Improvement Proposal to Standardize and Increase the Production of a Spinning Company Through Lean Manufacturing

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Abstract

In the present research paper, proposals for improvement related to lean manufacturing will be analyzed with the aim of standardizing production and increasing productivity in the production area of a spinning company, using automation and plant layout tools. Initially, a high variability in production time was identified within the fiber preparation and mixing area, which caused instability and decreased productivity in the zone. After a preliminary analysis, it was found that increasing the amount of fibers used in the process (e.g. from 2 to 3 fibers) resulted in an increase in total production time. Subsequently, a comprehensive evaluation was carried out in the selected company, observing the production processes in order to select the most critical stage of the process within the area to implement an improvement. Finally, different improvement proposals were compared, and it was determined that the most effective and viable ones were automation and a new distribution of the work area. After implementation, an average reduction of 31% in production time was achieved, circulation time was reduced, and monthly production in the area was stabilized.

Keywords
Lean Manufacturing, automation, textile industry, productivity, plant layout.

1. Introduction
The textile sector has always been one of the largest sectors in Peru, largely due to the abundance of fibers found in the country and their high quality. This sector generates around 400,000 direct jobs annually, which accounts for 2.3% of the national employment in 2019. The sector was relatively stable in recent years, however, in 2020 it was strongly affected by the global pandemic like many other sectors in the country. In 2020, the production of the textile and apparel sector fell by 32.1% due to the temporary cessation of activities and the decrease in demand. The sector has been gradually recovering throughout the years, but this blow has caused the closure of many companies.

The research will be carried out in a spinning company, where situational analysis and proposal development will be conducted. The company has 20 years of experience in the market and operates in the field of preparation and weaving of textile fibers, with its plant and sole headquarters located in Lurin, Lima-Peru. This is a satellite company, part of a group of related companies, and focuses entirely on providing short fiber spinning services to the parent company responsible for the manufacture and sale of yarns. Since the spinning company was created by the same owners to provide services to the other company, it will be considered as the initial part of the production process of the same entity. The group has more than 50 years of experience in yarn production and is characterized by its inexhaustible ability to combine fibers and create new yarns. In recent years, the company has been directing its production towards differentiated yarns based on fiber blends such as Peruvian cotton, alpaca, wool, silk, acrylic, polyester, viscose, and other synthetic and artificial fibers. Currently, it supplies its products to prestigious garment manufacturers and distributors in more than twenty countries in North, Central, and South America, Europe, and Asia.

The current problem lies in the factory of the company, whose machinery was originally designed to make cotton yarn. However, in recent years, the company has been directing its production towards differentiated yarns based on fiber blends. According to the information obtained in an unstructured interview with the general manager, the company has adapted its processes with a high dependence on manual labor and low levels of efficiency. This is because operators weigh the fiber one by one to then be manually mixed in the desired proportions according to the order. The current situation generates difficulties with complex orders of multiple fibers and makes small orders time-consuming. For this reason, the company needs to improve and automate this process in order to reduce labor, reduce production times, and standardize the process. The initial data provided by the company indicates the kilograms processed in the area and the man-hours that were used monthly in 2020 and 2021 (Table 1 and Figure 1). In this way, an indicator can be generated that measures the relationship between both data to see if there is a trend.

Table 1. Monthly production data of the Filtex company's preparation and mixing area.

2020	Jan	Feb	Mar	Apr	May	Jun
kg	19,105.0	26,153.5	13,327.6	0.0	6,529.8	21,657.0
Día	23	25	14	0	12	25
H	253	275	154	0	132	275
kg/H	75.5	95.1	86.5	0.0	49.5	78.8

2020	Jul	Aug	Sep	Oct	Nov	Dec	Total
kg	22,974.0	29,076.0	26,460.0	28,136.4	30,652.9	34,514.0	258,586.1
Día	21	26	24	26	25	24	245.0
H	231	286	264	286	275	264	2,695
kg/H	99.5	101.7	100.2	98.4	111.5	130.7	96.0

2021	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
kg	29,116.0	30,383.6	22,157.0	27,135.0	31,085.0	30,379.0	35,463.6	25,448.0	231,167.2
Día	24	24	25	22	25	25	26	25	196.0
H	264	264	275	242	275	275	286	275	2,156
kg/H	110.3	115.1	80.6	112.1	113.0	110.5	124.0	92.5	107.2

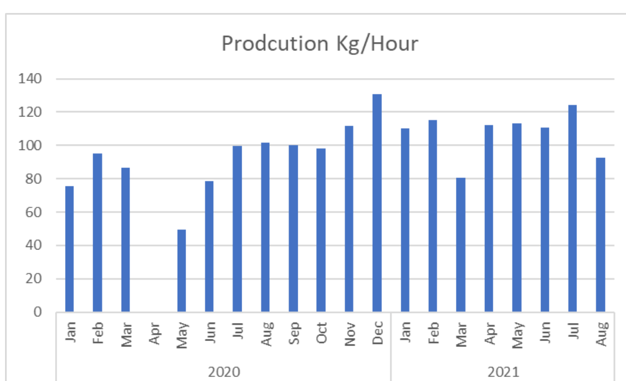

Figure 1. Monthly production chart of the preparation and mixing area of Filtex company.

