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A Model for the Implementation of Lean Manufacturing in Textile SMEs in the Department of Cundinamarca

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Abstract

This work presents an adaptation of Lean Manufacturing for the improvement of production systems in small and medium-sized enterprises (SMEs) in the textile sector of the Cundinamarca department in Colombia. The construction of the model was based on the characterization of the production systems of 31 textile companies in the department, from a Lean perspective. The proposed model is tailored to the specific characteristics of these production systems in SMEs, which face difficulties in applying the Lean philosophy due to lack of knowledge, personnel, and economic limitations for implementation. The model involves the study of the tools of the Toyota Production System, as well as some innovations of these tools that have been presented in recent years, leading up to the concept of Lean. The main conclusion is that the proposed model has been methodologically structured to improve the production systems of textile SMEs in the department, generating positive impact for the sector.

Keywords: Production systems, Lean Manufacturing, Toyota Production System, SMEs, Textile Sector, Lean Tools.

1. Introduction

Globalization and technological development have a profound impact on all companies worldwide, regardless of their type or size [1]. They have allowed customers to be better informed, which forces companies to compete for gaining more customers and survive in the constant evolution of the environment [2]. This generates an increase in customer demand for specific products, how they want them, and who produces them according to their requirements, compelling organizations to update their knowledge to become more competitive [3]. Companies require greater internal development to survive in competitive environments, so they must make appropriate use of the resources available to them and overcome economic, social, and environmental challenges [4] meeting the expectations of customers [2]. The development of competitive advantages has become a fundamental factor in ensuring the survival of companies in contemporary markets [5], so they are forced to improve their production systems and even their organizations to survive [4].

Small and medium-sized enterprises (SMEs) are the most impacted by globalization and technological development, as they exhibit lower levels of competitiveness compared to large industries, especially in developing countries [6]. In Latin American countries, SMEs are characterized by low productivity and a lack of qualified personnel for innovation, creating potential for the development of innovation capabilities in these companies [7]. To achieve this, it is important to understand that the competitiveness of the textile sector does not only depend on the actions taken by entrepreneurs seeking survival in the market, but also on the government [8].

Additionally, SMEs are an important component for the development of the economy in these countries [9], since they have a significant participation in the total production of goods and services of the economic systems [10]. These types of companies are flexible and adaptable organizations in the face of globalized environments [9]; however, they require support to overcome market challenges [5], which makes it important to investigate the production systems of SMEs to achieve competitiveness at both national and international levels [11].

Additionally, SMEs face several barriers to becoming more competitive, including scarcity of resources, access to technology, and low levels of knowledge about efficient manufacturing [5], [12], [13]. These companies aim to improve quality, performance, and customer satisfaction [14] ensuring sustainable profitability through cost savings, proper resource utilization, and quality assurance [10], [15]; however, they often require support to achieve operational excellence and be more competitive. Various techniques and tools exist in the literature to overcome the challenges of globalization and technological development, including Lean tools for continuous improvement [16], which enable companies to achieve business competitiveness through operational excellence [17]; however, it is necessary to study the implementation of these tools in SMEs, as they differ from large companies due to their particular characteristics [18].

Textile SMEs in the department of Cundinamarca are not exempt from this problem, as globalization and technological development have highlighted the need to achieve operational excellence to be more competitive. Significant efforts are being made in these SMEs to achieve operational success and become more competitive, focusing on cost control, quality, safety, and employee motivation; however, these efforts are not sufficient. Many companies have applied Lean tools, but in a disorganized manner, which hinders their ability to focus their efforts. This is mainly due to the lack of knowledge

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among the leaders of these companies about how to apply these tools [4].

Although there are models for the application of Lean in the literature, such as the one proposed in the original work of [19], these are presented in a generic way and do not fully adjust to the requirements of these companies. It is necessary to establish a model that allows textile SMEs in the department to stabilize and control the variables of their production systems, taking into account the limitations of these companies. Therefore, a model for the application of Lean Manufacturing methodology in small and medium-sized textile companies in the department is proposed.

To understand the characteristics of the production systems of textile SMEs in the department, the work of [4], was used as a reference, which presents the barriers that companies must overcome for the implementation of Lean and the state in which manufacturing systems are from a lean perspective. A model was developed for improving the production systems of textile SMEs in the department of Cundinamarca, based on the characteristics of the sector's companies and the literature found on different lean manufacturing tools to achieve operational success.

