

Lean Manufacturing Tools for Operations Management Based on PDCA Cycle

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Abstract

Processes management allows improvement in management and productivity since it allows to have a global vision of the entire organization, at the same time, lean manufacturing tools help to improve production/administrative systems and encourage continuous improvement. This work proposes a continuous improvement model that brings together the two aforementioned approaches, taking the PDCA cycle as a starting model. The methodology used in this work begins with a bibliographic review of the topics of interest, process management and lean manufacturing tools, then an analysis of the PDCA improvement cycle is carried out, focusing on the scope and objective of each stage. Finally, an improvement management model is presented that suggests which lean manufacturing tools are the most appropriate to develop each of the stages of the PDCA cycle. The results show that the proposals effectively combine these tools, and their implementation is feasible in companies of all kinds, regardless of their size and activity. The proposed model was tested through a pilot test in a footwear manufacturing industry located in the city of Cuenca-Ecuador with results consistent with the philosophy of continuous improvement.

Keywords

Lean manufacturing, Operations management, PDCA cycle

1. Introduction

Currently, SMEs face various and complex problems, but without a doubt one of the most critical aspects is inadequate management in aspects such as inventory control, optimization of production processes, education of human talent, among others. In many SMEs there are no process manuals that guide the manufacturing of different products, likewise, there is no adequate organization of work tools in different positions. SMEs cannot always be managed like

large companies, which means that poor management very often causes loss of money, high production costs, inventory accumulation and other types of problems that trigger the dissatisfaction of both internal and external clients. One of the practices that has worked in many small and medium-sized companies to improve management is to implement the use of Lean Manufacturing tools, this is because it is not necessary to make high monetary investments and the relative technical ease for their implementation.

Lean Manufacturing is a set of tools or techniques that form a system based on the reduction or elimination of waste in the production processes of a company, waste being understood as any activity that does not generate value for either the product or the customer (Rojas and Gisbert, 2017). The main purpose of Lean Manufacturing is to minimize losses generated in production processes, especially in those cases in which overproduction, high waiting times, defective products, etc. occur. In other words, Lean Manufacturing seeks to optimize resources (people, materials, machinery, methods) with the aim of achieving continuous improvement in quality, service, and organizational efficiency. That is why it is said that, for the application of this system, the commitment of the staff is necessary, both executives and employees, since its application demands a change in the organizational culture and in the administration, so that it is consistent with leadership to achieve motivation in self-growth (Socconini 2019). For Socconini (2019),

“ the true power of Lean Manufacturing lies in continually discovering the opportunities for improvement that every company hides, since there will always be waste that can be eliminated. It is about creating a way of working that recognizes that waste exists and will always be a challenge for those willing to find and eliminate it. (p. 20)”

On the other hand, process management, today, is important for all types of companies, since it allows them to have a high level of productivity and satisfy the requirements demanded by customers (Hammer, 2006). In addition, its application helps to improve the total quality of the product, since a comprehensive system of processes is carried out, thereby achieving continuous improvement (Zaratiegue 1999). This is why it has been considered important to propose a model that mixes the use of lean manufacturing tools and a process management model in order to propose a management alternative to company managers that allows improving the performance of companies in a simple way that can be put into practice without high complexity.

1.1 Objectives

This article aims to propose a process management model for SMEs based on the use of lean manufacturing tools. The model covers the stages of the PDCA cycle and presents a quick action guide that can be implemented without high investments or technical complexities.

2. Literature Review

Lean Manufacturing

Lean Manufacturing originated in the late 19th century with Sakichi Toyoda, founder of the Toyota group. Toyoda created several inventions, one of the most important being a system for automating manual work and detecting problems on looms. In addition, this system had the ability to detect errors in the machine called “Jidoka”, automation with a human touch. This device stopped production when defects were identified and this prevented the production of errors, thus increasing productivity, since only one operator was enough to control several machines (Hernández Matías and Vizán Idoipe 2013).

Later, his son Kichiro Toyoda opted for improvement techniques for his father's looms where the machines, facilities and people worked together to not generate any type of waste, thus adding value both in lines and in processes. In this way, he managed to keep the machines running without interruptions for several shifts; This working method was called Just in Time. After Eiji Toyoda took over the company, he managed to increase the productivity of workers; Furthermore, he created a model whose purpose was to produce only what was demanded when the customer needed it. This helped reduce tool change times and overproduction (Hernández Matías and Vizán Idoipe 2013).

