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THE IMPLEMENTATION OF LEAN MANUFACTURING TO INCREASE PRODUCTIVITY IN A TEXTILE COMPANY: CASE OF STUDY

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The Implementation of Lean Manufacturing to Increase Productivity in a Textile Company: Case of Study

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Abstract

Nowadays agile methodologies have been developed, and are used in organizations because companies face highly competitive and globalized markets with constant changes (Arias, 2020). The paper is going to be based on "Lean Manufacturing" which is a system that aims to eliminate waste from the process through continuous and systematic improvement (Palaniswamy, 2021), without generating waste or defective products. The case of the study is based on solving the problem of low productivity for a textile company in Peru, which had been caused by the excessive waiting times between operations and manual activities with a higher percentage of defective products, for example, 7% in the clothing area. In this paper first, we recollected the actual information like batches, the floor plan, production costs, etc. within we simulated the as-is and after that the as-if. This article uses the "Lean Manufacturing" methodology and with it, the losses of products in manual processes will be minimized, going from 10% of safety stock to 6% per order. This goal is going to achieve optimizing transfer times between areas and eliminate those activities that do not generate value for the company, using tools such as "5S", "Value Stream Mapping", "Acceptance Control Charts", "Just In Time", "Process Reengineering" and "Simulation". Through simulation with the Arena software, the results were validated, achieving an improvement in the reduction of times by 5.8% and increased productivity by 4.1% thanks to tools such as VSM, line balance, and control charts. The importance of this study is the findings can be replicated in other papers from the textile industry.

Keywords
Keywords: Textile, Lean Manufacturing, Productivity, Safety Stock, and Process simulation.

1. Introduction

The study has focused on a medium-sized textile company. This company presents problems according to its percentage of defectives, which requires manufacturing an extra 10% of the order units as safety stock; and waiting times for transfers between areas and garment manufacturing time.
Currently, the textile company has dedicated to exporting its garments to the United States of America. Likewise, the average number of orders manufactured by the company lies in batches of 2736 units of jeans.
In addition, throughout the study, the objectives will be defined, performance will be measured, results will be analyzed, the process will be improved, and the operations of the textile company will reduce time, achieving increased productivity.

The application of Lean Manufacturing's tools such as "5s" and "Just in time" will reduce the timing, increase efficiency and effectiveness, and reduce the variability of the processes, identifying the causes that generate low productivity and achieving the desired improvement.

The main problem for the company is the low productivity, which is due to the high waiting times between processes and manual processes that generate defective products. Also, the manufacturing time per garment is around 33,982 minutes, which is excessive compared to the engineering sheet, which indicates that it should be 28,239 minutes per garment. The difference is 5,743 minutes for each unit produced. However, the average number of orders manufactured by the company is 2736 units, with which this difference between times becomes significant.
This study is considering evaluating an order of 1000 units of jeans. On the other hand, the percentages of losses, are on average, 6% for each batch produced with a safety stock of 10%; in that way, the defectives do not affect the order. These problems were chosen based on the diagnosis of the current situation of the company using tools such as "Value Stream Mapping", "Acceptance Control Charts", "Line Balance" and "Simulation".

The diagnosis justified that these selected problems affected the productivity, either due to the times used in transfers, waiting times between operations, downtime, or the percentage of losses and defects generated, due to the human factor.

This study will answer the following research question: Can the implementation of "Lean Manufacturing" help to reduce waiting times and the percentage of defectives in the production of jeans?
The general hypothesis is "with the implementation of the "Lean Manufacturing" management model, productivity will increase by 4% in the jeans manufacturing process".

The first specific hypothesis is the implementation of "Lean Manufacturing" reduces the total excesses of execution time by 3%.
Null hypothesis: H0: u>=3%
Alternative hypothesis: H1: u <3%
The second specific hypothesis is the implementation of "Lean Manufacturing" reduces the percentage of defectives by 3%.
Null hypothesis: H0: u>=3%
Alternative hypothesis: H1: u <3%

1.1 Objectives

The general objective of the research is to implement "Lean Manufacturing" to increase productivity in the jeans manufacturing process.
Specific objectives:

- Demonstrate the inversely proportional relationship between the application of "Lean Manufacturing" and the total time.
- Reduce the margin produced by defective products from 10% to 7%, using the 5s tool through the line balance. Because due to human error, they have a safety stock of 10% for all orders and generate a cost in production that not be recovered.
- Validate the increased productivity using the simulation software "Arena".

