

# Lean manufacturing model for productivity improvement: application in an apparel SME

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## Abstract

**Purpose** – This study aims to propose a people-centered lean manufacturing model to improve productivity in apparel small and medium enterprises (SMEs) characterized by individualistic organizational culture, lack of long-term planning and null knowledge on lean manufacturing.

**Design/methodology/approach** – The proposed model adopts a people-centered perspective, acknowledging that production in many apparel SMEs still depends on workers' experience and skills. Lean tools were selected based on successful case studies and implementation critical success factors. The model consists of three stages: pre-implementation, implementation and post-implementation. In the first stage, value stream mapping (VSM) identifies process deficiencies. During implementation, 5S is used to standardize workstations, while kaizen promotes continuous improvement. The final stage focuses on assessing lean objectives and comparing key performance indicators before and after the implementation of lean manufacturing.

**Findings** – Applying this model in a Mexican apparel SME led to a 40.23% increase in productivity.

**Practical implications** – The lean tools were adapted to fit the local organizational context.

**Social implications** – Replacing traditional production approaches with lean models can significantly enhance productivity in SMEs within the apparel sector.

**Originality/value** – A lean manufacturing model tailored for the apparel industry considering individualistic organizational culture, lack of long-term planning and null knowledge on lean manufacturing.

**Keywords** Lean manufacturing, Value stream mapping, 5S, Kaizen, Small and medium enterprise

**Paper type** Research paper

## 1. Introduction

Lean manufacturing (LM) is focused on eliminating and reducing all production processes that do not add value to the final product (Ohno, 1988), without affecting production or



quality (Womack, 1996). However, its implementation is not straightforward, as the specific necessities and problems of every enterprise must be analyzed.

Currently, most of the enterprises that have adopted and adapted with success an LM production model have been large ones (Maware *et al.*, 2022). Consequently, they have enhanced their competitiveness in the global market. Whereas, few small and medium enterprises (SMEs) have exploited the advantages provided by production models based on LM. 75% of large enterprises have implemented LM compared to 50% of SMEs (Maware *et al.*, 2022; Sinkamba *et al.*, 2025). This despite SMEs play an essential role in promoting economic growth and inclusive globalization. In other words, SMEs are key players in the economy and broadening business ecosystem. Note that, in countries integrating the Organization for Economic Co-operation and Development (OECD), the SMEs are the dominant form of enterprises, accounting for almost 99% among all kinds of enterprises. Also, SMEs are the main source of employment (about 70% of jobs) and value added (between 50% and 60%). Furthermore, in emerging economies, SMEs account for nearly 45% of total employment and 33% of gross domestic product (GDP) (OECD, 2017). When the contribution of informal enterprises is added, SMEs contribute to more than half of employment and GDP in many countries, regardless of income level (Berthaud *et al.*, 2013). Moreover, among the three economic sectors participating in the global GDP (services, industry and agriculture), industry has a participation of 28.04%.

Some efforts have been made to introduce LM in SMEs. Hence, literature can be grouped as follows: identification of the most beneficial LM tools for SMEs (Matt and Rauch, 2013; Nordin *et al.*, 2010; Vienazindiene and Ciarniene, 2013); implementation of one or more LM tools in SMEs (Carvalho *et al.*, 2017; Dhingra *et al.*, 2019; Demirtas *et al.*, 2023; Guzel and Asiabi, 2022; Damian-Garcia *et al.*, 2023); proposals for the implementation of LM models in SMEs (Anvari *et al.*, 2011; Mostafa *et al.*, 2013; Belhadi *et al.*, 2016; Minh and Kien, 2021; Villamil and Arteaga, 2023); LM model implementation from an existing model proposal (Hodge *et al.*, 2011; Kumar *et al.*, 2018; Rochman *et al.*, 2024); and LM model proposals and their implementation in SMEs (Huang *et al.*, 2022; Memari *et al.*, 2024; Dahab *et al.*, 2023).

Regarding *identification of the most beneficial LM tools for SMEs*, surveys were centered in the results obtained with lean tools implemented in SMEs of different industries from Hungary, Italy and India, respectively. Then, a categorization of the LM tools was performed by considering the impacted key performance indicators (KPIs). Contributions dealing with *implementation of one or more LM tools in SMEs* are based on the review of existing literature of LM tools implemented with success for a KPI that was desired to improve. The works in *proposals for the implementation of LM models in SMEs* carried out a proposal by means of an extensive review of existing models in literature, focusing on the repetitive steps and the recommended tools from literature. Whereas, the papers in *LM model implementation from an existing model proposal* are limited to implement existing models from literature in a particular SME. The objective was to resolve a specific problem and create a lean culture in the SME. Finally, contributions focused on *LM model proposals and their implementation in SMEs*, perform a more complete contribution by designing an LM model departing from existing literature and direct interviews on SMEs. For the implementation of the proposed model, a SME is then selected as a case study to verify the effectiveness of the model.

Note that few efforts have been devoted to the proposal and implementation of LM models in SMEs. Also note that such works have been designed for specific industries such as automotive components, metal construction, office furniture, automotive assembly

(Belhadi *et al.*, 2016), mechanical (Minh and Kien, 2021), textile (Hodge *et al.*, 2011; Dahab *et al.*, 2023; Villamil and Arteaga, 2023) and metal products (Huang *et al.*, 2022) industries.

Among the previously mentioned papers, only two are centered on apparel industry, which is a relevant industry for LM implementation, as it contributes in 2% to the global GDP. This is more than half of the 3.2% and 3.05% that automotive and electronics manufacturing industries contribute to global GDP, respectively. Note that among manufacturing industries the automotive and electronics ones contribute the most to the global GDP. Also, global apparel market revenue reached \$1.73tn in 2023 and for 2024 sales increased to more than \$1.79tn. It is stressed the important participation of the apparel manufacturing SMEs in the global economy, despite their production models are generally based on common sense.

With the intention of contributing to literature in *LM model proposals and their implementation in SMEs* and, in consequence, to close the literature gap between *proposals for the implementation of LM models in SMEs* and *LM model implementation from an existing model proposal*, this paper proposes and implements *in situ* an LM model for productivity improvement for an apparel SME. The proposal and implementation of the model have a people-centered approach, because first line employees are important for lean implementation (Knapić *et al.*, 2023). To evaluate the effectiveness of the model, five KPIs are measured and compared from the initial values. These KPIs are production capacity (PC), cycle time, lead time, defects and work in process.

The remainder of the paper is organized as follows. Section 2 presents a literature review regarding LM models for SMEs. Whereas the methodology for the proposal of the LM model for apparel SMEs is described in Section 3. Section 4 describes the SME of interest and its production process. Whereas, Section 5 describes the application of the proposed LM model in the case study, the obtained results and their corresponding discussion. Finally, conclusions are given in Section 6.