As can be observed, there is quite a variation between months in the kilograms produced per working hours, which makes sense according to what has been mentioned. The different sizes and types of orders (simple or complex mixes) generate difficulties and delays in the production line, which directly affects production time. This is where the central problem of the investigation lies. How does the new production plan and new products (threads with mixed and varied fibers) affect the productivity of the fiber preparation and mixing area due to the low flexibility of the current process? Would it be advisable to make the process more flexible by automating it with a new plant layout? It is also important to note that the variability of the productivity of the area presents, as can be seen in Figure 1, decreases in productivity that would evidence low productivity in some months due to the lack of flexibility of the production process to adapt to the new demands and products of the company (complexity of the order), for example the great difference between March 2021 with 80.6 kg/h and July of the same year with 124 kg/h, data that evidence the notable drop in productivity of the area.

1.1 Objectives

The objective of the present investigation is to standardize monthly productivity, avoiding high variations and thus increasing production in the fiber preparation and mixing station. Therefore, the aim is to reduce production times and the number of workers used, while maintaining these values constant regardless of the type of order being processed. These objectives will be achieved through the implementation of partial process automation with new machinery and an updated plant distribution to reorganize the workflow.

In order to achieve the main objective, several specific objectives were projected that would be fundamental to chart the path of the investigation:

- Determine the causes of the decrease in productivity.
- Analyze the impact of automation and the new plant distribution on productivity.
- Calculate indicators that measure the performance of the area before and after the proposed improvements.
- Improve the productivity of the workstation through the implementation of a machine responsible for weighing, providing, and mixing fibers.
- Improve the productivity of the workstation through the implementation of a new plant distribution.

Subsequently, the variables involved in the problem and solution of this improvement proposal will be identified and studied in detail. Likewise, the relationship between them will be determined and the form and measurement tools to be used for a more exhaustive study, understanding their nature and changes over time, will be defined.

2. Literature Review

It is of utmost importance to determine the factors that directly influence the productivity values of a production area in order to better understand it and seek a proposal for improvement. Schmenner (2015) in his article "The Pursuit of Productivity" presents variables that have an immediate impact on labor productivity. Among these, the most outstanding were automation, worker specialization, standardization, the factory itself and its production capacity, distribution, the flow of the production process, Lean Manufacturing techniques, the supply chain, and costs with profitability. Automation is highlighted as a very efficient alternative for increasing productivity, although it brings with it defects such as the large investment in the purchase of new machinery (in addition to the training and hiring of specialized operators to operate and maintain it) and the decrease in process flexibility. Within this set of factors, 2 of them were identified that could be applied in our case due to their characteristics and suitability in the spinning company: automation and plant layout. For this process of selecting variables to evaluate and work on, the general manager of the company was consulted about the factors identified by Schmenner, who agreed with the selected variables explaining the direct and practical relationship that exists between them.

It is worth noting that Lean Manufacturing includes both automation (lean automation) and plant layout (systematic layout planning) and according to Leyva (2018), who conducted a case study in a textile factory in Ecuador, the implementation of lean manufacturing tools reduced production times and gave the company the necessary capacity (increasing the bottleneck) to meet the existing demand in their market; they were able to cover the 31% gap (reducing it to 0%) thanks to lean techniques and tools. Likewise, Ambrus (2017), through the implementation of machinery and lean techniques, was able to increase productivity by 30% on the production line of an automotive factory, increase quality by 10%, and reduce labor time by 40% (saving on salaries due to the decrease in necessary labor).

After the variable selection, a relevant study was carried out on their functioning and how they could be applied in our case to increase labor productivity. Islam, Rashed and Hasan (2017) present a case study of a textile company that produces garments, where productivity is improved through the application of a planned technique of systematic plant layout distribution. This redistribution achieves improvements by eliminating unnecessary flows (referred to by the authors as "zig-zag" due to the production process route) and better use of space in the plant. Quantitatively, an increase in labor productivity of 20.9%, machine productivity of 8.17%, and production line efficiency of 20.91% was calculated. These results demonstrate the direct relationship between labor productivity and plant layout (significant increase in the former due to improvement in the latter). Due to the conclusions and real correlation between plant layout and labor productivity, and seeing that by improving the former, an increase in the latter could be obtained, it was decided to investigate plant layout tools.

The first approach was through the article by Fuentes, Del Solar, Samillán and Vásquez (2014), which investigated the Theory of Constraints (TOC) and its application in a textile plant in the city of Chiclayo, Lambayeque-Perú. It is necessary to mention that this theory was created and developed by the physicist Eliyahu M. Goldratt, who received recognition for the speed of development and growth of his software company, which led him to publish his theory in his novel "The Goal." This theory focuses on the study of limitations (physical, political, and/or market) of the system to identify the bottleneck and expand its capacity to achieve a set goal or objective (Goldratt and Cox, 1985). Fuentes, Del Solar, Samillán & Vásquez applied this theory in the spinning stage of the Textile Company S.A. to evaluate the reduction of production time. Through this case study, the production process was streamlined by reducing downtime and reducing workers, as an optimal number of workers was obtained for efficient and effective development of proposed activities.

Montenegro (2020) considers the application of different methods and tools essential for better plant layout planning. Among these is the Guerchet method, which defines the physical space occupied by machinery, work areas, and personnel to optimize the available space in the plant (taking into account static, gravitational, and evolutionary surfaces to calculate the required area). Likewise, the importance of relational analysis is mentioned, a technique that analyzes the relationships between activities in the production process (considering the value or degree of proximity) to define a relative location and optimize the arrangement of productive and administrative areas, which consists of 4 phases (sequence): relational table, relational activity diagram, relational space diagram, and general arrangement. It is worth mentioning the relevance of line balancing, which according to Rau, Vargas, and León (2010), is where the loads of workstations are balanced with the objective of reducing waiting times for work-in-progress and those waiting for work from a previous station, in order to eliminate bottlenecks.

