SSRG International Journal of Mechanical Engineering
ISSN: 2348-8360/ https://doi.org/10.14445/23488360/IJME-V11I11P102

Volume 11 Issue 11, 15-23, November 2024

Original Article

Improving Service Level in Textile SMEs through Lean and MRP Integration: A Case Study

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Received: 09 September 2024 Revised: 13 October 2024 Accepted: 08 November 2024 Published: 30 November 2024

Abstract *- This case study explores the application of Lean and MRP integration to improve service levels in Peru's textile industry. The study identifies the challenges faced by textile SMEs in meeting market changes and proposes a model that integrates Lean and MRP methodologies to optimize resources and eliminate waste. The model is applied to a micro-enterprise in the textile sector, and the results are analyzed through quantitative indicators. The study shows a 4% improvement in the main service level indicator, a 3% reduction in the stock-out indicator, a 9% reduction in the downtime index indicator, a 12% reduction in the cycle time indicator, and a 7% reduction in the percentage of defective products. The study also contributes to the literature by proposing an alternative approach to planning production and innovatively combining Lean tools with MRP, which has rarely been explored in previous research. The study provides valuable insights for textile SMEs looking to enhance their operations and improve their level of service.*

Keywords - *Lean, MRP, Textile Industry, Lean Manufacturing Tools, SMEs.*

1. Introduction

In Peru, the textile and clothing sector contributes 6.4% to the manufacturing GDP and contributes 0.8% to the national GDP. [1] Sales of the clothing subsector during 2020 were 3,659,000 units, being the lowest level in the last five years. [2] The figures show that the pandemic and the excessive entry of Asian garments aggravated the situation in the textile sector at the national level, especially in micro-enterprises that registered drops in production, decreased orders and a lack of capacity to provide the requested level of service by your clients. The research gap identified in the article centers on the lack of studies that integrate Lean Manufacturing and MRP (Material Requirements Planning) tools to improve service levels in textile SMEs in developing countries, specifically in Peru. While there is existing research on each tool individually, combining Lean and MRP in the context of microenterprise in the textile sector is still underexplored.

According to the literature, the problem found originates from the non-compliance of orders in terms of quantity, quality, and time. The presence of this problem in other countries is identified in the following investigations. In the first case, high-order processing times were observed. To improve these inefficiencies in the processes, lean tools and standardization methods were applied, which allowed the service level to increase from 56% to 63%. [3] The second case shows a textile company that could not quickly meet market changes due to its inflexible supply chain. Given this situation, a collaborative cloud platform was proposed to develop a sustainable garment supply chain by assignment. [4] In the third case, multiple quality failures were identified in the clothing produced by a Turkish company. To deliver a better level of quality, the negative impact failures were discovered and tools such as FMEA and PA were used, which allowed for reducing the negative effects and risks. [5] Research shows that the problem is mainly due to poor quality and late delivery; therefore, industrial engineering solutions are required to increase current service levels.

As mentioned in the previous paragraph, the sector's main problem is the level of service, and to propose an appropriate solution for the sector, a micro-enterprise was taken as an example where the necessary tools were applied to improve quality and delivery time. The main reason for this research is to seek a significant contribution to the textile sector and its subsectors, such as clothing. The main contribution of the research is evidence of the results for applying methods and techniques to improve the level of service in the textile sector SME. Lean tools such as 5S, Jidoka, Heijunka and Kanban are used for this.

This research is divided into the following five sections: The Introduction presents the background in the textile sector together with the main problems encountered to relate the problems of the company under study. Likewise, in this chapter, you will find success stories of similar companies that have progressed thanks to the suggested methodologies. State of the art chapter contains the typologies to be developed in the present investigation: the level of service, the MRP tool and Lean tools such as Kanban and Jidoka. The contribution chapter includes the basis of the model, the proposed model, the components of the model, and the indicators to be measured. The Validation chapter details the initial diagnosis, the validation design and comparison with the initial situation, and the improvements obtained from the pilot test.