The document is structured as follows: following the introduction, the literature review is presented; next, the methodology for constructing the model is described; subsequently, the model for the application of Lean in the textile SMEs of the department of Cundinamarca in Colombia is presented; and finally, the conclusions and bibliographic references.

2. Literature review

The dynamics of globalization and technological development have made continuous improvement in the contemporary industry indispensable. Therefore, companies seek to generate competitive advantages by employing techniques and tools for quality control, productivity, and employee motivation [20]; This allows them to be flexible when meeting customer needs, delivering the right products in the right place and meeting delivery times [21], [2]. The Lean Manufacturing philosophy, also known as the Toyota Production System proposed by [22], allows for continuous improvement management [16], cost reduction, increased productivity, quality, safety, and employee motivation, which are important factors for maintaining business competitiveness [17], [23].

Lean production is one of the most commonly used methods by companies to solve production problems and increase competitiveness [24]. *Lean enables the achievement of operational excellence* [25] by promoting a culture of continuous improvement within companies [26]. The philosophy primarily focuses on eliminating waste in manufacturing systems, enabling production control, and increasing flexibility through the proper use of resources [10]. With the help of Lean, benefits such as cost and inventory reduction, and increases in quality, safety, efficiency, employee motivation, and customer satisfaction can be obtained [27], leading to increased competitiveness.

The administration under the Lean philosophy involves a variety of tools that allow companies to receive strong benefits when implemented properly [28]. Among these are VSM (Value Stream Mapping), 5S, HEIJUNKA, KANBAN, SMED (Single-Minute Exchange of Die), TPM (Total Productive Maintenance), JIDOKA, ANDON (Visual Control), KPIs (Key Performance Indicators), POKA YOKE, and SIX SIGMA, among others. The tools are practical and seek to involve the entire organization, ensuring the commitment of all, empowering employees, and making the results of their work visible [28]. Lean tools have allowed manufacturers to achieve operational excellence, meeting traditional and contemporary organizational objectives by evaluating variables such as profitability, efficiency, quality, and customer service [29], making it an excellent alternative to achieving operational excellence and competitiveness.

It is necessary to integrate Lean tools as done by [30], but considering the requirements of the contemporary industry, as well as the innovations that have been presented in recent years in different Lean tools, since according to the literature, they have demonstrated practicality in solving problems related to environmental, social, and economic impacts [4].

3. Methodology

The methodology employed for the construction of the model is divided into three phases: i) literature review on trends in research on the Lean Production System, ii) characterization of the production systems of textile SMEs in the department of Cundinamarca, and iii) structuring of the model for production in textile SMEs. The results of the first phase are evidenced in the work of [4], which shows in detail the trend of the evolution of Lean tools in the contemporary industry during the last five (5) years, as well as the existing barriers for the implementation of Lean in SMEs.

The second phase, related to the characterization of textile SMEs, is detailed in the work of [31], which presents in detail the state of 31 textile companies in the department of Cundinamarca, from a Lean perspective, but which is taken up in this work, relating the information exposed in the literature on the existing barriers for the implementation of Lean in these companies, and which served as a basis for the development of the third phase.

For the third and final phase, a conceptual analysis was carried out on the traditional Lean model structure, taking as reference the one presented by [30]. In this phase, the Lean tools that must be applied to achieve operational excellence in textile SMEs were established, as well as the logical sequence for their application.

Finally, it is important to highlight that this document focuses on presenting the Lean production model for textile SMEs, given that the results of phases one and two are found in the works of [4] and [31]. The results of the third phase are presented in two sections: the first, an analysis of the existing gaps found between the traditional Toyota production model and the production systems of textile SMEs in the department; and the second section corresponds to the presentation of the proposed model.

4. Results

In accordance with the methodology, the results of the third phase of the study are presented, which include the existing gaps between the Toyota production model and the production systems of textile SMEs in the department, as well as the proposed model. These are detailed in the following sections.

4.1 Existing gaps between the Toyota production model and production systems in the textile sector of Cundinamarca

To identify the existing gaps, the traditional Toyota production model is used as a reference. The model proposed by [30], is illustrated in Figure 1.