As previously mentioned, Schmenner (2015) indicates automation as a crucial factor in productivity. Furthermore, through an interview with the manager of Filtex company, the relevance of this factor for plant performance was confirmed. According to Moreno (2001), automation in an industrial process, which includes the machine, equipment, or industrial assembly, consists of incorporating a set of technological elements and devices that ensure good control and behavior; and its objective is to reduce production costs, increase product quality (consistent quality, meaning it is repeated in all product units without defects), and save human beings from carrying out dangerous and/or tedious activities. As a complement, Córdoba Nieto (2006) points out that: "Automation is essentially the convergence of three technologies: mechanics, electronics, and informatics, which have gradually been weaving a reticular convergence such as the specific universe of mechatronics" (p. 1).

Dong Zhai, Goodrum, Haas and Caldas (2009), after conducting a case study in the construction sector, concluded that there is a significant correlational relationship between the implementation of automation, the use of information technologies, and labor productivity. Greater automation was observed to have a positive impact on workers who increased their productivity. Likewise, Ulloa, Castro and Gervasi (2012) argue, after studying the Peruvian textile company N & P Atelier S.A.C., that the use of new technologies is allowing for increased production volumes, reduced waste and final product cost, and facilitating diversification of products to compete internationally and meet specific foreign requirements with a standardized and quality product. On the other hand, Schmenner (2015) concludes that automation increases factory productivity. However, this represents less process flexibility (depending on the machinery or equipment to be implemented) and an increase in production costs since a greater outlay is required for the acquisition of these machines. While some labor is replaced, it prevails in other activities (especially for equipment handling and maintenance).

3. Methods

The type of research to be conducted is a case study. Eisenhardt (2004) defines it as a "research strategy that focuses on understanding the dynamics present in the phenomenon under examination [...] Case studies can be used to achieve several objectives: to provide a description, test a theory, or generate concepts."

In this research, we will seek to determine the correlation of dependent and independent variables after the implementation of an improvement proposal through observation, data collection, and analysis of the production process of Filtex company (time studies and interviews) as in Figure 2. In this case, the dependent variable is the productivity of the process, which will be related to the independent variables of automation and new plant distribution. As Eisenhardt (2004) mentions: "Case studies typically combine data collection methods such as files, interviews, questionnaires, and observations. Evidence can be qualitative (e.g., words), quantitative (e.g., numbers), or both."

The research approach is mixed because it is a case study that seeks to conduct a detailed analysis of an improvement proposal, and it is necessary to analyze it quantitatively and qualitatively to add value compared to using a single approach (Hernández, Fernández and Baptista, 2014). In the qualitative field, structured, semi-structured, and unstructured interviews will be used to collect information related to the operation of the process, the company's context, indicators used by the organization, among others. This will allow determining a strategy to implement the improvement proposal optimally by seeing the problem from an external perspective. On the other hand, it will be complemented with qualitative data collected in the production line to implement the proposal and analyze the results obtained (prior and posterior to its implementation).

Regarding the scope, the research is correlational, whose utility is to know how a concept or variable can behave by knowing the behavior of another or other related variables (Hernández, 1997), as it seeks to analyze the relationship and the impact that improvement proposals (independent variables) have with productivity (dependent variable). The independent variables would be the partial automation of the process and the new plant distribution that would come with it, while the dependent variable would be the productivity of the fiber preparation and mixing area process.

Likewise, the implementation of the improvement proposals will result in a smoother production process in the fiber preparation and mixing area to provide fiber rolls in less time to the carding area, which is the next area in the total production process.

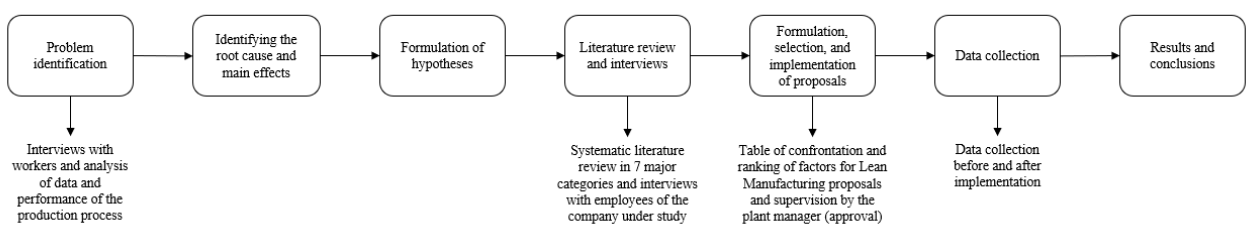

Figure 2. Methodological process flow diagram

4. Data Collection

The analyzed area is the preparation and mixing of fibers, the initial stage of the entire production process. The following information about the area was obtained through a semi-structured interview with the plant manager of the company.

The process begins with the weighing of the different fibers independently. If the fibers are too compressed, they have to go through an opening machine to facilitate the rest of the process. Then, the fibers are manually stacked according to the desired proportions, and at each layer, a sizing agent is added using a manual sprayer. The stacked fiber is then manually transferred to the opening machine, which is connected to a mixer in order to loosen and homogenize the sample. The fiber then moves through an air duct to one of the two specific warehouses for collection before continuing with the process.