## 2. Literature review

This section presents a literature review related to LM models for SMEs. The revised papers belong to groups *proposals for the implementation of LM models in SMEs*, *LM model implementation from an existing model proposal* and *LM model proposals and their implementation in SMEs*, introduced in Section 1. The review was limited to papers published in journals indexed in Scopus and Web of Science. For which, the following keywords were used: “lean manufacturing” and “Small and Medium Enterprise” or “SME”.

Regarding *proposals for the implementation of LM models in SMEs* (without practical implementation), Anvari *et al.* (2011) proposed a value stream mapping (VSM)-based model, adaptable to reduce any kind of waste associated with sales and profits. This proposal requires LM knowledge by at least one person in the SMEs. Also, Mostafa *et al.* (2013) reviewed 28 existing frameworks, roadmaps and assessment checklists to identify the main factors impacting LM implementation. By their part, Belhadi *et al.* (2016) proposed a model based on an analysis of the steps, tools and critical success factors (CSFs) considered in the implementation of lean transformation process in four SME of automotive components, metal construction, office furniture and automotive assembly industries. These three models, (Anvari *et al.*, 2011; Mostafa *et al.*, 2013; Belhadi *et al.*, 2016), were derived from extensive research of existing models. The latter was also supported by direct interviews conducted with the four SMEs of interest.

Following in group *proposals for the implementation of LM models in SMEs*, Minh and Kien (2021) proposed a four-phase framework based on the interview results from six SMEs from the mechanical industry in Vietnam. Recently, Villamil and Arteaga (2023) proposed a model

with three-phases: literature review on trends in research on the Lean Production System, characterization of the production systems and structuring of the model for production.

With respect to *LM model implementation from an existing model proposal*, [Hodge et al. \(2011\)](#) developed a model for implementing lean tools and principles in the textile industry, based on interviews, plant tours and case studies, to help USA manufacturers stay competitive with overseas production. [Kumar et al. \(2018\)](#) implemented lean-kaizen supported by the define, measure, analyze, improve, control system. [Rochman et al. \(2024\)](#) designed a lean implementation framework specifically adapted to SMEs, with the objective of minimizing waste and enhancing operational efficiency. To achieve this, the proposed framework integrates lean principles with the Plan-Do-Check-Act (PDCA) cycle and simulation techniques.

With regards to *LM model proposals and their implementation in SMEs*, [Memari et al. \(2024\)](#) introduced a model to improve the operational efficiency in a Malaysian SME stationary manufacturer. The implementation results were: travel distance reduced, labor efficiency increased and non-value activities eliminated. [Huang et al. \(2022\)](#) designed a model for a SME in the metal products industry. The approach focused on VSM and the combination of kaizen projects and the PDCA cycle. VSM was used to identify connections between operations and activities. Recently, [Dahab et al. \(2023\)](#) validated a lean implementation in a small Egyptian candle manufacturer, which led to increase daily production by 31.95% and decrease cycle time by 19.82%, using tools as VSM and 5S.

The stages of LM models provided in the reviewed papers are listed in Tables S1 and S2 in Section SM1 of the Supplementary Material.

Having carried out the literature review on model proposals and implementation of LM models for SMEs, the model proposals by [Anvari et al. \(2011\)](#), [Mostafa et al. \(2013\)](#), [Belhadi et al. \(2016\)](#) and [Minh and Kien \(2021\)](#) were found to have the limitation of not being supported by either interactive simulation or practical implementation. Furthermore, even though [Memari et al. \(2024\)](#), [Huang et al. \(2022\)](#) and [Dahab et al. \(2023\)](#) achieve a practical implementation, they do not consider the CSFs and barriers of the LM implementation in SMEs. Furthermore, these three latter proposals ([Memari et al., 2024](#); [Huang et al., 2022](#); [Dahab et al., 2023](#)) assume that the SMEs have trained personnel to implement the lean transformation.

Note that CSFs are key elements that must be considered during project planning to increase the likelihood of achieving each of the objectives set forth in the plan ([Collins, 1996](#)). Among the barriers to implement LM in an SME, in addition to economic and human resources, is resistance to change ([Rymaszewska, 2014](#)). In Latin America, some authors have related it to an organizational culture based on individualism ([Ogliastri et al., 1999](#)) and absence of long-term objectives ([Calderón-Moncloa and Viardot, 2009](#)). Also, [Dauda et al. \(2024\)](#) indicate that an emphasis on short-term objectives, the pursuit of immediate financial returns and the duplication of activities caused by limited collaboration collectively contribute to operational inefficiencies and waste within the Lean implementation in SMEs.

Based on the above, an opportunity has been identified to develop and apply a model focused on implementing LM in SMEs with an individualism-based organizational culture and hence a lack of long-term objectives. Consequently, this research proposes an LM implementation methodology that enables these organizations to enhance productivity, specifically within the apparel industry. In contrast with the existing literature, this research has the following distinguishing features:

- A people-centered approach is considered, as the production method in a vast number of apparel SMEs still depends on the experience and abilities of the workers.
- Main CSFs and barrier for implementing an effective LM in SMEs are considering.

- Model effectiveness is comprehensively evaluated with five KPIs: *PC*, cycle time, lead time, defects and work in process; instead of one or two commonly used in literature.
- The five fashions in literature presented in Section 1 are analyzed to perform the methodology design. This because, to our knowledge, no other work has applied LM specifically to apparel SMEs.
- The proposed methodology is validated in a Mexican apparel SME interested in enhancing productivity.

### 3. Research methodology

Lean methodology is used due to its widespread industry application (Yadav *et al.*, 2018; Narayanamurthy *et al.*, 2021) and focus on eliminating non-value activities through continuous improvement. It involves applying and validating lean tools in case studies, preceded by diagnosing the current state as well as gathering and analyzing data prior to implementation (Sharma and Bhoat, 2020).

Before defining the phases and steps for our LM model, we identified the CSFs and barriers for the implementation of LM. For that, we review the literature (Rymaszewska, 2014; Binti Aminuddin *et al.*, 2015; Bortolotti *et al.*, 2015; Belhadi *et al.*, 2016; Thanki and Thakkar, 2018; Kafuku, 2019; Salma *et al.*, 2021; Bhadu *et al.*, 2021; Sakataven *et al.*, 2021; Bhadu *et al.*, 2022; Gastelum-Acosta *et al.*, 2022; Knapić *et al.*, 2023). However, most of the literature focuses on large companies, with very little in relation to SMEs. Hence, we focus on detecting similarities in CSFs and barriers affecting both large companies and SMEs. Resulting that the CSFs with the highest level of impact in the implementation of LM in SMEs are as follows: involvement and commitment of top management (Bhadu *et al.*, 2022; Salma *et al.*, 2021), training and education (Knapić *et al.*, 2023), appropriate selection of LM tools and techniques due to limited organizational resources (economic barriers) (Salma *et al.*, 2021), customer focus (Thanki and Thakkar, 2018) and supplier relationships (Bortolotti *et al.*, 2015). Concluding that the most crucial factor for successful implementation of LM in an SME is strong commitment and involvement from top management (De La Vega *et al.*, 2020; Jeyaraman and Teo, 2010; Belhadi *et al.*, 2016; Bortolotti *et al.*, 2015; Knapić *et al.*, 2023). This means that top management must actively participate in the transition to an LM-based production model. Their presence ensures that the project is perceived as significant, motivating the personnel to exert the necessary effort for a successful implementation.