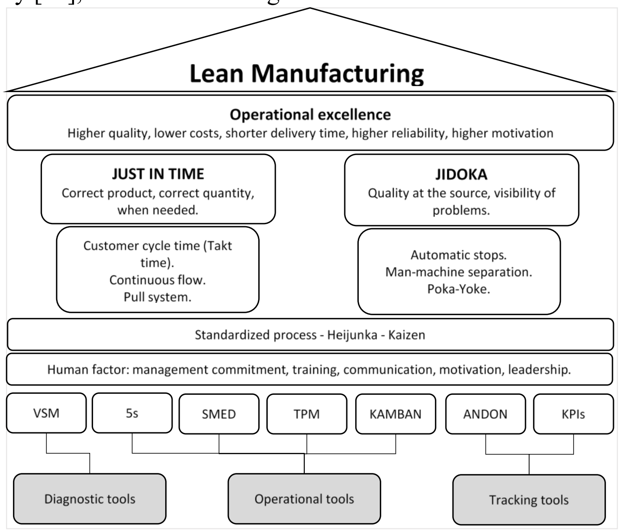

Fig. 1. Toyota Production Model. Source: [30].

Although the model presented by [30] integrates a large number of Lean tools and seeks to improve variables considered important in production systems, it is important to highlight that there are other tools and variables of study that are not contemplated in this model. In general terms, the model does not include two Lean tools considered for the improvement of textile production systems and does not emphasize measuring, controlling, and improving variables within the study.

Among the tools that are not integrated into the model of [30] are the SIX SIGMA tool and the Failure Mode and Effects Analysis (FMEA). These two tools are intended to be included in the Toyota production model, as they are considered relevant to the improvement and excellence of the textile production systems in the department of Cundinamarca. FMEA allows for the identification of faults in products and processes, and evaluates their causes, consequences, and detection elements to avoid their occurrence [32]. SIX SIGMA has statistical methods and techniques for continuous improvement in industrial and business management, primarily seeking to ensure the quality of each job position and significantly improve the quality of products and services [32]. Although SIX SIGMA is not part of the Lean tools, it is considered important for the study because of its excellence in fine-tuning quality aspects in production and controlling variability in the production process, which is key for adequate material and information flow throughout the system.

On the other hand, [30] present as the main variables for measuring operational excellence, quality, costs, delivery times (Lead Time), safety, and motivation. However, after the characterization carried out on textile SMEs in the department of Cundinamarca by [31], other variables were identified to achieve operational excellence. It was found that companies make great efforts to improve process efficiency and reduce waste generated by production, while also focusing on improving the variables of the traditional Toyota production model. Additionally, efforts are made to properly control inventories, reduce environmental impacts, generate value, and increase productivity and process effectiveness.

The model proposed by [30] does not directly study variables such as environmental impact, inventories, value, productivity, efficiency, effectiveness, and waste of the production system. The model should include all variables studied, focusing on those of greatest relevance to textile companies in the department. However, considering that the production systems of textile SMEs are mostly smaller in size and require low complexity to control and improve their operations, it is necessary to establish priority variables under which the model should focus. Figure 2 illustrates the variables and their dependency relationships.