Next, the mixture is removed from the warehouses to proceed to the last part of the process, consisting of four machines connected by ducts. The mixture enters the opening loader where the fiber is released again to pass through the fine and coarse cleaners where small debris, dust, and dirt are removed. Finally, the clean fiber mixture passes through a roll former where metal tubes are loaded to obtain the finished fiber rolls to continue to the next carding area as shown in Figure 3.

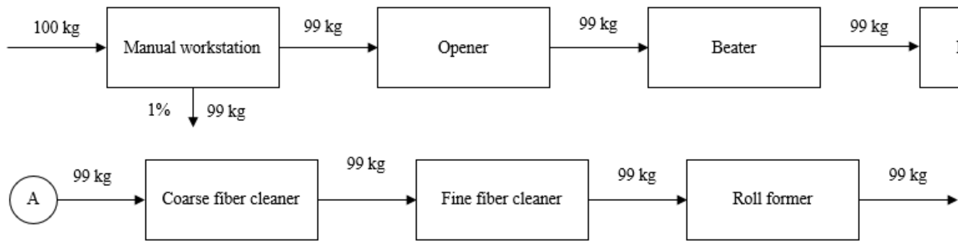

Figure 3. Process block diagram

To quantitatively evaluate the performance of key processes, certain critical indicators will be used to determine the current state of the different key processes. Among these indicators are the processing time in the different stages of the process, the man-hours and overtime used, the number of workers in the plant, and the waste generated in the process. The processing times in the different stages of the process were measured in the same plant for different production batches of 200 kg of fibers shown in Table 2:

Table 2. Key Process Times

Rounds	1	2	3	4	5	6	7	Average
Manual Workstation	51.02	51.45	50.37	50.28	51.56	52.54	52.09	51.38
Opener	5.18	5.1	5.25	5.02	5.13	5.16	5.22	5.15
Beater	2.49	3.1	3.02	2.58	2.53	3.03	3.01	2.82
Feeder Opener	8.52	8.13	8.4	8.32	8.35	8.21	8.18	8.3
Coarse Fiber Cleaner	3.5	3.1	3.58	3.32	4.01	3.44	3.52	3.5
Fine Fiber Cleaner	5.1	4.55	5.21	5.18	5.14	5.08	5.23	5.07
Roll Former	12.52	12.41	12.56	13.02	12.49	12.57	12.48	12.58
Total (min)	89.53	89.04	89.59	88.52	90.41	91.21	90.53	89.83

On the labor hours side, workers operate in shifts of 8 hours, with 1 hour of break time. However, in all shifts, workers work an additional 4 hours of overtime, for which they are paid an extra amount. This makes the shifts quite hard and results in gradually decreasing performance due to fatigue. This was reinforced by the head of the spinning mill, but there is no exact value on how much performance decreases, and this can vary depending on the worker and their health status at the time.

The next indicator is the number of workers in the plant. The head of the plant informed us that 3 workers work in the area per shift. The first 2 workers are in charge of the manual work station, which includes weighing, providing, cake forming, and spraying with sizing. Additionally, after finishing what is done at the manual station, they proceed to load the mixture into the opener connected to the beater and finally to the mixture warehouses. On the other hand, 1 worker is responsible for moving the mixture from the warehouse to the opener loader connected to the rest of the machinery. That is why this worker is only in charge of loading the first machine and removing the rolls from the last one when they are ready.

After conducting a detailed internal analysis of the company and the fiber preparation and mixing area, it was determined that the key process to improve is the manual workstation. At the station, fibers are weighed and provided manually, which is inefficient and opens the possibility of errors by the workers. Additionally, the process of manually stacking the fibers and spraying them with sizing to form the cake is an extremely slow and tedious process when there are several smaller orders. For these reasons, the manual workstation is the area's process with the greatest need and potential for improvement through lean manufacturing proposals.

It is worth noting that a very important factor to consider is the complexity of orders, which can vary in both size and components, making workers' tasks difficult and slower. Being a completely manual operation, it can be said that the process is highly dependent on labor, resulting in little flexibility and adaptation to the constant change of order types. Likewise, considering the workers' work hours, it is expected that their performance may decrease throughout the day (due to fatigue, exhaustion, boredom, etc.). This is where the main complication and bottleneck lie with an average of 51.33 minutes (the second operation with the longest time is the roll forming, which averages 12.58 minutes, 4 times less than the manual workstation).

5. Results and Discussion

5.1 Results

To determine the study process for the "Manual Workstation (MW)", a Pareto Diagram shown in Table 3 and Figure 4 was created to compare the time of different activities in order to determine which has the longest processing time, creating a bottleneck.

Table 3. Stations of the production process to analyze.