2. Literature Review

2.1. Level of Service

Lean techniques are used and managed to improve the old results in the textile sector; an integrated Lean-BPM model is proposed due to the positive correlation that exists between these and the significant improvements that their joint application means to increase the level of service. [8] The service level represents one of the most valued factors when selecting a manufacturing technology; therefore, having reached high levels of technology, the company under study focuses on the service level indicator. [21] Another factor to consider in the level of customer service is the social performance of the life cycle of products in the textile industry, which is negative in a study carried out on shirts sold in the Netherlands but produced in China. This is considered for the legibility of the companies and to define their competitive advantage; the 3 main ones are the cost of the product, the customer's sensitivity to the market and the collaborative relationship. [16, 22]

Taking this into account, the current research work seeks to use a service model to improve the service level of the company under study. In addition, it can be shown that the case studies reviewed show improvements in their processes, leading to a better level of service. Likewise, it is possible to highlight the presence of research regarding the level of service in the textile sector. However, this literature is not abundant, and sometimes, some of these turn out to have a deficient contribution. Having said this, the need to validate and disseminate service models to improve the level of service in the textile sector is highlighted.

2.2. Kanban

The Kanban tool is widely used to reduce the level of inventory, and for this, it is complemented by other tools such as Value Stream Mapping (VSM). The combination of these two tools generates a great positive impact on the company since it allows for optimal reduction of costs in inventories. Thus, the company would have a competitive advantage in the market. [6, 7] A study was carried out in which the result was that the level of availability of products on the shelves helps to improve the level of customer service; in this way, the importance of availability on the shelves is discussed to guarantee an excellent level of service to end customers and for this reason, proposes two Lean initiatives. The first is the VSM, and the second is a visual inventory management system using the Kanban methodology [8,9,6].

The conclusions of all the articles showed an increase in inventory turnover, which allowed a flow of materials with greater flexibility and reduced the inventory of finished products. In this way, Carvalho managed to generate value for the companies under study. The same happened with the companies studied by José Vásquez, which managed to reduce approximately 20% of sewing times. However, these investigations present the same tools to solve the same problem, which is inventory management. In this case, it is necessary to disseminate more Lean tools to help optimize the stock of raw materials and finished products in the companies under study.

2.3. Jidoka

It is proposed that Jidoka be used to detect defects at the source, reduce defective products, improve the flexibility of the production system, and thus not neglect the quality of finished products. [11] It is concluded that applying this technique under the Jidoka tool saves up to 14.2% in costs of the importance of stopping the processes in case of failure or doubt. However, ignoring inspection or repair opportunities could generate a significant increase in costs and a decrease in the quality of the products. [12,13]

For these reasons, in the current work the Jidoka tool is used to carry out self-control of quality during the production process. However, there are very few case studies on the application of Jidoka to improve the quality of finished products in the textile sector, even though research shows improvements in production processes in other industries. Due to this, it is necessary to validate and define the use of the Jidoka tool in the textile sector to contribute to improving the quality of the products.

2.4. MRP

The combination of tools in the production system, such as MRP and the ABC method, presents many practical benefits. In a study, a Lean-MRP model is proposed to reduce the reprocessing rate, improve the work method and be able to have inputs in production; in addition, the Adkar model was used to ensure the correct implementation and commitment of the members towards this change. [14] On the other hand, one of the most complementary tools of MRP is JIT because it is valuable for the flow of inventories. It is also used for traditional MRP systems because it allows for the adaptation of industries with little technological capacity [15,16]. Finally, in many articles, it is mentioned that the main benefit is improving the level of customer service because the products are available in the warehouse, so the market share is increased. Likewise, this technique is statistically not complex, as demonstrated by Roy Ram Naresh in his study. Finally, this tool is complemented by many others, such as the ABC method, to save daily time in the production process of a product, as Malindzakova demonstrated. However, many of these tools have drawbacks when developing them in the field since, according to most articles, hours are lost to modifying the current method. In this sense, as shown in Table 1, it is recommended to propose tools that help the change process towards the method sought to be implemented.