The importance of Lean Manufacturing at an organizational level lies in the fact that companies currently face increasingly competitive and demanding markets, which is why they are in a constant search for people, tools, models, and systems that are essential in the management of their operations. that allows them to optimize resources by

eliminating all those activities that do not generate any value and that represent unnecessary costs or other types of waste within the company's operation (Malpartida Gutiérrez 2020).

Furthermore, it is important to establish that Lean Manufacturing offers different tools that can be applied individually or together depending on the needs of the company. Thus, when an organization applies the Lean system, it achieves continuous improvement in its operations, offering higher quality to the customer, greater productivity and reducing costs in its operations. However, despite all the benefits that Lean Manufacturing provides, its implementation is far from simple, which is why small and medium-sized companies are not usually in favor of applying this philosophy. In fact, to achieve this, a solid organizational culture is needed where all members share and pursue the same business objectives (Malpartida Gutiérrez 2020).

Lean Manufacturing and its relationship with the value chain

Lean Manufacturing has a close relationship with the value chain of companies because, on the one hand, what the former seeks is to generate value by eliminating waste; and, in turn, what the second seeks is to create value for the client, minimizing costs based on key activities and areas for management, direction and support in operations. Furthermore, this relationship allows us to establish that Lean Manufacturing influences the improvement of the value chain by identifying and eliminating waste in any activity of the links that make it up through the application of its tools with the main objective of providing greater added value to the client and allowing the company to differentiate itself within the competition, achieving efficiency and effectiveness in its operations (Vaca 2020).

Now, it is also important to remember that the value chain, being made up of several activities where waste that is visible or hidden can be found, Lean Manufacturing has the capacity to manage it in such a way that, working together with These two management tools can produce quite favorable results for companies, creating competitive and attractive advantages for markets that are increasingly demanding and that are at the forefront of new processes and methodologies to be much more competitive (Vaca 2020).

Although Lean Manufacturing is important in the business environment because it improves efficiency and effectiveness in organizational activities, even more so is the importance it acquires when talking about production processes carried out by manufacturing companies. The reason for this is that one of its main organizational objectives is to increase productivity, which will be achieved when waste or activities that do not add value are identified and managed. In this way, the company will minimize losses, improve quality, reduce manufacturing times and costs, which will in turn translate into great economic and business benefits (Rojas and Gisbert 2017).

Lean Manufacturing Tools

Numerous tools are part of Lean Manufacturing, which have been developed over the years and can be implemented alone or together, among the most relevant are those mentioned below.

5's Philosophy

It is a tool oriented by a Japanese culture that is based on order and cleanliness, that is, its objective is to maintain clean, organized, and safe work areas. It is important to recognize that the 5's are the basis for the application of other improvement tools because it promises that the processes are aimed at total quality (González Correa 2007). The 5's is made up of the following stages, (1) Seiri: Separate and discard those elements that are not necessary in the work area, both in production areas and in administrative areas. (2) Seiton: Sort and identify the elements that are essential to carry out the work in such a way that it is easy and quick to find said elements. (3) Seiso: Cleaning of the workplace and equipment to avoid dirt and maintain safe work areas. (4) Seiketsu: Standardize to preserve the organization, to achieve Seiketsu it is necessary to have carried out the previous three S's. (5) Shitsuke: Systematize or discipline, that

is, maintain previous procedures. It involves controls, surveillance, and self-control on the part of employees (González Correa 2007).