Process Stations	Average Time	Percentage of Process	Total Time	Total Percentage
Manual Workstation	51.33	57.84%	51.33	57.84%
Roll Former	12.58	14.17%	63.91	72.01%
Feeder Opener	8.3	9.35%	72.21	81.36%
Opener	5.15	5.80%	77.36	87.17%
Fine Fiber Cleaner	5.07	5.71%	82.43	92.88%
Coarse Fiber Cleaner	3.5	3.94%	85.93	96.82%
Beater	2.82	3.18%	88.75	100.00%
Total	88.75	100%		

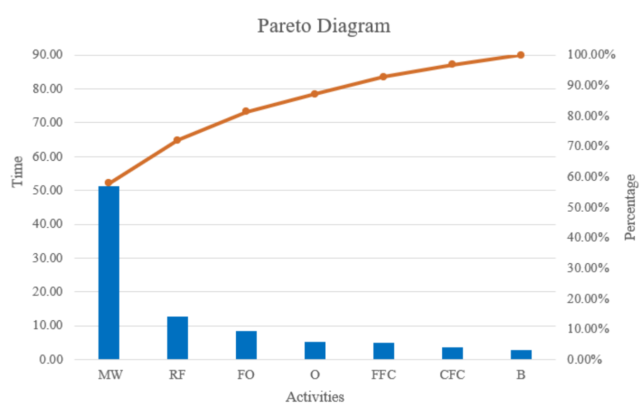

Figure 4. Pareto diagram for time comparison

Within the fiber preparation and blending station, a greater focus will be given to the section known as the manual workstation, which includes weighing, an initial fiber opener, cake formation, and spraying with sizing. The main indicator for this process is the production time at different stages of the process, which will allow us to understand in detail the state of its parts. These activity times have a significant impact on the entire production chain, as the longer they take to complete, the longer it takes to reach the other production processes. Improving these times will result in lower costs for the company, as the product can be manufactured in a shorter overall time, increasing its capacity.

The dependent variable, which is the production of the process (kg/h), is directly affected by the processing times of the manual workstation shown in Table 4, as the working time is limited by the hours in each shift. On the other hand, the independent variables (proposed solutions) aim to reduce the overall time that fibers take to pass through this section, thus increasing production.

Table 4. Times in the manual workstation

Rounds	1	2	3	4	5	6	7	Average
Weighing	1.17	1.05	1.08	1.06	1.08	1.02	1.07	1.08
Initial fiber opener	18.12	18.14	18.09	18.01	18.18	18.35	18.02	18.13
Cake forming	30.02	30.16	29.18	29.28	30.25	31.02	30.42	30.05
Spraying	2.31	2.1	2.2	2.03	2.05	2.15	2.18	2.15
Total (min)	51.02	51.45	50.37	50.28	51.56	52.54	52.09	51.33

5.2 Proposed Improvements

To address the identified problem, a proposed improvement has been decided upon that is capable of covering the following aspects: reduction in production time, increased bottleneck, greater reliability for consistent production over time (reduction of variability due to orders and labor efficiency), and medium-term investment recovery capacity.

Based on the reviewed case studies for the problem solution, the following possible tools and techniques will be used to find the most suitable ones that can satisfy the described purposes:

- Single Minute Exchange of Die (SMED)
- 5S
- Automation
- Kaizen
- Systematic Layout Planning (SLP)

To have a quantitative comparison of the alternatives to be implemented, a table of criteria comparison was created (cost, time, impact, feasibility, and risk) in order to determine the priority order of each one and subsequently a ranking of factors to delimit the most appropriate and effective proposals to solve the problem.

The criteria weighting will be based on the importance assigned to each criterion. This will be a direct comparison between one factor and another individually (0 will determine a lower "weight" and 1 will represent the factor with the highest hierarchy). The total sum of scores between different factors will yield the weighted score per criterion, which will determine the order or hierarchy of the indicators.

Table 5. Confrontation Table

	Cost	Time	Impact	Feasibility	Risk	Total	Weighted Average
Cost	X	1	0	0	1	2	0.182
Time	0	X	0	0	1	1	0.091
Impact	1	1	X	1	1	4	0.364
Feasibility	1	1	0	X	1	3	0.273

Risk	0	0	1	0	X	1	0.091
Total						**11**	**1**

After sorting the comparative criteria by weight in Table 5, a comparison of alternatives will be carried out through a ranking of factors (Table 6). To compare the possible improvement proposals, a rating will be assigned to each alternative in relation to each comparative criterion. The values will range from 1 to 5, with 1 representing poor satisfaction of the factor and 5 representing total satisfaction of the comparative criterion.

Table 6. Ranking of factors

	Weighted Average	SMED		5S		Automation		Kaizen		Plant Layout	
		C	P	C	P	C	P	C	P	C	P
Cost	0.182	4	0.73	4	0.73	2	0.36	4	0.73	4	0.73
Time	0.091	3	0.27	3	0.27	3	0.27	3	0.27	3	0.27
Impact	0.364	1	0.36	2	0.73	5	1.82	2	0.73	3	1.09
Feasibility	0.273	3	0.82	3	0.82	4	1.09	3	0.82	4	1.09
Risk	0.091	4	0.36	4	0.36	3	0.27	4	0.36	3	0.27
Total	1	2.545		2.909		3.818		2.909		3.455	

Based on the weighting of comparative criteria, it has been determined that the alternative with the highest satisfaction of comparative criteria is automation with a total value of 3.818, an option that stands out for its impact as it involves a reorganization of the production process and a series of improvements, but also stands out for its cost, which is approximately $35,000 USD ($20,000 for machinery, $10,000 for programming and arrangements, and $5,000 for installation and testing). The second option is a new plant layout with a total value of 3.455, which complements the first option very well, as the implementation of new machinery requires a rearrangement of the plant to generate a production flow that maximizes space utilization (a plant layout that is in line with the production process sequence).