1.2 Justification

The selected company has waiting times, which affect the production of jeans. This company has four areas: "Cut", "Clothing ", "Laundry" and "Finishes".
We applied the selected methodology because the company does not reach its capacity due to dead times, excessive time on transportation, and loading of raw materials, inputs, and products.
According to the engineering sheet, the estimated time per garment is 28,239 minutes. We analyzed the times with the VSM, and it revealed for a finished batch of 1000 units, only on the manufacture, a time of 33 982 minutes, when it should be delayed, according to the engineering sheet, 31 062.9 minutes, which we infer is due to the manual processes carried out in the finishing area.

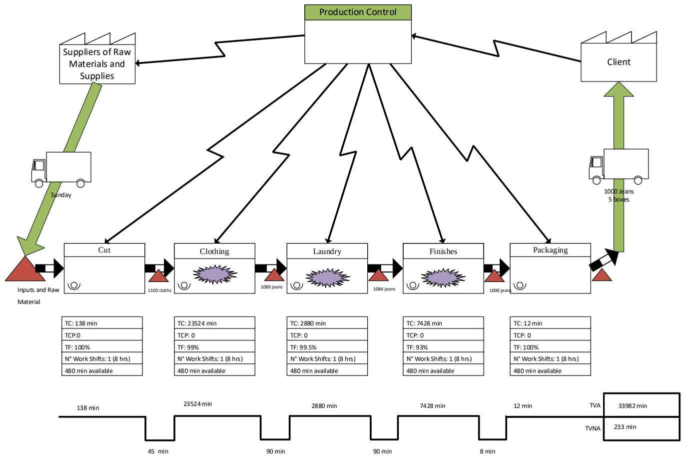

Figure 1. Initial VSM diagram

With the VSM is possible to observe problems between the cutting area and the dressmaking area because it takes 45 minutes to mobilize materials. Likewise, it takes around 23,524 minutes in the clothing area, which is excessive time to carry out these activities. In the finishing area, there are 7% defectives because of the manual activities. The maximum waiting time used between operations happens in the clothing-to-laundry area and the laundry-to-finish area. Nevertheless, the laundry is an outsourced service.

Additionally, with the control chart, a variable to be measured in the process was defined by attributes, and the finished product is accepted or rejected. For the elaboration of this chart, we used a P chart for different batch sizes evaluating the percentage of defective products in each one. Consequently, we will take the initial state of the process, considering the points out of control to be able to show the process with the proposed improvements later.

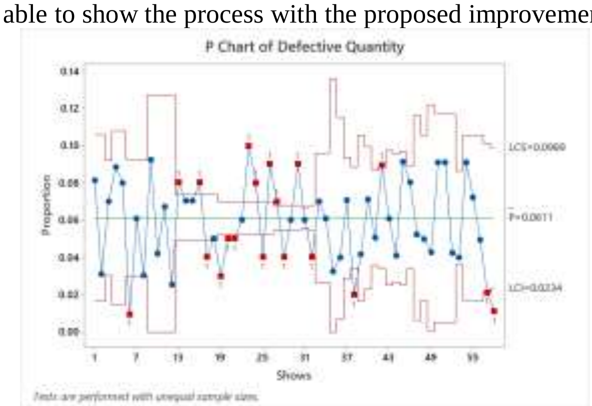

Figure 2. Initial Control Chart

Similarly, to show the lack of control of the process, the process capability (Cp) could be calculated with a value of 1.05, which indicates that the process is adequate, but requires control. Similarly, the process capability index (Cpk), with the heat of 0.81 that comparing it with the Cp indicates that the process is not centered, becoming an incapable process. Likewise, the technical methodology called line balance will also be used, a technique that is applied with the purpose or need to reduce idle or dead times through the reduction or relocation of jobs or stations respectively, reducing cycle time (Muñoz, 2018), because, in the current situation, there are initially 4 work tables located in parallel, which is where idle times are incurred when transporting the product from one table to another, this being a distribution problem, in addition to the income of the product.

Finally, to obtain approximate data, a simulation was carried out with the "Arena" software, in which the current process was simulated with its results, before proposing improvements and using agile methodologies. Then, the initial results of the simulation for a sample of 144 jeans.