With the implementation of the 5's, positive results are obtained for the company, such as, for example, increase in quality, reduction in manufacturing time, longer useful life of machinery and equipment, decrease in defective products, control of the workplace, among others (González Correa 2007)

Single minute exchange die (SMED)

It is a methodology that allows the reduction of machinery preparation times or reduce manufacturing times through rapid changes. Manufacturing time is given by three times: manufacturing time, waiting time between processes and transportation time. If a reduction in any of these three is achieved, the manufacturing time of the product will have been reduced. This is where this tool comes into action since it seeks flexibility and above all has the ability to react quickly to the client's needs (González Correa 2007). Among the benefits that SMED can bring to companies we can mention, (a) Reduced downtime: SMED's focus on quick changeovers led to significantly reduced downtime, resulting in increased production capacity. (b) Improved flexibility: Quick changeovers allowed for more frequent product changes and improved response to customer demands. (c) Enhanced quality: Minimized setup times reduced the potential for errors during changeovers, leading to improved product quality. (d) Cost savings: Reduced setup times translated into cost savings related to labor, energy, and maintenance. (e) Employee engagement: The involvement of employees in SMED activities increased their engagement and problem-solving abilities (Shingo 1985, Singh et al. 2018, Singla and Sharma 2023).

Total Productive Maintenance (TPM)

This is a tool that allows you to eliminate or minimize time losses due to unscheduled machine stops. To carry out this tool, it is important that workers know in detail the processes and equipment that exist in the company. Furthermore, it is important that the 5's have been applied, given that for TPM cleanliness plays a primary factor, since when the workplace is kept clean it facilitates the identification of problems (Lazala Rosario n.d.). Some of the benefits of TPM are, (a) Increased equipment efficiency, TPM's emphasis on proactive maintenance and improved operator skills led to a significant increase in equipment efficiency and reduced downtime. (b) Cost reduction, Planned and predictive maintenance reduced maintenance costs and minimized unexpected breakdown expenses. (c) Enhanced safety: Improved equipment reliability and maintenance procedures led to a safer working environment. (d) Employee Engagement: TPM fosters a culture of ownership and participation among employees, driving higher levels of engagement. (e) Quality Improvement: Reduced equipment failures and improved reliability contributed to higher product quality (Gupta V. and Tewari, R. 2008, Nakajima, S. 2014, Narayanan and Periyasamy 2016).

Standardization

Standardization creates consistent guidelines to ensure uniformity, quality, and efficiency across a wide range of industries and domains, to obtain excellent quality products, it is necessary that the work is always done in the same way, that is, that the same process is carefully followed and, to do so, employees must align themselves with certain standards and procedures established by the company in the production area. Standardization offers substantial benefits such as, (a) Innovation acceleration: Standardization acts as a catalyst for innovation, facilitating interoperability and compatibility among different technologies and products. (b) Efficiency and Cost Reduction: Streamlined processes reduce costs and enhance operational efficiency, as seen in manufacturing. (c) Quality and Safety: In any industry standards are crucial to maintain the safety and proper operation of equipment and machinery. Two tools that are very useful for working on standardization are the Standard Operating Sheet (SOS) and the Job Element Sheet (JES) (Rhoades D. and Waguespack B. 1999, Zekos G. 2003, Parker L. 2003, ISO 2023).

PDCA Cycle

The PDCA (Plan-Do-Check-Act) cycle, a fundamental tool in quality management and continuous improvement, has been a cornerstone in various industries. The core principles of the PDCA are, (a) Plan: This stage involves identifying a problem or opportunity, setting objectives, and developing a plan to achieve those objectives (Deming, W. E. 1986). (b) Do: In this stage, the plan is executed, and the proposed changes or improvements are put into action. (c) Check: Performance and results are assessed to determine whether the objectives are being met, using data and key

performance indicators (Langley, G. L. et al. 2009). (d) Act: Based on the check stage, necessary adjustments and improvements are made, and the cycle begins again.

Although the PDCA cycle is not new, it is still a highly consistent management tool, especially when it comes to organizing work in small and medium-sized industries. Among the advantages that this tool can provide are: (a) Continuous improvement: The PDCA cycle fosters a culture of continuous improvement by regularly reviewing processes and making necessary changes (Ishikawa, K. 1985). (b) Problem solving: It provides a structured approach to problem-solving, ensuring issues are addressed systematically (Shewhart, W. A. 1939). (c) Data-Driven decision-making: The check stage emphasizes the use of data and analytics to make informed decisions. (d) Risk Mitigation: By continually checking and acting, potential issues can be addressed before they become significant problems (Moore, D. S. et al. 2015). (e) Adaptation to Change: The PDCA cycle is flexible and adaptable, making it suitable for various industries and scenarios

While the PDCA cycle offers numerous advantages, it also presents challenges, such as the need for effective data collection and analysis, and sustaining a culture of continuous improvement (Radnor, Z., and Johnston, R. 2016). The core principles of planning, doing, checking, and acting remained consistent, while contemporary challenges and case studies emphasized its enduring relevance in diverse fields. The PDCA cycle has adapted to modern business environments, offering a robust methodology for achieving excellence in processes and outcomes.