Table 1. Comparative matrix of causes vs stage of art

Root cause / Articles	Poor quality finished product	Low availability of raw material	High percentage of downtime	Low percentage of service level
Matzka J. et al., 2009. Rewers, P.&Diakun, J., 2021.			Kanban	
Deuse, J. et al.,2020. Grout, J.,&Toussaint, J., 2009.	Jidoka			
Haydeé, D. et al.,2020. Cristina, R. et al., 2020			Heijunka	
Zamora, S. et al., 2020.	Jidoka	MRP		5S
José, V. et al., 2018.		MRP		
Shen, L. et al., 2021				5S
Proposed	**Jidoka**	**MRP**	**Kanban /Heijunka**	**5S**

3. Contribution

Although the case studies reviewed consider workforce planning and semi-automated methods to stop production as they are applied to companies with mass production, the reality in Peru is that most of the companies in the textile sector are SMEs. [1] The model's contribution lies in presenting an alternative approach to planning production and determining the conditions and parameters of the process that generate the best results in production time, order fulfillment, and degree of use of the machines.

Likewise, growth is generated for the company that is analyzed since it receives training and improvement tools, and the results are compared through quantitative indicators. Most of the articles focused on companies that export and pay thousands of dollars in taxes, where the application of lean tools such as Kanban demonstrates a significant improvement in production flow and delivery times. [9] In our case study, the same tools will be applied with the aim of improving the level of service, but in reduced spaces and with a low budget, and the efficiency of the tools will be measured. This research seeks to support all SMEs in the textile sector that present the same difficulties and wish to improve their level of service.

Regarding the MRP methodology, which is applied mostly to carry out a continuous and standardized production plan to ensure adequate availability of primary products, [17] This tool will support us in optimizing the company's resources by eliminating waste that cannot be recycled or stored since we have small spaces. In the present case study, the company currently uses certain waste to manufacture second-category products, which differs because it is a make-to-stock item, and the company mostly receives make-to-order orders and applies the JIT method.

The contribution of this research regarding this tool is based on the innovation of applying Lean tools in combination with MRP since few articles have applied this methodology. Finally, the application of standardized methods for the most requested orders and the planning of materials will help us to optimize downtime and have a tolerance time for unforeseen events that may occur in production.

3.1. Proposed Model

The proposed model, as shown in Figure 1, aims to increase the level of service in the textile sector through SMEs based on Lean and MRP techniques. To achieve this objective, the low level of service is established as an input. Then, each component is executed sequentially to obtain output with less downtime, greater availability of raw materials, fewer defective products, low cycle times, and, finally, a higher level of service.