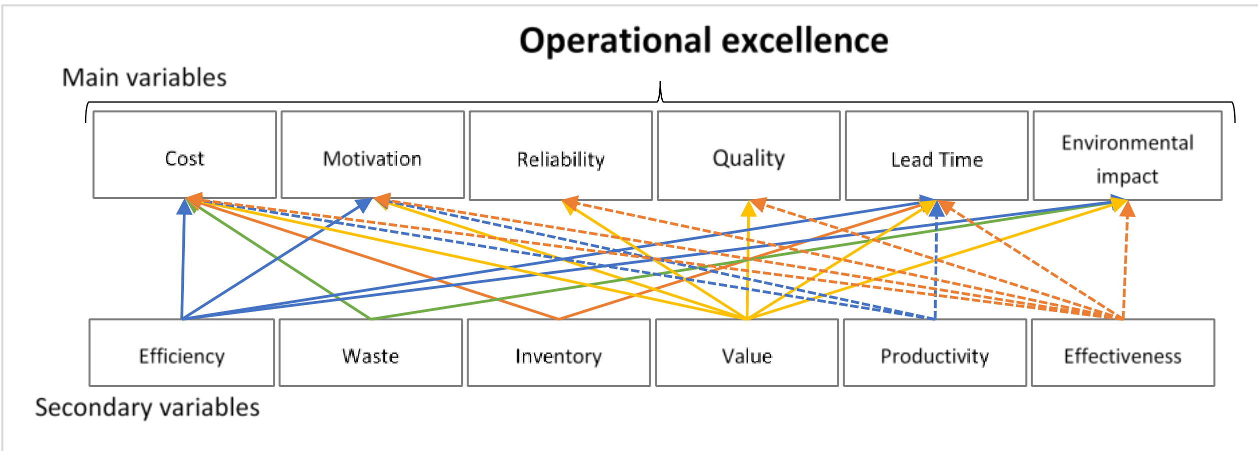

Fig. 2. Relationship between the variables studied in textile production systems. Source: [31].

In terms of the relationships between the main and secondary variables, the following is established:

- Increasing efficiency can indirectly impact variables such as costs, employee motivation, delivery times, and environmental impact in a positive way.
- Reducing waste in production systems has a positive impact on cost and environmental impact variables.
- Proper inventory management has a positive impact on costs and delivery times.
- Value is practically related to all main variables, since its analysis can evaluate costs, motivation, job safety, quality, delivery time, and environmental impact, depending on the variable being focused on for value analysis.

- Increasing productivity can reduce unit production costs, and in turn, reduce delivery times. With the proper incentive plan, employee motivation can be increased.
- Effectiveness is related to the goal and achieving objectives, and is measured with all main variables depending on the established goals (related to each variable).

In general, measuring, controlling, and improving the main variables intrinsically improves the secondary variables, suggesting that only the main variables should be included in the production model for textile SMEs in the department of Cundinamarca.

4.2 Lean Model for Application in Textile SMEs

The house structure proposed by [30] is partially modified, as illustrated in Figure 3. The proposed house integrates Failure Mode and Effects Analysis (FMEA) and SIX SIGMA tools. Additionally, the study of environmental impact variables is included.

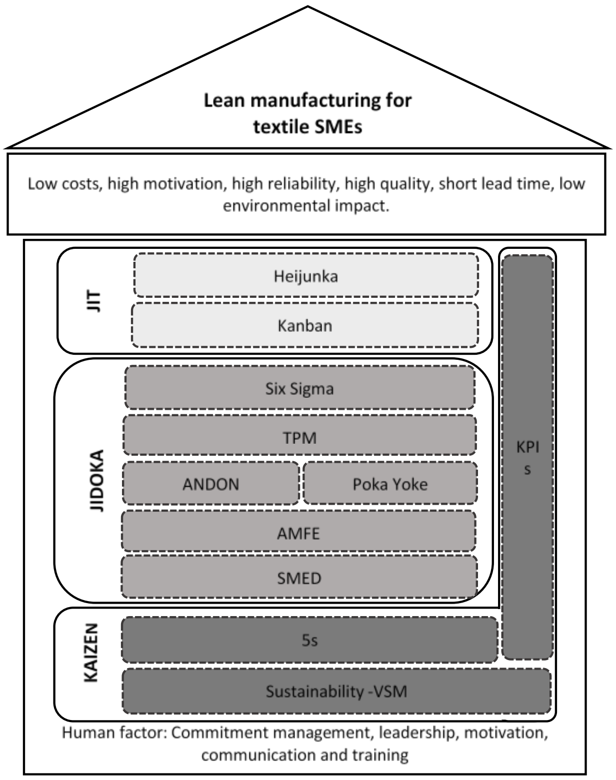

Fig. 3. Integration of variables and tools in the Toyota production model. Source: Adapted from the model proposed by [30].