Regarding barriers, (Rymaszewska, 2014; Salma *et al.*, 2021; Sakataven *et al.*, 2021; Knapić *et al.*, 2023) agree that cultural factors within top management and among personnel are key reasons for the failure of the model implementation. Top management may halt implementation if results are not immediately apparent, perceiving the changes as ineffective. Personnel, accustomed to long-standing practices, may resist change, believing processes are already optimized and resistant to improvements that could disrupt production. Additionally, new responsibilities associated with changes may be perceived as outside their initial job scope, complicating the shift in mindset.

From the above findings, the CSFs *commitment of top management* (CSF1), *appropriate selection of LM tools and techniques* (CSF2) and *training and education* (CSF3) as well as the *resistance to change barrier* (B1), are considered in our LM model to enhance its effectiveness.

Motivated by Belhadi *et al.* (2016), our LM model proposal considers three phases: *Pre-implementation*, which is the proposal on how to apply the LM approach in the SME production model from a diagnosis; *implementation*, which refers to the application of

the proposed LM model in the production system of the SME of interest; and *post-implementation*, focused on the results analysis and comparison of the performance indicators before and after the LM model application. This analysis verifies the effectiveness of the proposed LM model in achieving its objectives. Figure 1 represents in general terms our proposed LM model. Their phases and steps are detailed in later sections.

We emphasize that our goal is to provide a very simple yet effective LM model, so that top management and personnel of an SME without experience on lean approach can handle the application of the proposed LM model on their own.

### 3.1 Pre-implementation

The pre-implementation stage focuses on collecting information from the SME to understand its initial state before starting LM implementation. This to highlight potential improvement areas, even beyond LM, that are important to address. It also must prepare and motivate personnel for upcoming changes, encouraging them to explore the organization's data and operational limits. Thus, the following steps are recommended:

- Development of lean policy and objectives. Top management and personnel should collaboratively develop a lean policy and specific, measurable, achievable, realistic

Phase	Steps	Tools	KPIs	CSFs - Barrier
Pre-implementation	1. Development of lean policy and objective	Interview		CSF1
	2. Initial analysis and diagnosis	Questionnaire (García and Sánchez, 2015) VSM		CSF1
	3. Measurement of initial-state indicators	Basic statistics	a. Production capacity b. Defects c. Cycle time d. Lead time e. Work in process	CSF1
	4. Assessment of LM techniques and tools knowledge level within the organization	Authors' lean initial diagnosis questionnaire		CSF1 B1
	5. LM tools selection and training manual	Literature review		CSF2
	6. Designing the master plan for LM model training and implementation			CSF1
Implementation	1. Personnel training	Training manual		CSF1 CSF3 B1
	2. Implementation of LM tools	5S Kaizen		CSF1 B1
Post-implementation	1. Monitoring of LM tools implementation	VSM Basic statistics	a. Production capacity b. Defects c. Cycle time d. Lead time e. Work in process	CSF1 B1
	2. Documentation and standardization			CSF1
	3. Assessment of lean objectives	Basic statistics	a. Production capacity b. Defects c. Cycle time d. Lead time e. Work in process	CSF1 B1
	4. Promotion of continuous improvement culture			CSF1 CSF3

**Figure 1.** General diagram of the proposed LM model

Source: Authors' own work

and time bound objectives aligned with the SME’s overall strategy. This ensures everyone understands the purpose behind the proposed changes (Belhadi *et al.*, 2016). The policy should reflect the organization’s values and philosophy. While objectives should define specific goals to be achieved with personnel collaboration. Both are essential to evaluate progress during LM implementation.

- Initial analysis and diagnosis. For apparel SMEs aiming to LM, maturity assessment is essential to obtain an initial organizational diagnosis. Thus, the yes/no questionnaire developed by García and Sánchez (2015) (see Supplementary Material, Section SM2), tailored for the apparel industry, is recommended. Although this questionnaire is designed to be completed by the top management, it is suggested that the personnel be involved to foster an environment of transparency, collaboration and trust. This tool evaluates key areas such as management, market, finances, production and technological development. It helps identify and resolve issues before LM implementation. In manufacturing SMEs, the most important areas are production and technological development. Then, it is recommended to proceed with VSM (Villamil and Arteaga, 2023; Memari *et al.*, 2024; Sarria *et al.*, 2017; Ahmad *et al.*, 2022; Hodge *et al.*, 2011), as it is one of the most used and effective tools in SMEs (see Table S4 in Section SM4 of the Supplementary Material). Also, it promotes team involvement, leveraging their process knowledge to detect waste and improvement opportunities. Furthermore, VSM enables comparison of KPIs before and after LM implementation.
- Measurement of initial-state indicators. To assess the current state and enable post-LM comparison, simple and relevant KPIs should be measured (Memari *et al.*, 2024; Mulugeta, 2021; Nedra *et al.*, 2021; Rochman *et al.*, 2024). To define these KPIs, a literature review was conducted to identify the most common KPIs used to measure the LM impact. Such KPIs are detailed in Table 1. It is recommended to use at least three KPIs to ensure reliable evaluation before and after LM implementation.
- Assessment of LM techniques and tools knowledge level within the organization. The knowledge level of LM techniques and tools within the organization should be

**Table 1.** Key performance indicators

KPIs	Description
Production capacity, <i>PC</i>	Quantity of products that an organization can manufacture using materials, workforce, machinery and facilities within a period (Saleeshya <i>et al.</i> , 2012; Sánchez-Partida <i>et al.</i> , 2018; Huang <i>et al.</i> , 2022; Damian-Garcia <i>et al.</i> , 2023; Guzel and Asiabi, 2022)
Defects	Products that do not meet customer standards (Dora and Gellynck, 2015; Díaz-Reza <i>et al.</i> , 2016)
Cycle time	Time required to perform an activity in the production process (Bugvia <i>et al.</i> , 2021; Damian-Garcia <i>et al.</i> , 2023; Rochman <i>et al.</i> , 2024)
Lead time	Time elapsed between the moment the customer places an order until they receive it (Kumar <i>et al.</i> , 2018; Choudhary <i>et al.</i> , 2019; Martins <i>et al.</i> , 2021; Bugvia <i>et al.</i> , 2021; Huang <i>et al.</i> , 2022)
Work in process	Work in process inventory (Choudhary <i>et al.</i> , 2019; Bugvia <i>et al.</i> , 2021)

**Source(s):** Authors’ own work

assessed to ensure effective implementation. Understanding LM strategies is essential for identifying waste, implementing improvements and monitoring changes (Anvari *et al.*, 2011; Vienazindiene and Ciarniene, 2013; Dahab *et al.*, 2023). Personnel must also grasp the functions and limitations of LM tools and the processes required for successful application. The custom yes/no questionnaire on Section SM3 of the Supplementary Material is recommended to evaluate SME personnel's knowledge.