3. Methods

The following research is of the non-experimental, exploratory-descriptive type since it is based on observation and analysis of information. The research conducted has a qualitative approach, since it is based on techniques that allow the diagnosis, implementation, and evaluation of management models.

The proposed method consists of three phases: in the first phase, techniques are proposed to diagnose the current situation of the company and detect problems and their possible causes; in the second phase, a method is proposed to organize process management based on the PDCA cycle, focusing on the management of the problems detected; and finally, a set of lean manufacturing tools is proposed that can be used to support each of the phases of the PDCA cycle. The proposed model has been tested in several small and medium-sized industries in the city of Cuenca-Ecuador with a high level of success over four years.

4. Results and Discussion

Through the bibliographic review it has been possible to identify a series of basic tools that can be useful to create a process management model of great applicability in small and medium enterprises, since simplicity and low investment have been prioritized for the development of its stages. In the first stage, the aim is to know the current situation of the company (area), for which three activities are proposed: first, the structuring of a process map, the identification of the organization's value chain, and the elaboration of a SWOT analysis (general or local).

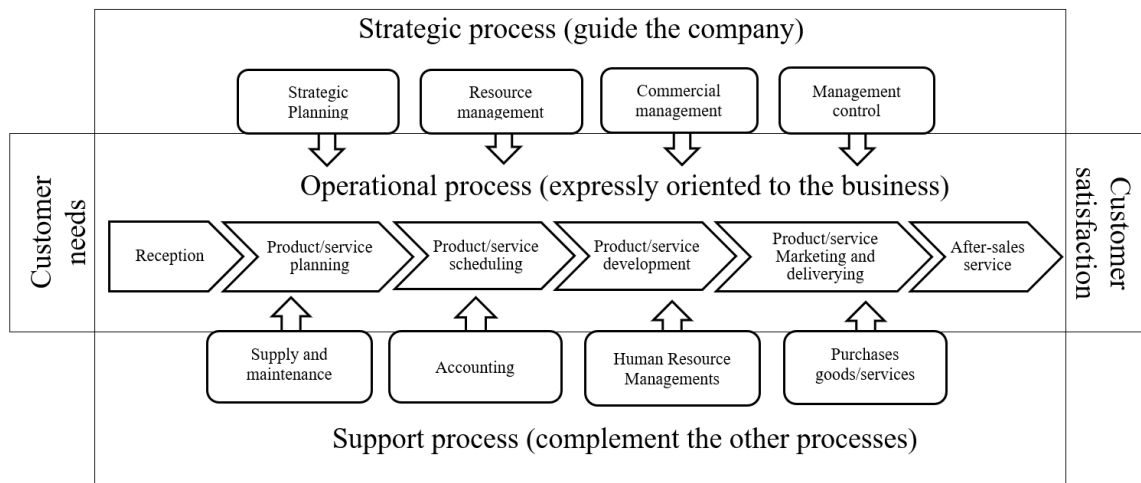


Figure 1. Generic process map

Structuring a process map consists of identifying the organization's strategic, operational, and support processes. This task is important because first, it provides a clear understanding of how the organization is functioning, and second, it helps to delimit the areas of work, considering that improvement activities carried out on the strategic or support processes will always have the greatest impact, since these guides the actions developed in the operational processes. Figure 1 presents a guide to some of the processes that can be identified in each of the groups, it is also convenient to develop a process interaction matrix to evaluate how each process impacts on the rest of the activities throughout the organization, although the processes may be multiple and diverse in each area, it should be remembered that SMEs will not always have a large number of them, this should not cause fear or be a limitation to continue with the subsequent stages since SMEs are often not organized in such a formal way as large companies.