The human factor is considered key, so it must be taken into account at all times during the application of the pillars of Lean Manufacturing: Kaizen, Jidoka, and Just in Time, in accordance with the principles set out by [30] to maintain commitment, leadership, and motivation in textile SMEs in the department. The model begins with the application of the philosophy of continuous improvement and ends with the Just in Time pillar. While the Jidoka and Just in Time pillars can be applied simultaneously, their separate application has been proposed, starting with Jidoka and then Just in Time, with the purpose of providing textile SMEs in the department of Cundinamarca with a model that is as practical as possible. Since small and medium-sized enterprises do not have a large number of personnel who can oversee the simultaneous monitoring of the different Lean tools, as they sometimes share resources intended for production and those intended for equipment maintenance, a proposed order of application of each of the Lean tools that articulate them was put forward for the study of the aforementioned pillars, which begins with Sus-VSM and ends with Heijunnka, in an ascending manner as illustrated in Figure 3.

As the Kaizen philosophy refers to continuous improvement, it was vertically integrated into the model, so that it is present in every stage of the implementation, involving the Sus-VSM, 5S, and KPIs tools. As in the model proposed by [30], the value analysis of the production system should be initiated to identify waste and problems that need to be addressed, as well as to know the state of the company. For this, the tool presented by [33] and validated by [34], el Sus-VSM, the Sus-VSM, which allows evaluating the system in economic, environmental, and social terms, is available. Once the production system has been diagnosed, the application of the 5S's is recommended to stabilize the production system and generate a culture of continuous improvement in the personnel. Additionally, this will be the tool that will allow the company to visualize the impact of a new way of doing things. Key performance indicators (KPIs) should be applied at the same time as the 5Ss, with the caveat that they must be present at all times to be able to monitor and control textile production systems based on the continuous improvement process (KAIZEN). These can be improved over time once measurement begins and results are evidenced.

For the study of Jidoka related to improving quality from process problems identification, there are SMED, FMEA, ANDON, POKA YOKE, TPM, and SIX SIGMA tools available. It is considered important to start with the application of the SMED technique to continue organizing the processes, identifying internal (with the machine off) and external (with the machine on) operations in cycle changes and, at the same time, increasing flexibility to be able to produce smaller batches without increasing processing times, thus improving Lead Time. Subsequently, it is recommended to carry out failure mode and effects analysis (FMEA), whose purpose is to identify problems in processes or products, their causes, and their consequences [32], which would facilitate the establishment of visual control mechanisms (ANDON) and the implementation of POKA YOKE devices, which are the next tools to be applied.

It is important to make it clear that visual control and Poka Yoke should be applied as much as possible in the processes of textile production systems, both in operations directly related to product manufacturing and in operations related to cycle changes, in order to provide personnel with the necessary mechanisms to ensure quality, agility, and safety in the processes.

Subsequently, it is relevant to implement a Total Productive Maintenance (TPM) plan, as this will allow for efficient use of machinery, cost reduction, and increased process safety, among other benefits that can be obtained through its application. This will strengthen what has been achieved with the SMED, ANDON, and Poka Yoke tools.

Although SIX SIGMA is not part of the Lean tools, it has been included in the model because it allows for the reduction of variation in production and product quality assurance [32]. It is considered convenient to be the last tool to apply from the Jidoka pillar; this will facilitate the analysis and control of operations under the SIX SIGMA scheme, thanks to the stability provided by the other tools applied earlier. Additionally, it allows for an increase in process flow, productivity, and communication by providing a common language for all [35], which is convenient for facilitating the application of the tools in the Just in Time pillar.

The Just in Time pillar integrates the complementary tools of Kanban and Heijunka. Kanban allows for the control of information and the regulation of material transportation in the production system based on the use of inventory control cards [36]; and Heijunka allows for the leveling of production to meet demand [32], seeking to reduce inventory, costs, and delivery times [36]. To implement Heijunka, it is necessary for the Kanban system to be mature [32] so it should be the last tool to apply within the proposed model. Heijunka combined with Kanban will allow the company to control its inventory to improve the flow of materials and work on smaller batches of various products, which is precisely what a SME demands.

While the structure of the proposed model has been explained, it is necessary to describe the different tools presented for its application in the textile SMEs of the department. The procedure to follow for the application of the tools is presented according to what has been exposed by different authors. For the procedures established by each author, the commitment of the companies for the application of the model has been omitted in order not to repeat information. The commitment of the company's management must be present at all times, which is included in the human factor of the Lean House presented in Figure 3.