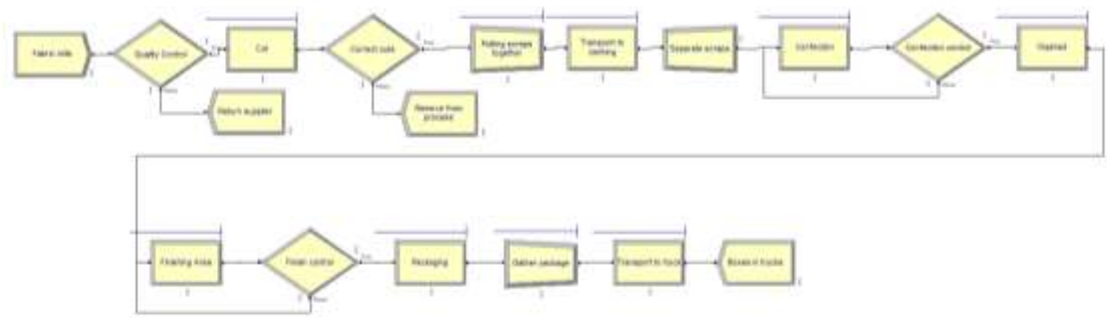

Figure 3. Process Simulation for the Elaboration of a Basic Jean

Time

Waiting Time	Average
Confection.Queue	55.1172
Cut.Queue	57.3955
Finishing Area.Queue	86.8666
Gather package.Queue	50.3375
Packaging.Queue	0.00296773
Putting scraps together.Queue	23.4832
Transport to clothing.Queue	0.00
Transport to truck.Queue	0.00
Washed.Queue	1.6907

Table 1. Initial simulation queuing time

There is a disorderly distribution of the spaces that avoid the continuity of the operations generating queues because it is necessary to wait for a certain number of products in the process to accumulate to be transported to the next area. When analyzing the initial state of the time variable, a total of the time used in the simulation is obtained, counting the queues and delays of the process, there is a total of 3366.89 minutes for a total of 100 finished products, while 44 of these are still, they are products in process, so taking said data to the proportion of 1,100 garments, we total a total time of approximately 37,037 minutes.

The main problem is "the number of defective products generated by the human factor" and the "excessive waiting times" due to movement between areas. Because the manufacturing processes are in-line in this area, this generates downtime when an operator must stack the batch and go to the next area.

On the other hand, the problem in the finishing area is the buttons because there is only one operator who performs this manual activity, which reduces the speed of the production.

$$\text{Low Productivity} = \text{Lead Time} + \%\text{Defective Products}$$

This equation means that low productivity is due to the sum of the lead time with the percentage of defective products.

After analyzing this information, we made a problem tree to implement a tentative solution.

Effects	Increase in delay times Excessive transfers and material handling Long routes Increase in defective products Long times
Core Problem	Low Productivity
Causes	Bad design in plant facilities Manual processes Bad design in material flow Delays between operations

Table 2. Problem tree

Similarly, a survey was conducted to confirm that the diagnosis was correct. The survey found that the diagnosis was correct because 42.9% of the population considered the factor that most influenced the low productivity was the waiting time between areas, as well as 28.6% selected the option of defective products and heavy shipments.

2. Literature Review

Agile methodologies:

Agile methodology is a new way of doing business processes to obtain better returns with high-performance teams and clients (De La Torre, 2018). Nowadays, agile methodologies have been developed, are used in organizations because companies face highly competitive and globalized markets with constant changes (Arias, 2020) in which the most recognized and successful lean manufacturing methods will be defined, such as the "small batches" method, "Just in Time", "kaizen", among others, since textile production requires systemic analysis where simulation helps with ways to carry out the study (Marín et al., 2021).

Lean Manufacturing:

It is a system that aims to eliminate waste from the process through continuous and systematic improvement (Palaniswamy, 2021), and is based on manufacturing or producing without generating waste or defective products. (Verma et al., 2021) since this methodology supports the identification and elimination of waste, being classified as waste also any activity that adds cost or time without value to the client, eliminating unnecessary time. (Demirci et al., 2020). Likewise, this methodology has three main objectives, firstly, to satisfy customer demand on time, an objective related to just-in-time methodology. In the second place, it eliminates worthless work. Finally, it creates a flexible working method that allows for adaptation to changes, which can occur with the training of operators with high turnover between tasks, who will respond faster to the proposed changes. In addition to this, lean manufacturing has four important factors (Braglia et al., 2019), which are the supplier factor, process factor, human factor and control, and the customer factor.