- LM tools selection and training manual. To appropriately select the LM tools and techniques (CSF2) useful for the SME, a literature review must be conducted to identify the most effective tools for the SME of interest. In this respect, we have performed such a review (see Table S4 in Section SM4 of the Supplementary Material) from which 5S, kaizen, VSM, total productive maintenance, single minute exchange die and kanban were found as the most used and effective lean tools in SMEs. As 5S and kaizen are simple enough for a SME to implement independently, we strongly recommend them for SMEs with an individualistic organizational culture, lack of long-term planning and null LM knowledge. Departing from this, a training manual must be developed to facilitate knowledge transfer and continuity among current and new personnel. Therefore, the content must be simple and easy to understand. Thus, we introduce a training manual (Chavez-Escobedo *et al.*, 2024) consisting of four modules. Module 1 is an introduction to LM, Module 2 treats LM philosophy, Module 3 is devoted to 5S tool and Module 4 focuses on kaizen tool. Each module starts with an anonymous and written quiz to diagnose the personnel pre-existing knowledge of the subject. During each module, personnel receives lectures and dynamic activities to stimulate learning acquisition. Among the dynamic activities are brainstorming, kahoot activities and videos. After completing each module, the same starting quiz is applied again to compare results and verify knowledge acquisition. It is highly recommended to ensure a global average of 80% of correct answers before continuing to the next step.
- Designing the master plan for LM training and implementation. This step must establish timelines and assign responsibilities for activities. Also, it should set deadlines for personnel training activities and LM tool implementation. Most SMEs lack production and delivery planning, making it challenging to allocate specific times for tasks outside production. Hence, we recommend to define and schedule the master plan activities when workloads are low. Also, consider flexibility for changes since SMEs prioritizes production and on time delivery.

Throughout the entire pre-implementation phase, the CSF1 is essential. Top management must lead by example in each phase and foster a sense of responsibility among personnel, while ensuring an atmosphere of collaboration and trust. According to the questionnaire that evaluates the knowledge of LM of personnel, B1 often may arise and should be addressed with clear communication explaining that the goal is to improve and not harm anyone.

### 3.2 Implementation

The implementation phase focuses on training personnel in LM tools to boost productivity, standardize knowledge, promote continuous improvement and apply the tools in production:

- Personnel training. Use the manual with materials, evaluations and records developed in step 5 of pre-implementation phase to support the integration of new personnel from the start. Training should promote continuous improvement and emphasize the responsibility

of personnel in maintaining LM standards. In addition, it should be used to identify natural leaders who can oversee LM implementation and future projects.

- Implementation of LM tools. As selected in step 5 of pre-implementation phase, 5S is recommended to be implemented to promote organization and safety. Once 5S is established, kaizen is recommended to be used to foster continuous improvement through the participation of personnel. These tools are efficient, adaptable and suitable for SMEs with an individualistic organizational culture, lack of long-term planning and null LM knowledge.

During the implementation stage, CSF1 is also essential to assign responsibilities and ensure that activities are properly carried out. CSF3 is crucial when introducing personnel to LM and selecting and implementing tools. A process often met with B1. In addition to clear communication, it is recommended to involve personnel in the selection and implementation of tools to foster greater acceptance of the change.

### 3.3 Post-implementation

The post-implementation stage evaluates results using a new VSM to identify remaining opportunities. It encourages personnel-driven improvements and requires management support to sustain continuous improvement. With a strong culture in place and with further training and education, more advanced tools may be adopted:

- Monitoring of LM tools implementation. Post-implementation changes are identified by comparing initial and final KPIs and updating the VSM to detect remaining waste. A cyclical evaluation is recommended to reinforce continuous improvement. It is important that personnel is able to perform this evaluation themselves to ensure ongoing involvement and problem solving.
- Documentation and standardization. Changes in production-related processes must be documented and standardized to ensure efficiency, preserve knowledge and maintain consistency across the production system of the SME.
- Assessment of lean objectives. The top management with the participation of personnel must compare the results achieved with the LM goals, identify the unmet goals and plan further tool implementation if necessary.
- Promotion of continuous improvement culture. Personnel must be encouraged to suggest improvements beyond their tasks. Here, strong management-personnel communication is essential to sustain engagement and ongoing proposals. Also, further training and education on LM tools must be considered.

CSF1 remains essential to sustain continuous improvement strategies and ensure follow up on projects. B1 may arise during the monitoring of LM tools implementation and the assessment of lean objectives due to gaps between planned and actual outcomes. Continuous communication, personnel involvement in both strategy and execution and ongoing training and education (CSF3) are key to maintain progress.

## 4. Case study

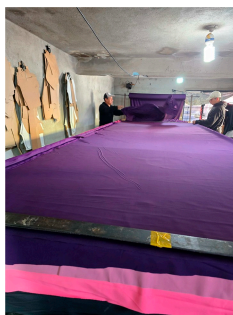
To test the previously described methodology, a unique case study was conducted. The case study in this research is a SME that operates in the apparel industry and is located in the State of Mexico, Mexico. It has been in operation since 2014 with a specializing in the manufacture of women sport pants. It offers a catalog of 12 models, which are produced on

request of two main clients and accordingly with seasonal temperature variations, as the fabrics used are lycra and cotton.

When initiating this research, the SME had 12 employees and operates with a total of fifteen sewing machines, a manual industrial fabric cutter machine, a stamping machine and a trimmer. The production space is 85 [m<sup>2</sup>], divided into two areas: one for cutting, stamping and packaging the fabric, and the other for sewing (Figure 2). The sewing machinery used is semi-automatic, making the sewing quality heavily dependent on the workers' skills. The sewing machines are classified into single-needle, overlock and cover machines. Due to the SME size, the workforce is solely dedicated to operational activities. The administrative processes are handled by the owner, who also participates as part of the personnel.