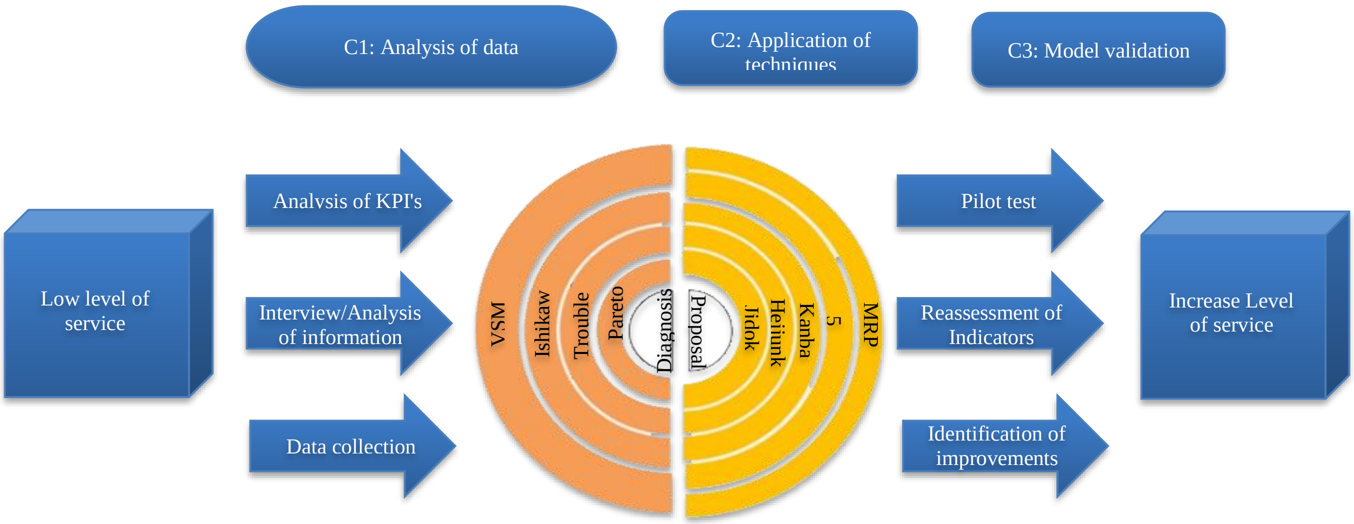


Fig. 1 Proposed model

3.2. Model Components

The first component is data analysis, for which a collection through visits to the company is necessary. Historical information is collected, and small interviews are carried out with the workers. Once the necessary information has been collected, the first analysis tool is prepared, which is the VSM with which the company's weaknesses and the stages that generate the greatest value are observed.

Next, a fish diagram, better known as an Ishikawa diagram, is made, which will allow us to know the causes of the main problem, which, in this case, is the low level of service. Finally, we have the tree and pareto diagram. The first complements the fish diagram since the causes of the main problem are also disaggregated.

Finally, the Pareto chart will allow us to identify the company's irregularities.

The last component is validating the proposal, which will focus on implementing the tools seen in Component 2 and verifying whether the techniques served to improve the indicators seen in the problem tree.

One of the methods that we are going to use is that of comparison, and it is going to compare the KPIs that were set as the objective and the real ones of the company at the end of the improvement project. In some cases, a pilot test will be applied to obtain the final indicators of the company.

3.3. Indicators of the proposed model

3.3.1. Service Level (SL)

The expected probability of not reaching a situation of lack of availability that prevents the orders from being delivered within the deadlines, in the quantity or quality established. It also represents the probability of not losing sales.

$$SL = \frac{Number\ of\ perfectly\ delivered\ orders}{Total\ number\ of\ products\ ordered} \times 100$$

3.3.2. Defective Product Rate (DPR)

It measures the percentage of finished products that do not meet the quality specifications for ready-made garments.

$$DPR = \frac{Number\ of\ garments\ with\ available}{Total\ number\ of\ garments\ produced} \times 100$$

3.3.3. Cycle Time (CT)

It defines the time required to produce a unit of finished product, in this case, the time to make a garment.

$$CT = \frac{Production\ time\ available}{Number\ of\ units\ produced}$$

3.3.4. Stock Out (SO)

It measures the percentage of raw material that was not available when it was required to start manufacturing. Not having the necessary quantity in the warehouse means customer demand cannot be met.

$$SO = \frac{Quantity\ not\ supplied}{Requested\ amount} \times 100$$

3.3.5. Downtime rate (DR)

It indicates the proportion of time not dedicated to effective production being devoted to activities other than clothing.

$$DR = \frac{Non - productive\ time}{Total\ process\ time} \times 100$$

4. Validation

4.1. Initial Diagnostic

After carrying out an analysis of the initial situation of the company under study, it was found that the main problem was a low level of service, this being 75%, unlike textile companies in Chile, with an average service level of 96. %. It was determined that in the last year, this problem represented a loss of 576 soles, equivalent to 7.34% of sales. Among the main causes of the problem were orders delivered with quality failures and orders delivered out of time.