Kaizen:

It consists of teamwork that allows to solve problems systematically and apply improvement solutions (Dimitrescu et al., 2018). Kai means change and Zen means improvement (Rossini et al., 2019). This methodology is also known as the "5S" method, because it is based on the five Japanese words: Seiri (Classify), Seiton (Organize), Seiso (Clean), Seiketsu (Standardize), and Shitsuke (Self-discipline). Applying these "5S" to all individuals involved in the organization with results in commercial and human resources areas (Gandhi et al., 2019), since it is based on small improvements in work standards, reinforcing the responsibility of collaborators and at the same time, it creates a learning mechanism that is reinforced by experience and discipline respectively. (Rossini et al, 2019).

Just in Time:

A method that maintains as basic principles the elimination of waste improves quality and increases efficiency by applying production without inventory (Kilic et al., 2021). Consequently, with this tool, it can obtain improvements in production costs, in manufacturing stages, which include finished products, and products in process, among others. This technique had been used in other articles and reduces the waiting time and the production rate was increased and the productivity loss rate was minimized from 18.5% to 13.88% (Ramasubramaniam, 2021). However, this methodology will not depend only on the internal changes in the organization, but to adopt the JIT some characteristics must be modified and adapted to the requirements of external factors (Fatehi et al., 2020), either from suppliers or customers, since if there is not a rapid adaptation to these changes, the JIT will not be successful.

Also, the environmental factor takes as part of the continuous improvement, so the impact on productivity presented by external variables such as intensity and frequency of the duration of the working hours and the light's intensity will be evaluated in research that supports the interest of the industries in regulating the exposure of labor intensity and noise and the control measures of this (Mendez et al., 2021), as well as an increase in problems in workers due to an inadequate climatic or environmental work condition due to poor lighting (Biadgo et al., 2021).

Finally, evaluating different agile methodologies, regarding the problem of the present investigation, which focuses on the production transport over time and the high rate of defective products, it is that the conclusion is reached that the main methodologies to be used will be mainly lean manufacturing, as well as the Kaizen methodology with its "5s" and just in time respectively.

3. Methods

The article has been taken as a basis for other jobs in which after the implementation of waiting time reduction techniques, the production rate was increased and the productivity loss rate was minimized from 18.5% to 13.88% (Ramasubramaniam, 2021), also in another study from the 10 practices evaluated, 4 are external, and, in our study, any of them was implemented in an integral way (Godinho et al., 2016).

3.1. Population, sample, and participants

This study presents a mixed approach: quantitative and qualitative because the collection and analysis of specific data will be carried out, such as a time study, as well as subjective ones, such as the survey. The diagnosis will be made according to the problems of the company, such as why unnecessary cost overruns, waiting times between areas, percentage of defectives, etc. In addition, this research is descriptive and correlational in scope because it will seek to specify, measure, collect real data and relate the dependent variable such as "productivity" with the "waiting time between areas and operations" and the "percentage of defectives".

The study is "Experimental" since assumptions will be simulated to assess whether the solution to be proposed is viable and profitable for the company studied.

To carry out the survey, the 7 administrative members of the company were considered (General Manager, Head of Planning and Demand, Head of Finance, Cost Engineer and Budgets, Head of Operations, Head of the Design area, and Head of Dispatches) these elected members are between women and men belonging to an age range around between 25 years to more than 55. They were chosen because each of them makes important decisions regarding plant production.

Variables	Dimensions	Indicators
Productivity	Study of times	Real-time Theoretical time
	Production	%Defective products Compliance with the production plan
	Internal distribution	Idle time delay rate

Table 3. Variables, dimensions, and indicators

The dependent variable is productivity, which is inversely proportional to the factors of waiting times in production and the percentage of losses, which means the shorter the waiting time in production and the lower percentage of defective products and losses, the higher the productivity of the company.

3.2 Techniques and instruments

- VSM: This was used to identify those production stages that present longer waiting times and problems in the area.
- Control chart: It was used to evaluate the percentage of defectives in each batch and their variability.
- Just In Time: It reduced routes, and production costs, and controlled inventories.
- Time study: Reduced lead times and in excess, to be more suitable and efficient.
- Survey: Collect data from the administrative staff for the company and possible long-term improvements.
- Simulation: It is inexpensive and will show which current situation can be compared with the proposal.
- Plant distribution techniques: The line balance evaluates and improves the current situation in the manufacturing area.