For the application of Sustainable VSM (Sus-VMS), the procedure presented by [36] for the traditional VSM application is followed, integrating the metrics for sustainability evaluation established by [33]. The process is described below:

1. Select the product or family to analyze.
2. Build the value stream map (of the current situation).
3. Establish metrics for time, operators, inventory, work in process, working conditions, employee safety, water consumption, raw material use, and energy consumption [33].
4. Build the future value stream map, which will indicate opportunities detected for applying Lean tools, increasing value generation.

Once the VSM is constructed, the next step is to establish and implement improvement plans under the KAIZEN philosophy. It is recommended to do this using KPIs, for which the following procedure has been structured based on [37], [38] and [39]:

1. Establish clear objectives for the metrics established in the Sus-VSM analysis.
2. Establish indicators to measure each established objective.
3. Establish action plans and monitoring for the established objectives.
4. Disseminate the action plans and monitoring to employees.
5. Implement the action plans and monitoring.

It should be noted that the objectives and indicators established can be improved as Lean tools are applied. Once the action plan has been established under the Kaizen philosophy, the 5S methodology must be applied, following the order established by [36]:

1. Train employees on the use of 5S's.
2. Separate unnecessary elements from necessary ones for operation (Seiri).
3. Arrange necessary elements in different work areas (Seiton).
4. Identify and eliminate causes of disorder and dirt problems (Seiso).
5. Establish rules to maintain discipline regarding order and cleanliness (Shitsuke).
6. Standardize rules in all work areas seeking synchronization of individual efforts (Seiketsu).

Once the production system has been organized and regularized, we can start with the Jidoka pillar, which begins with the application of the SMED tool presented by [19] to provide flexibility to the production system by reducing cycle or merchandise preparation and readiness change times. The following procedure is available for its application:

1. Identify all operations related to production cycle changes.
2. Separate external operations from internal ones to expedite cycle changes for each [19].
3. Convert internal operations to external ones to reduce cycle change times.
4. Optimize internal and external operations to reduce total preparation or readiness times.
5. Standardize internal and external operations so that all employees perform them the same way (document).

At this point, it is probably easy to recognize all the processes of the production system, both those strictly related to textile manufacturing and those of lot change. Therefore, the analysis of failure mode and effects (FMEA) of processes must be carried out, which is based on the process established by [36] and [40]:

1. Define the product or process to be analyzed.
2. Describe all phases through which the product passes or that make up the process.
3. Analyze the environment of the phases of the product or process (people, tools, equipment, materials, etc.).
4. Identify the possible failure modes that occur in each of the phases of the product or process.
5. Define the effects of the identified failures.
6. Identify the causes of the failures.
7. Identify current control methods for the causes of failure.
8. Calculate the risk priority of failures.
9. Identify corrective actions for the highest-risk failures (for which the use of ANDON, POKA YOKES, and productive maintenance plans is advisable).

Although the use of 5S's in work areas is vital and represents an important element in visual control, it is only a preamble to the true potential of visual control. Visual control allows for a holistic view of the production process and provides a means for actively managing the flow of product and information at all times [41]. To build visual control methods, it is advisable to start with the analysis of failure mode, effect, and analysis, which allows for the foundation of visual control methods to improve processes. The following procedure can be used to establish visual control mechanisms based on [41]:

1. Explain to personnel about visual control mechanisms and their importance.
2. Select the indicators that allow monitoring of process failures, based on FMEA. If a key performance indicator (KPI) that allows evaluating failures does not yet exist, it is recommended to construct a practical one and include it in the action and process tracking plans.
3. Establish the necessary visual control methods (demarcations, lights, colors, sounds, etc.) to improve the selected indicators.
4. Implement visual control methods.
5. Monitor the indicators to be improved.

Parallel to the development of ANDON, it is possible to construct POKA YOKE devices that facilitate the work of operators and, at the same time, improve the quality and safety characteristics of processes. To carry out the implementation of these devices, the following procedure, based on the work of [42] and [36], is suggested:

1. Explain to personnel the POKA YOKE devices and their importance.
2. Select the product or process indicators that need improvement, based on the analysis of mode, effect, and failure.
3. Identify the characteristics of the product or process that must be controlled (e.g. weight, dimensions, shape).
4. Establish control limits for the characteristics that need to be controlled.
5. Establish POKA YOKE devices that allow the product or process characteristics to be kept under control.
6. Implement the devices.
7. Monitor the indicators that are impacted by the use of POKA YOKE devices.