4.2. Validation Design

To validate our proposed model, including Lean and MRP techniques, a pilot plan validation method was applied for all the techniques used. Within the techniques, you can find 5S, MRP, Kanban, Heijunka and Jidoka. Below is the detail of each one.

4.2.1. 5S

A pilot plan for implementing the 5S was carried out, which was applied in the raw material warehouses, products in process, finished products, worktables and machines. The implementation lasted one month, and each S was applied sequentially. In the first S, Seiri, they began with the organization of the objects that were in the passageway; this added to the small available space and a large number of unnecessary objects in the station, and a significant improvement was made in the productivity indicators, in addition to the objects that were of great importance were classified by means of cards in their respective places. The second S, Seiton, consists of ordering the products that the company currently has in the warehouse since, as observed in the warehouse, there are both finished products in process and raw materials, which constitutes a waste of time searching for each product in one place. In the third S, Seiso, general cleaning of the clothing workshop was carried out, and a cleaning plan was prepared for its daily execution at the beginning and end of the work shift. In the fourth S, Seiketsu, a 5S training plan was carried out that lasted two weeks; additionally, a follow-up of the previous S's was carried out through a weekly checklist where compliance with each task with its respective assigned area was reviewed. In the fifth S, Shitsuke, didactic meetings were scheduled to reinforce knowledge and propose improvements; additionally, visual elements such as a 5S poster were located so the staff could visualize it and remember the importance of its application.

4.2.2. Heijunka

For the implementation of this technique, the Heijunka Board was used to facilitate the control of the production schedule. As shown in Figure 3, the garments to be programmed for the summer season were polo shirts, dresses, skirts, blouses and shorts. The takt time of each garment and its respective pitch time were found. Additionally, an Excel template was prepared to be filled out by the workers, in which the data can be viewed. With them, the production rhythm can be established, making variations due to variations in demand. Once the weekly production level is established, this schedule is transferred to the Heijunka board, where the Kanban cards are used.

Complementarily, a weekly control of compliance with the production plan was carried out; during the first month, an average compliance of 39% was obtained; this low percentage was mainly because the company was completing many service orders that it had accumulated. However, this trend was improving over the weeks.

4.2.3. Jidoka

The implementation of this technique was carried out with the objective of reducing quality defects in garments due to the inclusion of fluff in them. For this, self-control of quality was carried out during the preparation of the garments, which comprised four steps. The first step is to detect the problem; the main way to detect the presence of the problem is when the stitch skips or the spool is pushed out of place. The second step is to stop production, having detected one of the two alerts, the machine is stopped, and the supervisor is notified. The third step is to correct the problem; the affected fabric is removed, the affected area is unstitched, talc is applied, the bobbin case is cleaned, and it is sewn again. The fourth step is to find the root cause and establish countermeasures. As shown in Figure 4, it was identified that the accumulation of lint causes part of it to be transferred to the thread with which the fabric is sewn. Additionally, this accumulation also causes the machine to not work properly; for this reason, a daily cleaning of the machine is carried out.

To apply this technique, the production sequence and the composition of the garments to be made were identified. With this information, it is possible to find out the garments that are most prone to emitting lint and the main machines used to make them. Each machine was also tested for its likelihood of emitting lint. As a result, it was obtained that the main garments that must be considered are polo shirts and dresses, within the machines that should be placed more emphasis. To measure the degree of improvement in the quality of the garments, a control graph by attributes was made; the result of the first month showed that the lower control limit was exceeded, but in the last weeks, an improvement was visualized, and it is expected that this trend continues in the following weeks.