Firstly, there is automation which involves the implementation of a fiber weighing, feeding and mixing machine that will replace the entire manual workstation, which is the section where most labor is used and where the highest number of problems were found, thus lightening the workload of the process.

To use the machine, the product data is first entered into the computer, for example, a batch of 600 kg with 80% cotton and 20% wool. In the case where the order has already been produced before, there is a record of the products, so you only need to select the desired option. Next, the modules are loaded. The machine has four loading modules where the different types of fibers are placed separately. Once the modules are loaded, it is checked that the sprayers are full and that the program is running correctly to start the process. When the equipment is turned on, the modules start moving the fiber towards their respective scales, and once the specified weight is reached, the scales open, and the fiber falls onto the conveyor belt. This process takes place approximately every 30 seconds, and all scales open simultaneously. On the conveyor belt, the fibers move forward, and the sprayers spray them with the sizing agent every time they pass their sensor. There are two sprayers connected to the conveyor belt. Finally, the fiber reaches the end of the process and passes through a roller that mixes and opens it to move on to the next part of the chain.

Secondly, a new plant layout was designed with the new machinery implemented and with manual handling of the product only at the beginning and end of the production process in the area, thanks to the knowledge acquired and feedback from the company.

The new plant layout brings many benefits to the production process, both financial and functional. To begin with, the investment is minimal, and it would have to be changed anyway due to the implementation of the machinery, so the two solutions go hand in hand. The new layout would make the entire process connected, unlike the current situation where the fiber has to be moved to the scale, workstation, opener, and loader opener depending on the warehouse where it is being sent. In the new chain, only the fibers would be entered at the beginning of the process and the rolls would be removed at the end, in addition to eliminating the warehouses in between. Also, by eliminating these warehouses and the entire manual workstation space, there would be better organization, more space, and the fiber warehouse would increase in size and be closer to the entrance to facilitate handling. With all of this, valuable space in the plant and transportation times would be saved, thus considerably improving the current situation.

Table 7. Dimensions of Process Stations

Process Stations	Original Distribution	Proposed Distribution	Difference
Manual Workstation	24	0	-24
Weighing, Mixing and Proportioning Machine	0	44	+44
Opener	5	5	0
Beater	2.25	2.25	0
Feeder Opener	10.5	10.5	0
Coarse Fiber Cleaner	2.25	2.25	0
Fine Fiber Cleaner	2.25	2.25	0
Roll Former	13	13	0
Storage A & B	24	0	-24
Fiber Storage	20	45	+25
Roll Storage	84	84	0
Total Area (m2)	187.25	208.25	+21

As can be seen in Table 7, we are saving 48 square meters between the workstation and intermediate storage A and B, and despite the fact that the new machine takes up 44 square meters, space would still be saved. In terms of the fiber storage, it is possible to increase its capacity by 25 square meters if desired and placing it in front of the entrance would significantly facilitate the handling of raw materials. All of this would increase the utilized floor space and at the same time create greater order and easy traffic in the area. Additionally, time will be saved in material transportation, especially when loading a machine manually (opener and feeder opener). The comparison between the old and new process flow is shown in Figure 5.