3.3 Validity criteria

This research work will be validated using different tools such as VSM, control charts, line balance, just in time, and simulation. With these, it is possible to evaluate the hypothesis showing that it was possible to increase the productivity of the company.

4. Data Collection

An intentional sampling was carried out on seven administrative members of the company, each one of them takes important decisions on production in the company. Likewise, the collection and analysis of quantitative data were carried out with the control charts, VSM, and the simulation of the real situation of the company was elaborated, for later, as this study is experimental, the assumption of the proposed improvement, as well as the viability and profitability of the company.

5. Results and Discussion

This chapter will show the improvement proposed using tools such as control charts, VSM, just-in-time principles, and simulation.

5.1 Numerical Results

Dependent variable	Finishes area	Clothing area	Total
% Defective products	3% reduction	-	4% reduction
Time	2.7 stabs / min	Reduction of 22 818 minutes	5.8% reduction in total time

Table 4. VSM Results

The new capacity (Cp) is 1.69, which being greater than 1.33, indicates that the process is adequate, and in a Cpk of 1.13, a value not too far from the Cp indicates that the process is considerably focused.

Time

Waiting Time	Average
Confection.Queue	51.8606
Cut.Queue	57.7358
Finishing Area.Queue	42.1873
Gather package.Queue	36.8868
Packaging.Queue	0.00190701
Putting scraps together.Queue	23.5835
Transport to clothing.Queue	0.00
Trasport to trucks.Queue	0.00
Washed.Queue	1.8817

Table 5. Final simulation - queuing time

Likewise, the total production time has decreased versus the initial results before the proposed improvements, the total time being 2358 minutes for 101 finished products in the simulation, with their respective final equivalent after applied improvements of 25.683 minutes for the batch of 1,100 units, versus 37,037 minutes simulated initially, mainly reducing queue time by 51.28% in the finishing area.

5.2 Graphical Results

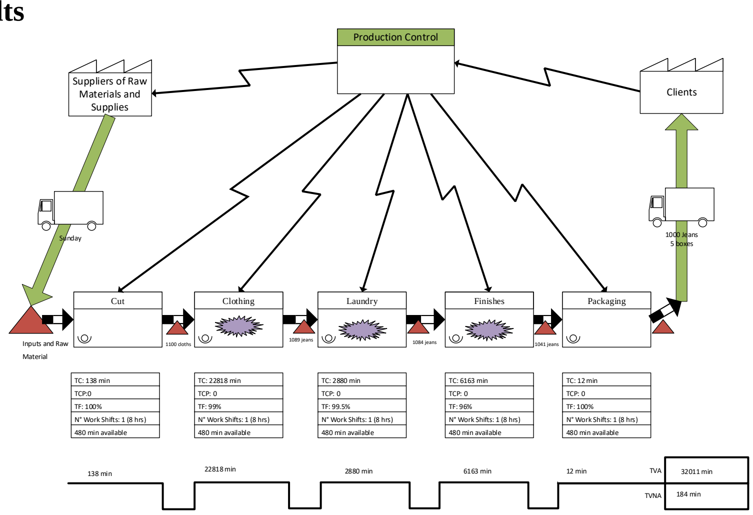

Figure 4. Final VSM diagram

By applying the improvement with hydraulic forklifts and forklifts, it was possible to reduce the total time from 33 982 minutes to 32 011 minutes, which means that it was reduced by 5.8%, to the times, as well as the amount of defective, which went from being 1,000 jeans to obtaining 1,041, that means that production increased by 4.1%. For this reason, we consider that the safety stock can be reduced from an initial 10% to approximately 6%.