At this point, the production system should present a basic level of stability, which facilitates the development of a Total Productive Maintenance (TPM) plan. Information from the FMEA can be used as a base to focus maintenance efforts on the equipment that requires it the most. Additionally, based on the work of [43], [36], [44] and [45] on Total Productive Maintenance plans, the following procedure is established:

1. Instruct and engage all employees on TPM.
2. Promote the culture of autonomous maintenance throughout the personnel (based on the 5S's). For this, personnel, especially operators working in production, should:
    a. Clean and inspect the equipment.
    b. Eliminate sources of contamination and dirt.
    c. Lubricate components and establish standards for cleaning and lubrication.
    d. Perform general inspections of equipment and/or machinery.
    e. Maintain the culture of inspection and control.
3. Develop an Overall Equipment Effectiveness (OEE) indicator.
4. Establish preventive and corrective maintenance plans for equipment to improve the OEE. To do this, it is recommended to consider the causes of failures related to the machines (FMEA).
5. Monitor autonomous, preventive, and corrective maintenance

SIX SIGMA aims to drastically reduce the variation of quality in processes or products [32]. Compared to other tools, it requires greater effort on the part of companies to implement, especially for small and medium-sized enterprises that often lack knowledge, financial resources, workforce, experience, and clearly defined procedures [46], [25], [47]. For this reason, the proposed methodology establishes the implementation of the SIX SIGMA tool as an alternative.

If textile SMEs face these difficulties, it is advisable to continue with the study of the Just in Time pillar and leave the application of SIX SIGMA for when the system has the appropriate conditions for it. For those SMEs in a favorable environment that wish to drastically reduce the variation of quality in their products and processes, a procedure has been established for the application of the tool. It is based on the work of [48], [49] and [32], which suggests the following steps:

1. Train and motivate personnel on the use of the SIX SIGMA tool.
2. Establish incentives to promote and maintain the momentum of the SIX SIGMA initiative in personnel.
3. Establish the team and leaders for the implementation of SIX SIGMA (highly committed personnel).
4. Define the characteristics of the processes or products that will be evaluated (establish objectives).
5. Measure the characteristics of the processes or products that need improvement.
6. Analyze and interpret the results obtained from the measurement.
7. Determine and implement the necessary actions to improve the characteristics of the processes or products.
8. Control the characteristics of the processes or products to maintain the improvements.

At this point, the application of the Jidoka pillar is complete, and the processes are known, the quality, safety, waste, and high degree of personnel participation are controlled. The production system is considered stable; however, it is advisable to reevaluate the objectives established from the beginning of the Kaizen philosophy, identify new objectives and/or improve existing ones. It is also necessary to evaluate the behavior of the indicators established in the improvement plans and establish new indicators as necessary. Essentially, a look back at what has been done is necessary to refine the process for continuous improvement.

The next pillar is Just in Time, which consists of producing the necessary items at the indicated time and in the necessary quantities to satisfy customer demand [50]. This pillar begins with the application of Kanban, which is a system of synchronized control and programming of production based on the use of cards [30]. The cards can be used to control the release of materials to be transported or produced. For the application of the tool, the following procedure is described based on the work of [32], [30], and [50]:

1. Instruct personnel on the Kanban tool.
2. Select the part numbers to be established in Kanban.
3. Calculate the number of pieces per Kanban.
4. Choose the type of signal and the type of standard container.
5. Calculate the number of containers and the production sequence rhythm (pitch), which will depend on the lot size.
6. Monitor the product in process.

The procedure was mainly based on the work of [32]. For a detailed explanation of each stage, it is recommended to consult this author's work. To properly apply Kanban, it is important to consider the following rules from [32] and [36]:

1. Defective products should not be passed on to the next stages of the process.
2. A Kanban should be removed when the parts from the previous process are removed.
3. No item should be transported or manufactured without a Kanban.
4. Kanban serves as an attached production order to the products.
5. Production should be done in the quantities specified by the Kanban.
6. The number of Kanban should be reduced over time.

