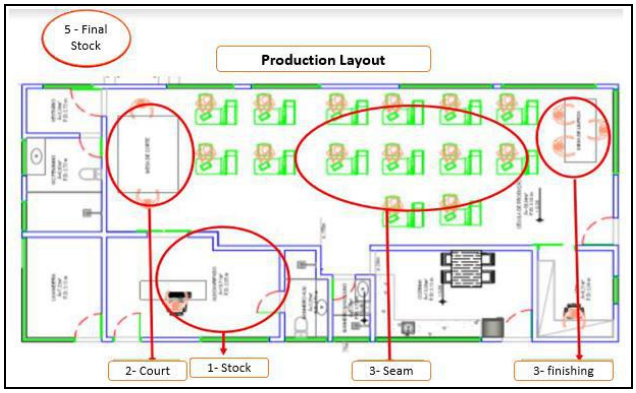

Fig. 1: Layout of the clothing company.

Through all the data obtained, one can identify the best actions in search of the expected results, and considering the needs pointed out so far, it was defined as a priority to structure the process by product type and based on this in the definition of this model , to define a better physical arrangement for the new process, thus identifying the process indicators that will assist in the periodic monitoring and evolution of the expected results.

The action plan was divided according to the schedule presented in Figure 2, where the first two steps are of studies and analysis of the process, and the rest are structuring and monitoring the results, in order to structure the proposed improvements and ensure that the expected results can be achieved.

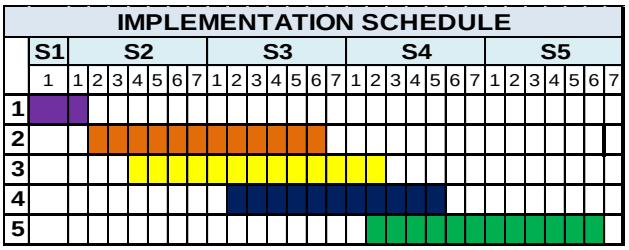

Fig. 2: Action plan.

1- Planning;

2- Process Analysis;

3- Process Structuring;

4- Process standardization and control;

5- Follow-up of the process.

IV. IMPLEMENTATION OF THE PROCESS

Through this proposed plan, activities were created focused on the structuring of all processes presented in figure 3.

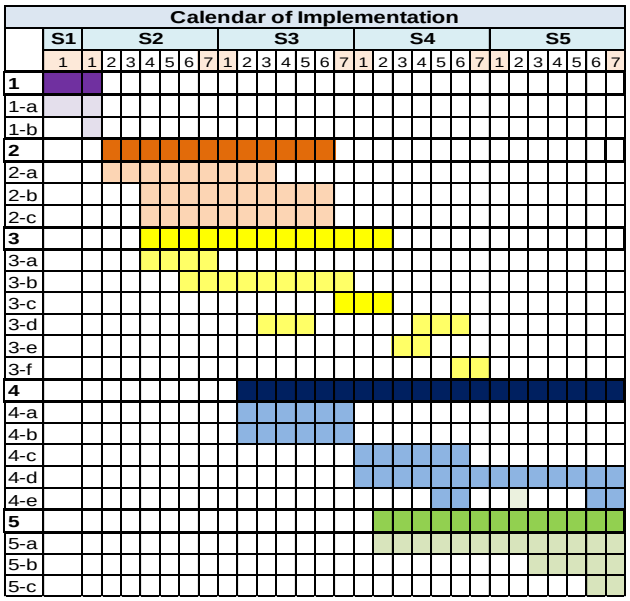

Fig. 3: Calendar of Implementation.

Figure 4 shows the description of the implementation calendar items

Implementation Calendar Activities	
Item	**Description**
1	**Planning**
1-a	Construction of micro activities schedule
1-b	Presentation of final schedule
2	**Process Documentation**
2-a	Definition of process documentation
2-b	Default Document Creation
2-c	Generate overcoat document
3	**Process Structuring**
3-a	Assemble updated layout sketch
3-b	Detail equipment layout
3-c	Make layout change
3-d	5S plan of the sewing process
3-e	Layout presentation to employees
3-f	5S training with employees
4	**Process Indicator**
4-a	Define indicators
4-b	Create process of daily productive control
4-c	Define tool for production management
4-d	Define index tracking method
4-e	Presentation of new process
5	**Implementation monitoring**
5-a	Follow-up of changes
5-b	Possible adaptations in the process
5-c	Final implementation presentation

Fig. 4: Description of the implementation calendar items

In the process analysis stage, the Process Documentation was defined, where it was possible to define and identify the processes by product. The main objective of this stage is to present to the employees how

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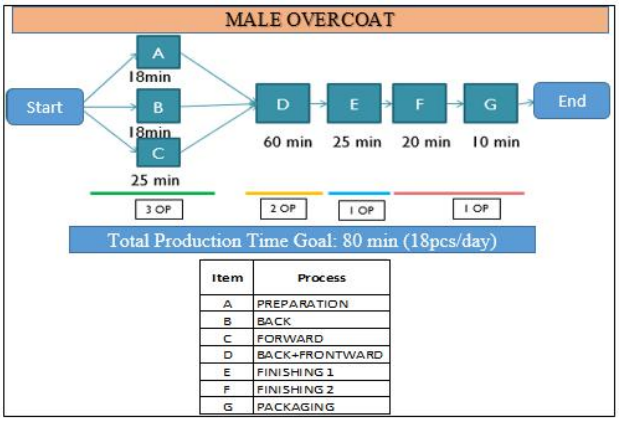
they were doing and look for improvements in the procedures and methods used. Then the process documents were elaborated with Flowchart information, steps and activities of the process, as well as the chronoanalysis data was inserted per step, to facilitate the division of activities depending on the quantity of seamstresses available.