The manufacturing process of women sports pants in the SME consists of the following:

- Unrolling the fabric. This considers from 12 to 15 layers of fabric, interspersing a light color and a dark color. It is performed in the mornings. As the fabric is deformed after the unrolling, the unrolled fabric is left to rest until the next day to continue the work process.
- Tracing the model. In this process pants patterns are used, which are manually organized without having a standardization of the number of pieces to obtain from each fabric. Operators use their own devise to obtain the quantity and sizes of pants requested by client.
- Fabric cutting. For this process a manual industrial fabric cutter machine is used. The cutter has an 8 [in] blade, this being the reason of the maximum number of layers unrolled in the activity 1.
- Separating the cut pieces. All the light colors are put together as well as all the dark colors. Depending on the model, each section piece must be separated into batches.
- Sewing the pieces. Involves up to thirteen operations depending on the model from the twelve of the SME's catalog. These operations are: strip to pants, pocket casing, pocket locked, frontside seam, backside seam, front with back seam, stitching over front and back seam, waistband casing, pants and waistband seam, stitching over waistband seam, cuff casing, pants and cuff seam and flip pants.



(a) Cutting, stamping, and packaging area



(b) Separation and sewing area

**Figure 2.** Production areas of the SME

Source: Authors' own work

- Stamping the pieces. This is carried out with two stamping machines, which are manual and have one piece capacity. The stamps used in the process are produced by the SME, where the stamps are clipped to the necessary size.
- Packaging the pieces. The completed pants are folded and packaged in plastic bags.

Figure 3 illustrates the manufacturing process of women sports pants in the SME.

## 5. Application of the proposed lean manufacturing model

In this section, the phases and steps from the LM model proposed in Section 3 are applied to the case study introduced in Section 4. It is worth mentioning that an author served as facilitator and followed up the owner and personnel throughout the LM implementation in the SME.

### 5.1 Pre-implementation

The five steps of the pre-implementation phase of the proposed LM model, suggested in Section 3.1, are applied to the case study as follows:

- Development of lean policy and objectives. Here the CSF1 (commitment of top management) is considered. Hence, the top management (owner) organized meetings to define the lean policy and objectives shown in Table 2, aligning them with the existing mission and vision of the SME. In particular, with productivity.
- Initial analysis and diagnosis. On the one hand, the yes/no questionnaire developed by García and Sánchez (2015) (see Section SM2 of the Supplementary Material) was collectively answered by the owner (CSF1 ensured) and the personnel to assess the maturity level of the SME. Hence, current limitations and opportunities directly related to the production process were identified. Regarding the management area, lack of knowledge of the mission and vision of the personnel was found, also no short- and long-term objectives were defined. With respect to the finances area, unknown unitary costs of production and minimal reinvestment were identified. Whereas in production area, the results highlighted the need to define a production scheduling, to determine acceptance criteria for finished products, as well as to document and communicate them along with the production process. Also, one issue was identified in technological development area: the production relays on outdated machines with defects due to lack of cleanliness and maintenance. Lastly, in human resources the need of designing training methods and absenteeism were identified. On the other hand, with the participation of the owner (CSF1 ensured) and the personnel, a VSM was built to visualize the entire production process for the manufacturing pants, so that non-value-added (NVA) activities were identified. Given the variety of sports pants produced, the most in-demand model was selected to perform the VSM. The initial VSM is shown in Figure 4, which represents the seven processes depicted in Figure 3. For the sewing, stamping and packaging processes, the cycle time was recorded 30 times. As the remaining processes (unrolling, tracing, fabric cutting and separating) are performed only once per week, only four measurements were taken for each one. Note the process five has thirteen operations (strip to pants, pocket casing, pocket locked, frontside seam, backside seam, front with back seam, stitching over front and back seam, waistband casing, pants and waistband seam, stitching over waistband seam, cuff casing, pants and cuff seam and flip pants). Hence, a total of 18 operations are in Figure 4. Due to seven of the twelve operators were assigned to the sewing process, a continuous flow process was not viable because the work load cannot be balanced. Furthermore, from

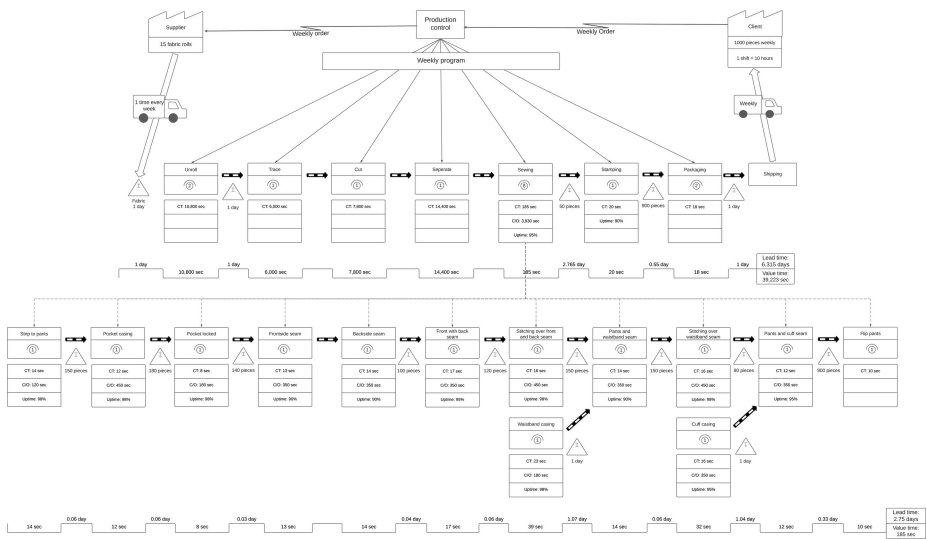


**Figure 3.** Manufacturing process of women sports pants in the SME  
**Source:** Authors' own work

**Figure 4**, lean wastes related to defects, unused talent, inventory and overprocessing were observed; the NVA activities being: five defects (oil stain, stitch jump, sewing failure, puckering stitch and damaged fabric) caused by unmaintained machines, human errors, and supplier, respectively; some operator ways to maneuver the fabric

**Table 2.** Lean policy and objectives

Lean policy	Objectives
Promote a continuous improvement philosophy among personnel with the aim of encouraging them to develop proposals for the solution of internal problems to eliminate waste and manufacture products without defects	<ol style="list-style-type: none"> <li>1. Increase the SME PC in 15%</li> <li>2. Reduce the production defects in 40%</li> <li>3. Reduce work in process in 10%</li> </ol>
<b>Source(s):</b> Authors' own work	



**Figure 4.** Initial VSM related to the production process to manufacture the SME's most demanded pants  
**Source:** Authors' own work

that lead to an operation more efficient, but unknown by the owner and the rest of the personnel; excess raw materials; and, prolonged searching for the correct yarn color. These situations resulted in NVA time.