4.2.4. Kanban

Since the products that are currently being sold are polo shirts and dresses because they present seasonal demand, the Kanban cards must detail the three main processes these products go through, which are the purchase of raw materials, production and the distribution of finished products, these have to be compared with the projection of the demand that was developed to find the safety stock and verify if the times in the delivery of the product were improved. In addition, this implementation should improve one of the main problems encountered, which is the low level of production presented by the company, especially in the textile sector. For poles, the details that were filled out on the Kanban cards are The description of the product, the quantity of products to be manufactured, taking into account the safety stock, the date on which the card is filled out and the date on which it has to finish the activity, the previous process, the subsequent process and the order of the card, being 1 for the purchase of the raw material, 2 for the production and 3 for the delivery of the finished product for which there will be 3 cards for each product. These cards will be found within a Heijunka board, which is the complementary tool that presents two variables: the first is the products that the company is making in the week, and the second is the days.

4.2.5. MRP

To be able to start with this tool, you must know certain necessary data to be able to apply the formulas found within the Excel tables, such as the safety stock that was found through a projection of the demand for the best-selling products. Figure 5 shows that the main products are polo shirts and dresses. In addition, it was considered that these products are seasonal, so the progression that was used was linear since the seasons that come in the coming months belong to spring and summer. The deviation of this demand for polo shirts and dresses is 20 and 8 units per month, respectively. The formula for the security stock is based on the deviation of each product and the lead time, which has a frequency of 7 days and the security level given was 95%. The safety stock for polo shirts and dresses is 18 and 7 units, respectively. Once these data are obtained, they are added to the Excel table. Then, a demand requirement is made, and the receptions scheduled for the next few days are posted in an Excel table. In addition, it is very important to quantify the gross requirement of the raw material based on the projected demand for the following month. The MRP planning horizon is divided into months; for this, it is necessary to have a materials master file, which will provide us with information on each element to be manufactured. Some vitally important data that we must find in the master material requirement is the waiting time for the scheduled receptions.

5. Discussion

5.1. New Scenarios vs. Results

In this section, we proceed to analyze the implementation of the proposed improvement model, using tools such as ERP and Lean tools such as 5S, Kanban, Heijunka and Jidoka. Table 2 show a comparison between the actual and previous situation through the information collected in the pilot test carried out for a month.

Improvements can be observed in the company under study, considering that the service level increased from 75% to 79%; the improvement of the indicator of the technical gap was due, in turn, to the improvement of the indicators of the root causes. In this case, the stock-out indicator was reduced from 22% to 19% thanks to implementing the MRP materials requirement plan, which made it possible to have raw materials when required. Likewise, the downtime index indicator was reduced from 18% to 9% due to the implementation of 5S, allowing to take advantage of the times in productive activities, complementing with greater order and cleanliness in the work areas as shown in Figure 2, which allowed workers to be more productive. Also, in Table 2, as shown, the cycle time indicator was reduced from 1.5h to 1.32h thanks to the implementation of Kanban, which made it possible to reduce the time needed to make a garment. Lastly, the defective product rate indicator was reduced from 38% to 31% after applying Jidoka, a tool that made it possible to reduce quality defects caused by the incorporation of lint in garments, preventive cleaning and defect detection allowed generating garments without defects, and without the need to carry out subsequent quality controls.

Table 2. Analysis of indicators and improvements

Indicator	Unit	As-Is	Improvement
Service level	Percent	75%	79%
Out of Stock	Percent	22%	19%
Downtime rate	Minutes	18%	9%
Cycle time	Hours	1.5h	1.32h
Percentage of defective products	Percent	38%	31%

Table 3. Analysis of indicators by scenarios

Scenario Table		Indicators				
		Service level	Out of Stk.	Dow ntime rate	Cycle time (H)	Percentage defective products
Scenario	1	0.79	0.19	0.09	1.32	0.31
	2	0.5	0.4	0.38	2.1	0.49
	3	0.9	0.09	0.04	1.05	0.18