The last tool to be applied is Heijunka. This requires the Kanban system to be mature in operation, meaning everyone in the company is using it properly. Heijunka refers to a set of techniques that plan and balance customer demand in terms of volume and variety over a period of time, aiming for a continuous flow of products [30]. The following procedure, based on the work of [32] and [36], is used to apply Heijunka:

1. Calculate the Takt Time, which refers to the time it takes to produce each unit of product according to the available production time and customer demand [32].
2. Calculate the pitch for each product, which represents the production and packaging time of one unit of product in its corresponding quantity of products per package [32].
3. Establish the production rate in units per day.
4. Create the Heijunka box.
5. Monitor the use of the Heijunka box.

For a detailed explanation of this procedure, it is recommended to consult the work of [32]. While it may seem that the proposed framework is complete at this point, it is necessary to re-evaluate action plans, objectives, and performance indicators in order to maintain the Kaizen philosophy of continuous improvement. It is possible to find indicators that do not meet the requirements of textile SMEs, so it is necessary to continuously re-evaluate how they are working and the usefulness they provide to companies to level and improve their production systems. It is important to note that KPIs should be limited, as SMEs may lack appropriate information systems or have limited personnel.

5. Conclusions and Recommendations

Although there are models and tools in the literature that allow the permeation of Lean philosophy in companies, an integrative model of different Lean tools that fit the requirements of textile SMEs in the Cundinamarca department has not been developed. The purpose of this model is to establish a logical procedure for improving production variables in the sector's companies. Different Lean tools found in the literature were integrated, seeking practical application considering the limitations that these companies face, such as lack of knowledge, economic resources, or workforce. The proposed model is suitable for the requirements of textile SMEs in the department and has the theoretical support to achieve operational excellence in the sector.

Some Lean tools have presented innovation in recent years, such as the Value Stream Map (VSM) currently known as Sustainable VSM. This tool evaluates traditional VSM metrics and assesses the environmental and social impacts of production systems' operation. Sustainable VSM has been integrated into the Lean production model because the environmental metrics it evaluates fit the requirements of textile SMEs in the Cundinamarca department, mainly the impacts of proper water and electricity use. The social metrics evaluated with this tool are directly related to the safety and well-being of employees, which is a cross-sectional factor in the proposed model.

The model was structured from literature review and the needs of textile production systems in the Cundinamarca department, presented under a theoretical structure requiring validation. It is recommended for future studies to apply and test the model in SMEs in the sector, demonstrating whether the proposed theoretical approaches overcome the limitations of small and medium-sized companies to apply Lean philosophy.

Although the procedure for applying and integrating Lean tools is explicit and practical, it is recommended that textile SMEs have a basic knowledge of the philosophy, mainly during the application of SIX SIGMA. This tool requires more effort from companies due to the limitations they face, such as lack of statistical knowledge and/or economic resources.

Small and medium-sized enterprises (SMEs) in the sector must address specific aspects before applying the model to overcome limitations. Here are guidelines to progress in this regard:

- Personnel Training: Provide training in Lean and descriptive and inferential statistics. Encourage research and self-directed learning by creating study groups to develop internal trainers or access shared or free online courses.
- Alliances and Collaborations: Establish agreements with educational institutions to allow future professionals to complement their education through practical experience in real organizations.
- Gradual Implementation: Initiate pilot tests in specific operations or processes to facilitate experiential learning and reduce the impact of inadequate implementation.
- Use of Data Analysis Software: Acquire low-cost or free computational tools for data collection, organization, processing, and analysis, addressing deficiencies in SIX SIGMA application.
- Governmental or Institutional Support: Explore programs or initiatives offering subsidies, financing, or training in Lean and SIX SIGMA. Seek support

from chambers of commerce, business associations, or agencies promoting quality and competitiveness.

In summary, when applying Lean Manufacturing and SIX SIGMA, SMEs should prioritize personnel training, establish strategic alliances, utilize online resources, implement projects gradually, and consider external consultancy. Continuous improvement and the identification of strategic projects are also essential to overcome limitations and achieve successful results in the textile sector. While these initiatives may not be part of the model, they are crucial in fostering a collaborative environment that facilitates the methodology's implementation throughout the textile industry.

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