- Measurement of initial-state indicators. The KPIs were measured with the owner participation (CSF1 ensured) to identify the SME's initial state (Table 3). For PC and defects, initial results were obtained from 35 data points. Then, PC was calculated as follows:

$$\frac{PC_b}{Tt_b} = \frac{1180}{56.83} = 20.76 \text{ units per hour,} \tag{1}$$

where  $Tt$  is total time in hours, and subscript  $b$  denotes computation for before LM tools implementation. A 95% confidence interval was also calculated. Whereas the cycle time, lead time and work in process were obtained from Figure 4.

- Assessment of LM techniques and tools knowledge level within the organization. The authors' own yes/no questionnaire in Section SM3 of the Supplementary Material

**Table 3.** Key performance indicators before LM tools implementation

KPIs	Initial-state result	95% confidence interval
PC	1,180 units per week 20.76 units per hour	1,144–1,215 units per week
Defects	22 units per week	20–23 units per week
Cycle time	39,223 [s]	
Lead time	6.315 days	
Work in process	110 units	

**Source(s):** Authors' own work

was administered in writing and anonymously by the owner to all personnel of the SME. With the participation of the owner the CSF1 is guaranteed and also the B1 is mitigated. The results indicated a null knowledge regarding LM among the personnel.

- LM tools selection and training manual. Since SME personnel had null knowledge on LM tools, the LM tools (5S and kaizen) recommended in Section 3.1 are adequate in this case (CSF2 achieved). Hence, the training manual provided by [Chavez-Escobedo et al. \(2024\)](#) is also applicable for the SME.
- Designing the master plan for LM training and implementation. The master plan was structured with the owner participation (CSF1 ensured) to cover one training module of the training manual ([Chavez-Escobedo et al., 2024](#)) per week. Also, one month was allocated for the implementation of each LM tool (5S and kaizen). Consequently, a total duration of three months was scheduled for the implementation phase.

## 5.2 Implementation

The application of the steps of the proposed LM model implementation phase is described below:

- Personnel training. To overcome the null knowledge on LM in the SME, the training manual ([Chavez-Escobedo et al., 2024](#)) was used. After completion of each module of the manual, the SME personnel obtained the average correct answers shown in [Table 4](#). While, 80% was obtained as global average by the personnel. Also, two natural leaders of the personnel were identified. They and the owner were engaged in all the activities of the training (CSF1 ensured) to face B1. Note that the whole step corresponds to CSF3. When treating subjects in modules 3 and 4 of the training manual ([Chavez-Escobedo et al., 2024](#)), which are related with 5S and kaizen, a collaborative atmosphere was encouraged through a brainstorming session to generate ideas for improving either the work areas and processes. This activity

**Table 4.** Results of applied quiz after lecture and activities

Module	Average result (%)
Module 1	78
Module 2	73
Module 3	86
Module 4	83

**Source(s):** Authors' own work

revealed: without a safe space to share ideas, personnel tend to keep their suggestions to themselves; the personnel improvement proposals, such as changing the way the separation process is done to reduce cycle time, keeping clean and functional work spaces, reducing time in changing yarns and reducing defects. These proposals were recorded for implementation.

- Implementation of LM tools. This was carried out only for the separation and sewing processes. During this step, two workers resigned the SME. Hence, the engagement of the owner (CSF1 ensured) and the natural leaders was essential to mitigate B1. On the one hand for 5S, a cascade schedule was agreed by the owner and the personnel to carry out the implementation of the first two S when each workstation had the lowest load. The third S was performed when the lot was completed, focusing on restoring all the machines to a near-fabric state. This advance so far was set as the fourth S. For the five S, two check lists were created; one to follow up the defined standard function of the sewing machines, and the other to check out the first three S in the workstations. Figures 5 and 6 are examples of the workstations state before and after the 5S implementation. On the other hand, kaizen was implemented



(a) Cover sewing machine state before 5S



(b) Cover sewing machine state after 5S



(c) Overlock sewing machine state before 5S



(d) Overlock sewing machine state after 5S

**Figure 5.** Machines before and after the 5S implementation

Source: Authors' own work



(a) Workstation before 5S. Work batches in process of separation by color are provoking a contingency and strips worn down are not labeled

(b) Workstation after 5S. Walking hall freed and new strips labeled by length and pants size

**Figure 6.** Separation process workstation before and after the 5S implementation

**Source:** Authors' own work

departing from VSM in [Figure 4](#) and the recorded improvements proposed by the personnel during training; reducing time and defects in the sewing process. Some improvements examples are described as follows. In separation process, the pants parts batches were separated just in two new batches, by light and dark colors, using strips with a color code for pants size. To ensure the shade of dark color parts matches when assembling a pants, numbers up to 12 were iteratively labeled on them. Previously, the separation process was performed making mini-batches for parts of each light and dark color as piled in the whole pants parts batches. Same color strips grouped by pants size were used. To verify the shade of the dark color parts, the strips were the ones numbered. See [Figure 7](#). After organizing yarn racks by most frequently used colors during 5S implementation, the yarn racks were arranged accordingly with the colors to be used for the layered batches, so that the next yarn color to be used is immediately after ([Figure 8](#)). To minimize rework caused by stitching defects due to human errors in the sewing process, the sewing thickness with cover machines was standardized by using guides of 2.5 [mm] thickness with tape, placed beside the foot presser (see [Figure 9](#)). This led to almost no stitching defects. As oil leaking in cover sewing machines was still a problem causing defects, a piece of fabric was wrapped around the machines control pistons above the foot presses ([Figure 9](#)). This fabric was changed twice a day to avoid leaking. Lastly, a major problem was the high work in process (110 pants of both light and dark colors) between each operation, consequently long lead times. To overcome this, the work was divided by color (light and dark), resulting batches of 60 pants on average.

### 5.3 Post-implementation

The steps of the post-implementation phase are described here:

- Monitoring of LM tools implementation. Once the implementation phase is completed, a before and after comparison was carried out to identify the impact on each KPI. For this, the VSM was updated ([Figure 10](#)) and production data was collected with the owner and personnel participation. Hence, CSF1 is achieved. PC and defects were tracked for six months having a data set of 30 points. This because they can be measured



(a) Fabric pieces (eight light and five dark colors) for a large size pants after cutting and before separation process



(b) Thirteen resulting batches in separation process before kaizen



(c) Two resulting batches in separation process after kaizen



(d) Several batches using color code strips for pants sizes (yellow for medium size and white for large size)