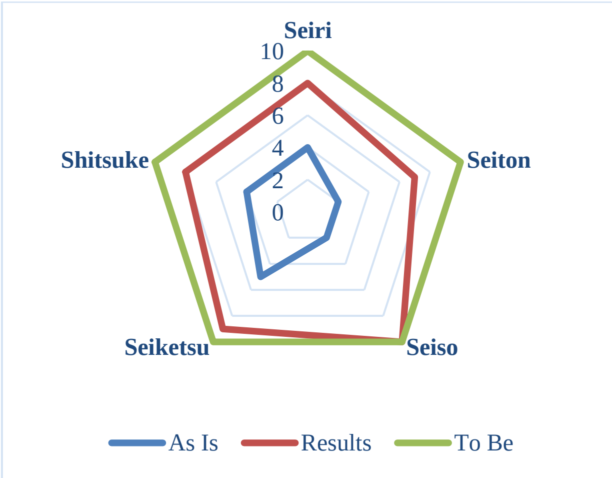


Fig. 2 Comparison of final and initial 5S evaluation

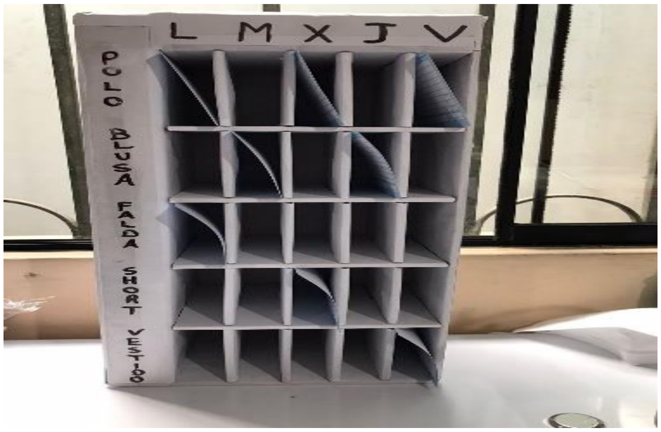
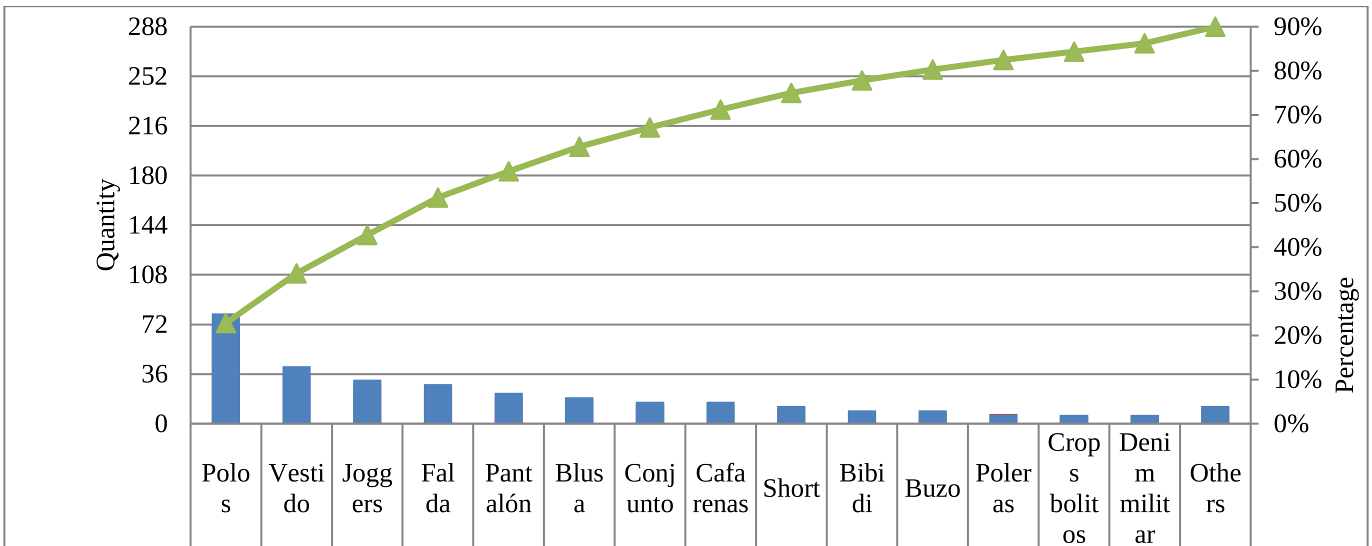