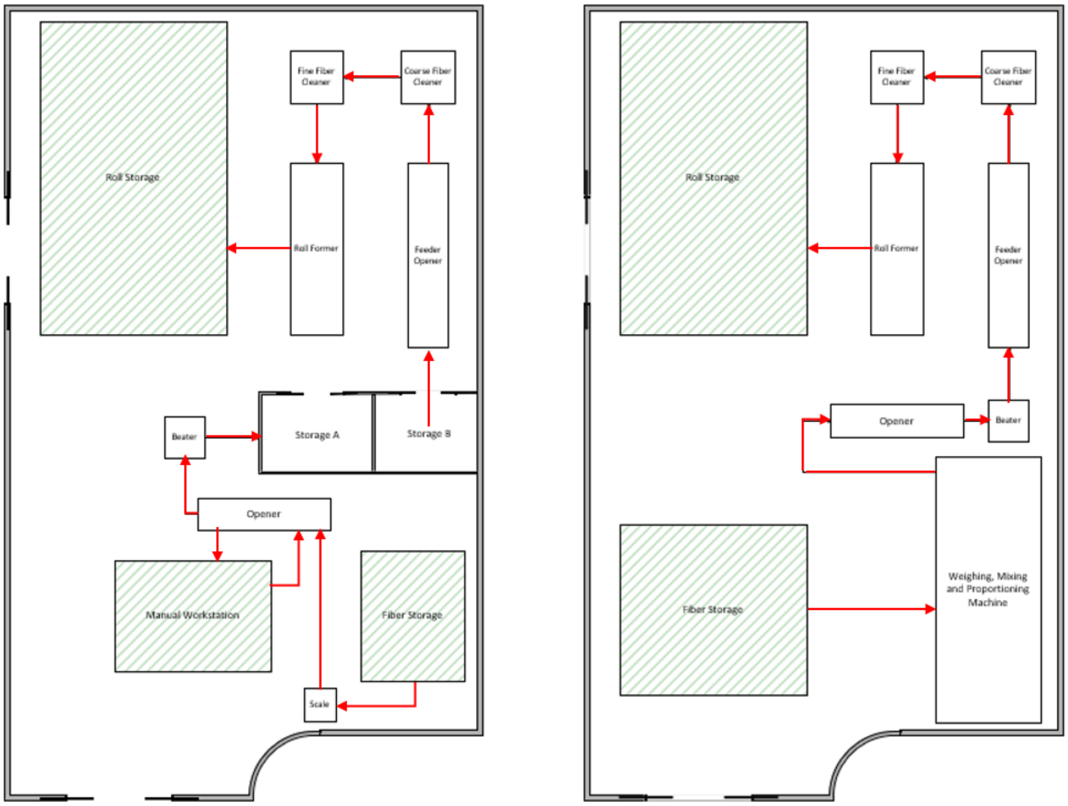

Figure 5. Comparison of plant layout

5.3 Validation

Once both proposed solutions were implemented, a considerable decrease in the times at the manual workstation was evidenced due to automation through the new machinery as shown in Table 8. There was also a reduction in time at the opener and loader, as loading would no longer be done manually since the new plant layout would keep everything connected through ducts. With these implementations, the production time for the analyzed batches was significantly reduced, not considering the time saved due to no variations in batch size or the number of fibers used.

Table 8. Production times of key processes with the implementation of solutions.

Rounds	1	2	3	4	5	6	7	Average
Weighing, Mixing and Proportioning Machine	27.16	26.23	23.33	24.16	25.08	25.42	24.58	25.14
Opener	4.42	4.15	4.23	4.18	4.37	4.31	4.19	4.26
Beater	2.49	3.1	3.02	2.58	2.53	3.03	3.01	2.82
Feeder Opener	7.15	7.12	7.06	7.14	7.14	7.18	7.16	7.14
Coarse Fiber Cleaner	3.5	3.1	3.58	3.32	4.01	3.44	3.52	3.5
Fine Fiber Cleaner	5.1	4.55	5.21	5.18	5.14	5.08	5.23	5.07
Roll Former	12.52	12.41	12.56	13.02	12.49	12.57	12.48	12.58
Total (min)	63	61.47	60.32	61.03	62.13	62.38	62.12	62.18

On the other hand, it should be mentioned that the process was standardized with a result of 150 kg/h, with a daily production of 1200 kg. In this way, the desired limit of 100 kg/h set by management is exceeded, compared to the previous average of 99.06 kg/h, an increase of 51.42% in the production of the area has been achieved.

After observing all the results obtained after the implementation of the improvement proposals, it can be evidenced that the hypothesis stated: "the monthly production in the fiber preparation and mixing area will be standardized through the use of lean manufacturing tools," is true since the process was standardized at 150 kg/h through the implementation of new machinery (partial automation) and a new plant layout, thus giving flexibility to the process so that it can adapt to different orders. Likewise, production capacity has increased by 51.42%, thus surpassing the acceptable standards initially set by management through the reduction of production times and process variability.

6. Conclusion

As demonstrated by the results obtained, following the implementation of the improvement proposal, a 31% reduction in production times was achieved at the fiber preparation and mixing station through the automation of manual operation at the "workstation" (fiber weighing, initial fiber opener, cake formation, and ensiling spray) and a reorganization of the plant with the new machinery. Through this automation, standardization of production in the aforementioned station is achieved due to the constant work of the machine (being a programmable device, it does not incur fatigue, downtime, or idle time) and in conjunction with the distribution of the plant and the savings of meters in the productive path (which can be translated into time), compliance with the regularization and increase in production in the fiber preparation and mixing station is achieved.

In this way, it can be affirmed that the problem of the research is solved, giving as true the principal and specific hypotheses initially proposed since the process was standardized and the production of the area was increased through the application of lean manufacturing (automation and systematic layout), providing flexibility in the production area so that the production process can adapt to the different and varied types of orders that presented problems initially due to the low flexibility and high dependence on labor (identified root causes), which could be quantitatively justified through the indicators presented in the previous chapters.

References

Aguilar, G. M., and Hernández C., T. C. Seguimiento De La Productividad en Obra: Técnicas De Medición De Rendimientos De Mano De Obra. UIS Ingenierías, 6(2), 45–59. 2007.

Ambrus, O. Lean Manufacturing - Process Automation and Elimination of Production Losses in Romanian Automotive Industry. Annals of the University Dunarea de Jos of Galati: Fascicle IX, Metallurgy & Materials Science, 35(1), 18–22. 2017.

Arredondo Ortega, G., Ocampo Jaramillo, K. V., Orejuela Cabrera, J. P., and Rojas Trejos, C. A. Modelo de planeación y control de la producción a mediano plazo para una industria textil en un ambiente make to order. Revista Ingenierías Universidad de Medellin, 16(30), 169–193. 2017. https://doi.org/10.22395/rium.v16n30a9

Campo, E. A., Cano, J. A., and Gómez-Montoya, R. A. Optimización de costos de producción agregada en empresas del sector textil. INGENIARE - Revista Chilena de Ingeniería, 28(3), 461–475. 2020.

Demirci, Ö., and Gündüz, T. Combined Application Proposal of Value Stream Mapping (Vsm) and Methods Time Measurement Universal Analysis System (Mtm-Uas) Methods in Textile Industry. Journal of Industrial Engineering (Turkish Chamber of Mechanical Engineers), 31(2), 234–250. 2020. https://doi.org/10.46465/endustrimuhendisligi.728061

Dong Zhai, Goodrum, P. M., Haas, C. T., and Caldas, C. H. Relationship between Automation and Integration of Construction Information Systems and Labor Productivity. Journal of Construction Engineering & Management, 135(8), 746–753. 2009. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000024

Eisenhardt, K. Building Theories from Case Research. The Academy of Management Review. Vol. 14. Núm. 4 (Oct., 1989). 532-550, 2004.