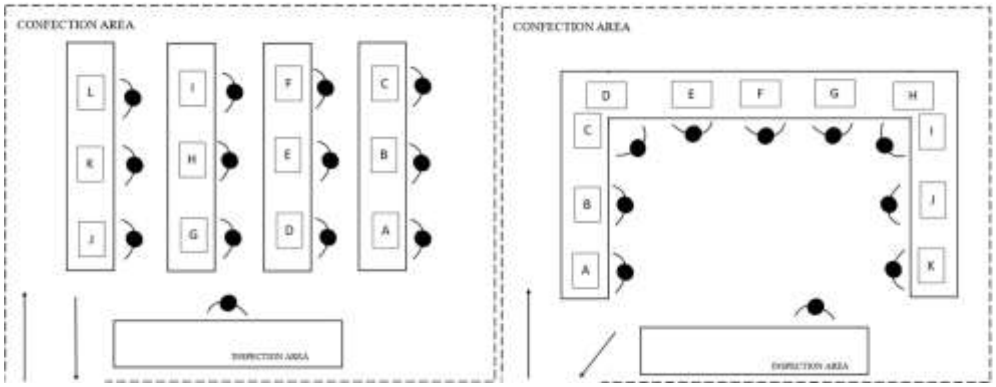

Figure 5. Initial and final Line Balance

The line balance allows reducing the required machinery by 1 unit and the operators by 3 people, grouping the processes in the corners of the proposed design, as can be seen with the "C and D" and "H and I" machines. In addition, it allows optimizing cycle times with the restructuring and distribution of the areas. This tool contributes to agile methodologies, since it classifies, organizes, cleans, and standardizes activities that are part of the 5s of Kaizen.

5.3 Proposed Improvements

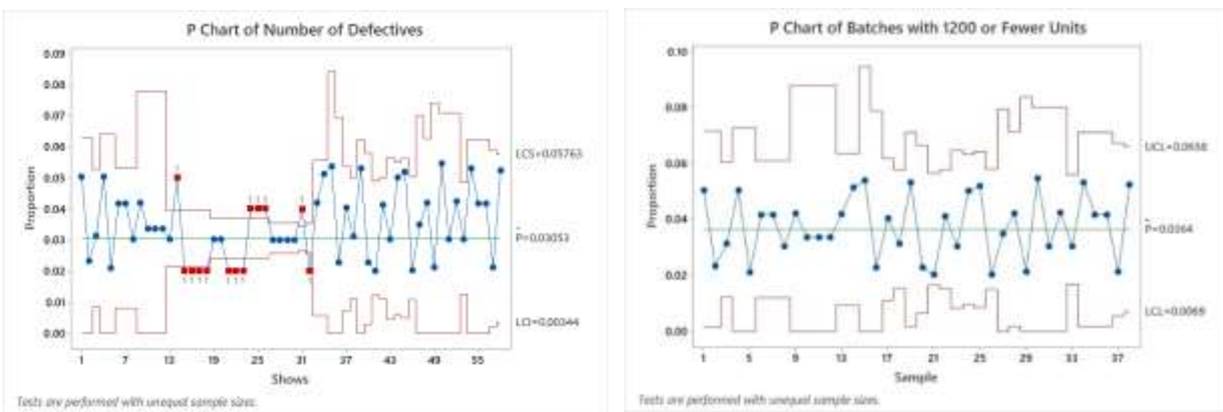

Figure 6. Final Control Chart

The application of alternative solutions is that the due control chart by attributes will be made again to evaluate the percentage of the defective finished products, and using randomness that is around up to 6% defective and multiplying by the planned number of each batch is that the new P chart can be obtained, where a better fit can be seen in the production batches, with the deviation in the number of defectives in the smaller batches respectively.

It is worth saying that if well the first figure had some points out of control is because there are big batches but the second figure is controlled because there is a small batch. That means that this improvement works with batches with 1200 or fewer units.

5.4 Validation

The general hypothesis is by implementing "Lean Manufacturing", productivity will increase by 4% in the jeans manufacturing process. This was corroborated thanks to the two specific hypotheses raised.

The first specific hypothesis is that the implementation of "Lean Manufacturing" reduces total execution time excesses by 3%.