In order to define a better physical arrangement for this type of process, a study was made and the production time of the overcoats was analyzed, relating these data to the quantity of labor existing in the process. Figure 5 shows the flowchart adopted with the average times collected from each step defined by the Process Document, and through these time data, the calculated balancing was indicated to achieve better productivity results.



Item	Process
A	PREPARATION
B	BACK
C	FORWARD
D	BACK+FRONTWARD
E	FINISHING 1
F	FINISHING 2
G	PACKAGING

Fig. 5: Flowchart and Process Balancing

According to this balancing, the proposal would lead the company to produce about 20 overcoats a day. Therefore, this information was used to create the physical layout proposal for the plant, where the new physical positioning of the machines takes into account the movement of the seamstress by the process, the time of each stage and the specifications of the different products. In Figure 6 one can identify these points of improvement

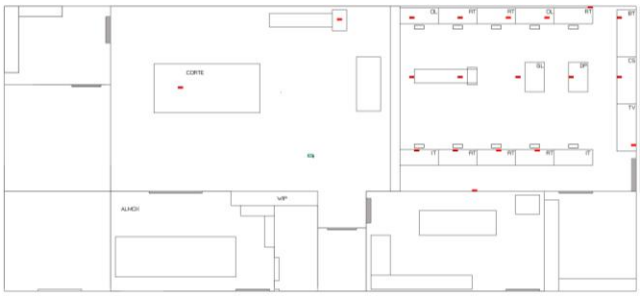


Fig. 6: New factory layout

In Figure 7 one can see the before and after the factory layout and the improvement in the process with regard to the movement between the process steps is visible, as well as the difference between the spaces between the workbenches, giving more room to organize the materials and tools used by employees

Fig. 7: Before and after the installation of the new Layout

With the structuring of the finished process, the identification of goals and creation of process indicators were performed, and the main ones to be followed are: Productivity, Efficiency and the number of failures found in the final product that need to be reworked, where all three need be accompanied daily to be able to give vent to the improvements implemented and also check new opportunities in the current process.

A methodology model was used to follow up these indicators through the Excel tool, and in a Vista Management Framework implemented in the factory floor to facilitate the visualization of the goals by the operation. These tools are the most important tools that have been deployed for data collection and project progress analysis, where they will assist in the daily analysis of process results.

V. RESULTS

Through daily monitoring of the evolution of production results, it was possible to periodically stratify the results and work on the critical points that affect the process itself. Thus, in Figure 8, one can find the productivity result of March, where the studies began, until June, when the implementation actions were finalized. Through the data of this figure we can verify the effectiveness of the implemented actions, where there was a 200% evolution between the beginning of the studies carried out.

	Mac	Apr	Mai	Jun
Productivity	12	16	15	36
Production	120	160	151	360

Fig. 8: Productivity and Quantities of Produced Parts

In addition to the evolution in the company's productivity result, we can see a significant improvement

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in the work environment generated by the change of layout of the factory floor, where production flow became clearer for all employees and the organization of the stages became more Figure 9 below. This improvement also helped the employees' satisfaction with the organization of the process, as well as the quality of the assembly and sewing process of the clothes.

Fig. 9: New factory layout

With the case study generating more than expected results, the standardization process was started to ensure that employees continued to carry out each stage and also had a basis for proposing improvements more objectively within their activities. Thus, all the data collected was documented, as well as all the standards of process aid documents.

VI. CONCLUSION

This clothing company used a traditional ideology in its methodology of productive process, where the operators carried out the activities of artisan form. By applying the analysis tools in its production system, it was possible to identify improvement points in its process and a better use of the available resources, where as a result of these analyzes one can carry out the structuring of the sewing process, adaptation of the floor layout standardization of new procedures and creation of management tools to improve indicator controls.

The use of quality tools was of paramount importance, since it contributed to the decision-making and prioritization of the various demands that appeared throughout the analysis process, where we had the search for problem solving and also the search for improvement of the process . And through these tools and production balancing it was possible to identify the best floor layout for this process, where we improved both the productivity indicator, without the increase of fixed costs, as well as improvements in quality assurance and ergonomics of the process as a whole.

ACKNOWLEDGEMENTS

To the engineering coordination of the FAMETRO university center, and the teachers Dr. Marden Santos and Dr. David Alencar, for the support in the development of this work.

To the Institute of Technology and Education Galileo of Amazon (ITEGAM), Brazil.

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