Fig. 3 Heijunka board

Fig. 4 Overlock machine



	Polos	Vestido	Joggers	Falda	Pantalón	Blusa	Conjunto	Cafarenas	Short	Bibidi	Buzo	Polera	Crops bolitos	Denim militar	Others
Quantity	73	36	28	27	19	18	14	13	12	9	8	7	6	6	12
Percentage	25%	13%	10%	9%	7%	6%	5%	5%	4%	3%	3%	2%	2%	2%	4%
Accumulated	73	109	137	164	183	201	215	228	240	249	257	264	270	276	288

Fig. 5 Pareto diagram main products

5.2. Analysis of Results

In this section, the improvements obtained from the implementation of the proposed model are analyzed. For this purpose, Table 3 compares the three scenarios contemplated through the root causes indicators and the technical gap indicator. Because scenario 3 is an optimistic case, the values exceed the one obtained, while in scenario 2, negative results are obtained because it is a pessimistic scenario.

The indicators of scenario 1 show a 4% improvement with respect to the main service level indicator, the stock-out indicator is reduced by 3% due to the improvement in the supply of raw materials, the downtime index indicator is reduced by 9 % after the application of 5S, the cycle time indicator is reduced by 12% thanks to the application of Kanban that allows the garments to be produced in less time and the percentage of defective products is reduced by 7% after applying Jidoka to reduce manufacturing defects quality.

5.3. Future Works

According to the results of this research, future work could include the following:

- The application and validation of the proposed model in other micro-enterprises in the textile sector, to evaluate its effectiveness in different contexts and operating environments.
- Long-term monitoring of improvements implemented to understand their sustainability and long-term effects on productivity and service level.
- Comparison with other continuous improvement methodologies to identify the specific advantages of Lean

and MRP integration in the context of textile microenterprises.

Such future work could help strengthen empirical evidence on the effectiveness of these tools in smaller-scale manufacturing environments.

6. Conclusion

The research results reveal that the integration of Lean and MRP has proven effective in improving service levels in micro-enterprises in the textile sector in Peru. Quantitative results show significant improvements in key performance indicators, including service level, inventory availability, downtime and product quality. These findings support the relevance and effectiveness of the application of Lean and MRP tools in smaller-scale manufacturing environments, such as microtextile companies. In addition, the study contributes to the literature by presenting an alternative approach to production planning and innovating by combining Lean tools with MRP. This approach has been little explored in previous research. In summary, this study offers valuable insights and recommendations for micro textile companies seeking to improve their operations and raise their service level in a challenging environment.

Regarding the challenges to implementing the model, It mentions that the primary challenges and barriers to implementing the integrated Lean Manufacturing and MRP model in textile SMEs include financial limitations, organizational resistance to change, and skill gaps. The model requires initial investment in technology and training, which can be a major hurdle for small enterprises with limited budgets. Additionally, implementing Lean and MRP requires a cultural shift towards continuous improvement, but this can face resistance if employees are not fully trained or supportive.

Another key challenge is SMEs' lack of adequate infrastructure and workspace, which limits Lean practices that rely on optimized workflows. MRP, in particular, depends on accurate data, yet many SMEs lack robust information management systems, which weakens inventory planning and control. Finally, challenges within the supply chain, such as unreliable supplier timelines, hinder the synchronized flow essential for Lean and MRP to function effectively.

These barriers emphasize the need for strategic adaptation to fit the unique constraints of textile SMEs.

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