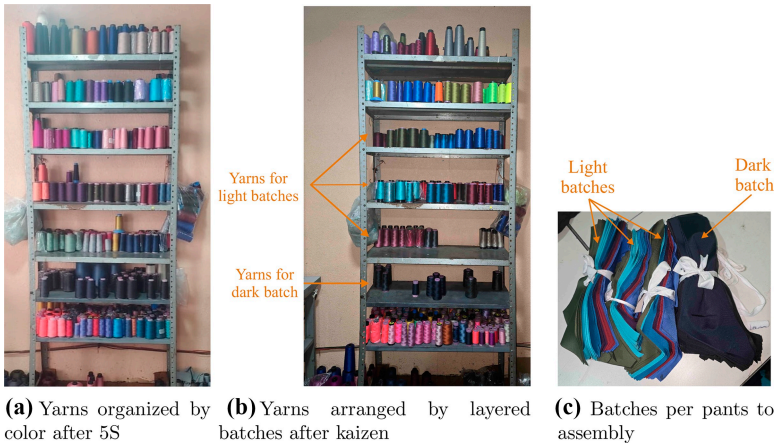
**Figure 7.** Changes made in separation process with kaizen

**Source:** Authors' own work

only at the end of the delivery of each of the orders, occurring this every 4.77 days. Now  $PC$  is found as follows:

$$\frac{PC_a}{Tt_a} = \frac{1250}{42.93} = 29.11 \text{ units per hour,} \quad (2)$$

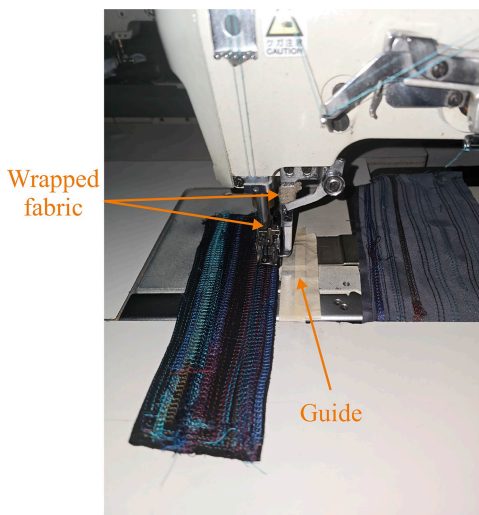
where  $Tt$  is as defined in (1), and subscript  $a$  denotes computation for after LM implementation. Whereas cycle time, lead time, and work in process were recorded within the next three months, obtaining also 30 data points after the implementation phase. Thus, an average was obtained for all KPI. For  $PC$  and defects, a 95% confidence interval was obtained. The KPI results after LM tools implementation are presented in Table 5. A graphical comparison between initial-state KPIs (Table 3) and final-state KPIs (Table 5) is shown in Figure 11. There, subscripts  $b$  and  $a$  stand for before and after, respectively, and Def is defects:



(a) Yarns organized by color after 5S (b) Yarns arranged by layered batches after kaizen (c) Batches per pants to assembly

**Figure 8.** Yarns arranged accordingly with the layered batches to assembly pants

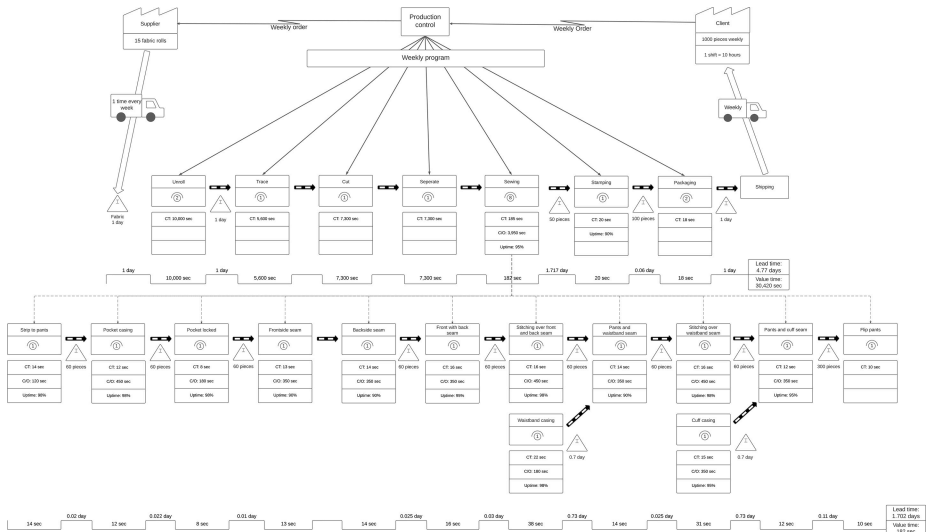
**Source:** Authors' own work



**Figure 9.** A guide positioned beside the foot press, preventing the stitch to go sideways and fabric wrapped around the machines control pistons avoiding oil leaking

**Source:** Authors' own work

- Documentation and standardization. The SME owner updated the operating manuals (CSF1 ensured) with the changes made in the past phases. This allows new personnel to be trained with up-to-date knowledge to keep the production system current and functional. In addition, follow up activities were standardized, including checklists, cleaning of workstations and organizing storage areas. In addition, standardized operation



**Figure 10.** Final VSM for the production process to manufacture the SME's most demanded pants  
**Source:** Authors' own work

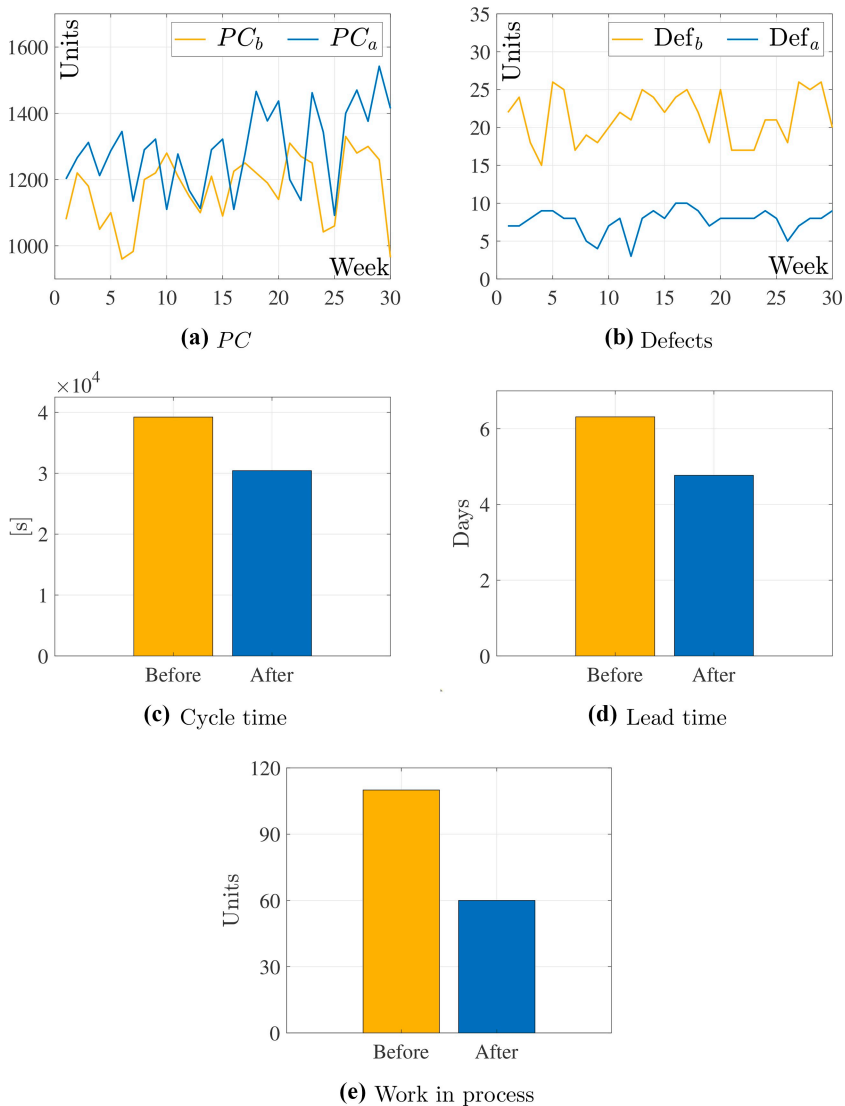
**Table 5.** Key performance indicators after LM tools implementation