Fuentes, S., Del Solar, E., Samillán, J., and Vásquez, L. Reducción del Tiempo de Producción en la Etapa de Hilandería de la Empresa Textil SA mediante la Teoría de Restricciones (TOC), en la ciudad de Chiclayo, Lambayeque-Perú. Revista de la Universidad Católica Santo Toribio de Mogrovejo, VII(1), 3-10. 2014. Obtenido de https://core.ac.uk/download/pdf/147579987.pdf

Freitag, B., Häfner, L., Pfeuffer, V., and Übelhör, J. Evaluating investments in flexible on-demand production capacity: a real options approach. Business Research, 13(1), 133–161. 2020. https://doi.org/10.1007/s40685-019-00105-w

Goldratt, E. M., and Cox, J. The Goal: A Process of Ongoing Improvement. Estados Unidos de América: North River Press. 1985.

Gürsoy, A., and Kircali Gürsoy, N. On the Flexibility Constrained Line Balancing Problem in Lean Manufacturing. Journal of Textile & Apparel / Tekstil ve Konfeksiyon, 25(4), 345–351. 2015.

G¨zel, D., Kabakus, A. K., & Şirin, M. S. A VALUE STREAM MAPPING IMPLEMENTATION: A CASE of TEXTILE INDUSTRY. Ataturk University Journal of Economics & Administrative Sciences, 32(3), 763–772. 2018.

Hernández Sampieri, C., Fernández Collado, C., and Baptista Lucio , P. Metodología de la Investigación. McGrawHill. 1997. https://www.uv.mx/personal/cbustamante/files/2011/06/Metodologia-de-la-Investigaci%C3%83%C2%B3n_Sampieri.pdf

Hernández Sampieri, R., Fernández Collado, C., and Baptista Lucio, P. Metodología de la Investigación (Sexta ed.). México: McGrawHill. 2014. https://academia.utp.edu.co/grupobasicoclinicayaplicadas/files/2013/06/Metodolog%C3%ADa-de-la-Investigaci%C3%B3n.pdf

Islam, M. A., Rashed, C. A. A., and Hasan, J. Productivity Improvement through the Application of Systematic Layout Planning Technique. Review of General Management, 25(1), 38–53. 2017.

J. Rau Alvarez, J. Vargas and M. León Planeamiento y control de operaciones, Lima: Lima: Fondo Editorial, 2010

Leyva, L. L. L., Perugachi, E. P. C., Piarpuezan, R. V. S., Orges, C. A. M., Montenegro, E. P. O., & Burgos, G. Lean Manufacturing application in textile industry. In Proceedings of the International Conference on Industrial Engineering and Operations Management (pp. 26-27). 2018.

Li, B., Chen, X., Wei, S., and Cheng, Y. The Elimination Effect of Take-Back Regulation on Backward Production Capacity Remanufacturing Supply Chains. Mathematical Problems in Engineering, 1–18. 2021. https://doi.org/10.1155/2021/4386370

Lozano, J., Saenz-Díez, J. C., Martínez, E., Jiménez, E., and Blanco, J. Methodology to improve machine changeover performance on food industry based on SMED. International Journal of Advanced Manufacturing Technology, 90(9–12), 3607–3618. 2017. https://doi.org/10.1007/s00170-016-9686-x

Malysa, T., and Furman, J. Application of Selected Lean Manufacturing (Lm) Tools for the Improvement of Work Safety in the Steel Industry. Metalurgija, 60(3/4), 434–436. 2021.

Montenegro Chafloque, T. O. Propuesta de un diseño de nueva planta de la empresa textil Confecciones Texmoda para incrementar la productividad. Universidad Católica Santo Toribio de Mogrovejo, Departamento de Ingeniería, Chiclayo. 2020.https://tesis.usat.edu.pe/bitstream/20.500.12423/2666/1/TL_MontengroChafloqueTais.pdf

Moreno, E. G., Automatización de procesos industriales. Valencia: Alfaomega. 2001.

Nieto, E. C., Manufactura y automatización. Ingeniería e Investigación, 26(3), 120-128. 2006.

Schmenner, R. W. The Pursuit of Productivity. Production & Operations Management, 24(2), 341–350. 2015. https://doi.org/10.1111/poms.12230

Seydelmann, A. Las ventajas de la automatización en el procesamiento industrial de la carne. Industria Alimenticia, 25(1), 48–50. 2014.

Ulloa, M. A., Castro, P. Q., and Gervasi, O. V. Mejorando La Competitividad De La Pyme a Través De La Tecnología: Caso Empresa N&P Atelier Sac. Revista de La Ingeniería Industrial, 6(1), 14–19. 2012.http://search.ebscohost.com/login.aspx?direct=true&db=egs&AN=77781762&lang=es&site=ehost-live

Valverde Alvites, K. V. Criterios de Evaluación para la selección de un sistema ERP Open Source para la empresa Inversiones Avícola Génesis, Trujillo, 2020. http://repositorio.uprit.edu.pe/bitstream/handle/UPRIT/455/ISI-TESIS-Kennedy%20Valverde%20Alvites.pdf?sequence=1&isAllowed=y

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