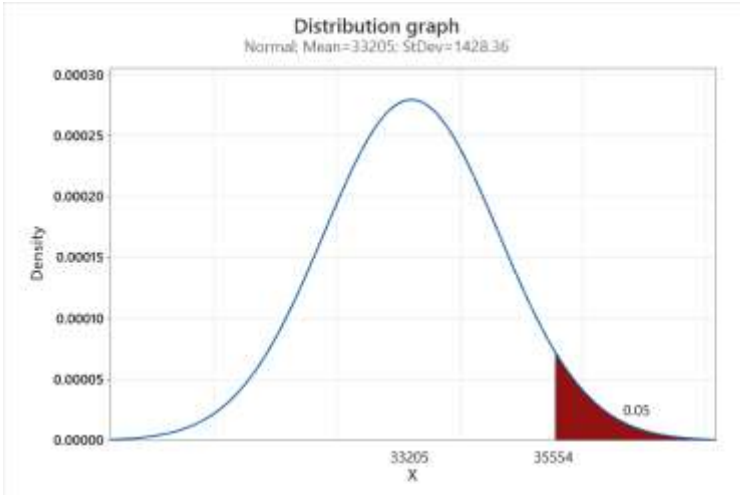

Figure 7. Distribution graph of total execution times

For this hypothesis, a normal distribution graph was made with which the curve was drawn, and an average was used for the jeans manufacturing process, for which the average of the total minutes of execution before and after the relevant improvements was calculated, with an average of 33,205 minutes and an error of 5%, that means the objective set was achieved, which was to reduce times by 3%. Since the total time spent in the production cycle went from 34215 to 32196 minutes, shows that productivity increased as a function of the time variable by 5.9%, which shows that a lower lead time, increases productivity, which means more units will be produced. This validates the null hypothesis of 3% proposed in the first chapter of this article.

This is because they have a forklift and hydraulic forklifts, which is demonstrated in the VSM, they went from being 1000 jeans to obtaining 1041 respectively, in terms of production is increased by 4.1%. For this reason, safety stock can reduce from an initial 10% to a final 5%; however, we will consider a 6% margin of error for safety or possible eventualities.

On the other hand, the second specific hypothesis is that implementation of "Lean Manufacturing" reduces the percentage of defectives by 3%.

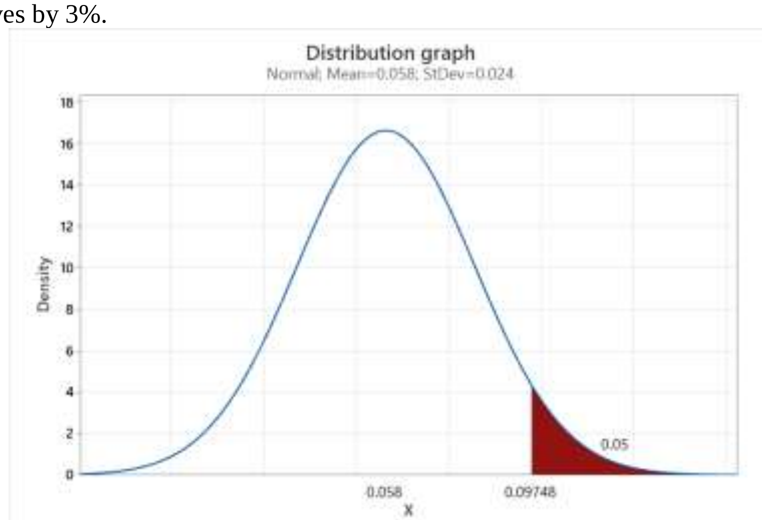

Figure 8. Distribution graph of the percentage of defective products

There are 5% of defective products outside the limits. At the beginning of the study were 10% of defective products and after improvements, the error tail decreased to 5%, which means the second hypothesis is fulfilled, validating the null hypothesis which indicates a minor improvement of 3% of defective products. With the VSM was possible to reduce the percentage of defectives in the finishing area, going from 7% to 4%, using the button machine, since this operation was previously carried out in 1.5 minutes, while the machine would have a value of 2.7 punctures per minute. Likewise, in the clothing area, the total time was reduced to 22,818 minutes in the area.

Finally, the hypotheses and objectives set were met, since the implementation of "Lean Manufacturing" and its tools, productivity increased by 4.1% reducing execution times, which shows that this variable is inversely proportional to the total time production, in addition to reducing the margin of the safety stock, from 10% to 6% versus the margin of safety stock outlined in the objectives of this article, which were 7%.

6. Conclusion

In conclusion, by implementing “Lean Manufacturing” tools (control chart, line balance, VSM, and simulation) it was possible to increase productivity by 4.1% to the total manufacturing time.

It was shown that there is an inversely proportional relationship between the application of the “Lean Manufacturing” tools and the total time since, when implementing these tools, the time is reduced by 5.9%.

Also, it was possible to reduce the extra margin produced by defectives from an initial 10% to a final 5% due to the application of the VSM; however, a 6% slack will be considered to cover the margin of human error.

The increase in productivity with the time variable could be evidenced by simulation with the Arena software, taking an initial simulation sample of 144 units, an improvement of 19.78% of the total time was obtained, and a 51.28% improvement in the finishing area.

- Increase productivity by 4.1% to the total manufacturing time.
- Reduced waiting time by 5.9%.
- Reduce the extra margin produced by defectives from an initial 10% to a final 5%.
- Improvement of 19.78% of the total time was obtained, and a 51.28% improvement in the finishing area.

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