KPIs	Final-state result	Impact (%)
PC	1,250 units per week 29.11 units per hour	+ 40.23
Defects	8 units per week	-63.63
Cycle time	30,420 [s]	-23.71
Lead time	4.77 days	-24.46
Work in process	60 units	-45.45

**Source(s):** Authors' own work

process sheets were elaborated with the required specifications to accept or reject pants based on quality.

- Assessment of lean objectives. The achievement of the goals established in the pre-implementation phase was corroborated by the SME owner (CSF1 ensured). The goal of increasing PC by 15% was achieved by raising the number of units produced per hour from 20.76 to 29.11, resulting in a productivity increase of 40.23%. The defect reduction was higher than the planned, exceeding the established goal by a margin of 23.63%. Regarding work in process, a reduction of 45.45% was achieved, exceeding the initial target by 35.45%.
- Promotion of continuous improvement culture. Having adopted the LM production model, it is the owner's responsibility to encourage personnel to continue improving the production activities of the SME (CSF1), by providing further training and education on LM tools (CSF3).



**Figure 11.** KPIs result comparison before and after LM application  
**Source:** Authors' own work

#### 5.4 Discussion and results

The proposed LM model in Section 3 was applied in a case study: a Mexican SME that produces lycra and cotton pants, initially with 12 employees and then with ten employees managed by the owner. An initial lack of interest was observed from the personnel regarding the transition to the LM model, as they did not see how the approach would personally benefit them. Hence, an individualistic organizational culture and the existence of B1 was

confirmed. Also, the pre-implementation phase revealed minimum resources for investment, a lack of long-term planning and null knowledge of LM approach. Therefore, the SME belongs to the type of organization for which the LM model in Section 3 was designed. To successfully deal with the cultural, organizational and financial drawbacks, the owner's example and eloquence (ensuring CSF1), as well as the identification and the engagement of the natural leaders, were central to successfully complete the transition from the common-sense production model to the LM model in the SME.

During the implementation phase of the LM model, 5S delivered significant improvements in the workstations. However, the most effective tool was kaizen, which led to improvements such as organizing the yarn racks by color sequence for the sewing process, separating the pants parts so that the number of resulting batches was reduced by half, and designing guides to avoid defects in the sewing operation. Therefore, the post-implementation phase yielded results with a positive impact on all KPIs, exceeding the established goals and confirming the success of the LM model application. These results also confirm an appropriate selection of LM tools for the model (achieving CSF2) and an adequate personnel training and education (accomplishing CSF3).

### 5.5 Limitations of the study

One of the main limitations of this study is that it is based on a single case. Further research should replicate the proposed LM methodology across SMEs from different industries to validate its generalization. Nevertheless, since the approach adopted is people-centered and CSFs and barriers were considered, the findings may serve as a useful reference to escalate its application in other manufacturing SMEs characterized by individualistic organizational culture, lack of long-term planning and null knowledge of LM approach.

As the company is small, another limitation concerns the direct participation of the owner throughout the entire application of Lean tools, such as kaizen. This situation can lead to two scenarios: the presence of top management during implementation could restrict employees' freedom of expression; and a genuine top management commitment in the improvement tools being implemented, as highlighted by [Knapić et al. \(2023\)](#). In the case presented, such participation proved to be effective, i.e. the second scenario, although it cannot be generalized as a universally applicable condition.

## 6. Conclusions

This paper has proposed a people-centered model to implement LM approach for improving productivity in SMEs characterized by individualistic organizational culture, lack of long-term planning and null knowledge of LM approach. The model was designed on the basis of literature review with case studies applying LM. From that review, firstly the similar CFSs and barriers between large enterprises and SMEs that most impact them when applying LM were determined; and, secondly the most used and effective lean tools for SMEs were identified. Thus, motivated by [Belhadi et al. \(2016\)](#), we define three phases for our LM model, each one with steps completely personalized by us.

The proposed LM model was applied in a Mexican apparel SME fitting the characteristics for which the model was designed. The obtained results, improving the five KPIs (*PC*, defects, cycle time, lead time and work in process) defined to evaluate the model, confirmed a successful implementation and validated the effectiveness of the proposed LM model. This proposal and the application *in situ* of the LM model contribute to the literature in group *LM model proposals and their implementation in SMEs* and, consequently, close the gap between the literature in groups *proposals for the implementation of LM models in SMEs* and *LM model implementation from an existing model proposal* in Section 2. Thus, we conclude that

the proposed LM model can be applied to other SMEs, not just those in the apparel industry, belonging to the type of organization for which it was designed.

Note that the success of the LM application in the case study is mainly due to the achievement of the CSFs, which mitigate B1 in a strong way. Hence, it is important to note that the involvement of employees, through the commitment of the top management, keeps them motivated to continue making improvements, even with limited financial resources.

Future research includes the implementation of this methodology in other manufacturing SMEs to test its robustness and generalization in different industrial contexts. Also, Lean principles could be aligned with Circular Economy strategies, enabling SMEs the creation of value through the reuse of process by-products or residues, for example, by transforming waste into inputs for new products. Additionally, Lean practices can be applied in organizational areas beyond operations. One promising direction is their application in Human Resources, where Lean could support strategies to reduce employee turnover and improve workforce stability. Furthermore, in line with current trends, it would also be relevant to integrate Lean practices with green manufacturing approaches to promote that SMEs not only improve efficiency but also minimize their environmental impact.

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### Supplementary material

The supplementary material for this article can be found online.

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