A second activity within this stage consists of identifying and locating the processes according to their position in the value chain. The most widespread concept of value chain is the one created by Porter in 1986 (Figure 2). In this scheme the author divides business activities into two main groups, primary activities, and support activities; primary activities include all those that are directly involved in the creation of the product, its marketing and post-sales support. On the other hand, the support activities are those that sustain the operation of the primary activities, these have the characteristic of being cross-functional since they support the actions of all the primary activities. Qualitative methods are the easiest to identify the activities of the value chain, for this you can use questionnaires such as those proposed by Gonzalez et. al, (2023) as they are easy to apply and do not require a high level of technical knowledge.

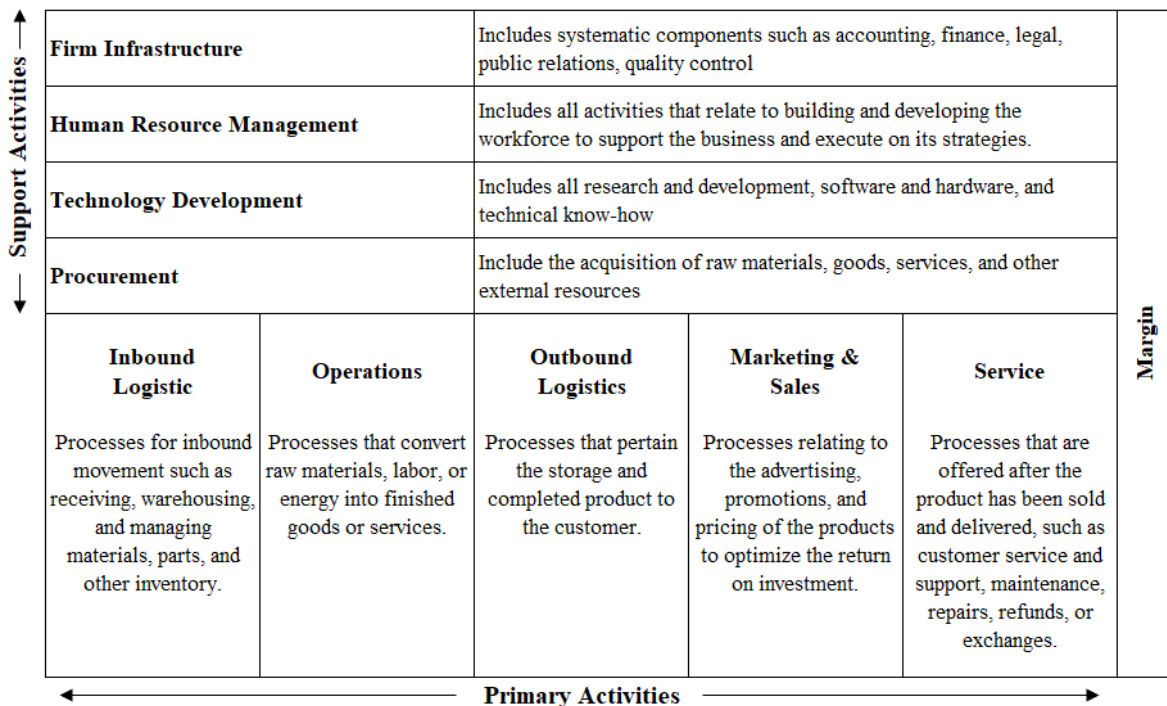


Figure 2. Porter's Value Chain

The final activity consists of performing a SWOT analysis, which basically consists of identifying the environment in which the company operates. This analysis helps companies to identify the strengths and weaknesses, as well as the opportunities and threats of a business. With this tool it is possible to evaluate the strategic position of a company, organization, or project, and strategies can be defined to maximize strengths, minimize weaknesses, take advantage of opportunities, and confront threats. Any business can use SWOT analysis, regardless of the segment or size of the company. The technique can be applied even in different sectors of the same organization; however, it is necessary to have a detailed knowledge of the reality of the company and the environment, this is where the two previous activities become relevant. In this last activity of the diagnostic stage, the focus is on weaknesses and threats since this is where the proposals for improvement can have the greatest impact.

Once the company's internal environment has been determined and its critical points have been identified through the SWOT analysis, it is necessary to determine the origins or causes that have led to the development of weaknesses and potential threats. It is important to work on this point since working only on the visible effects (not the root causes) will only result in palliative actions that will diffuse the problems for a moment but allow them to return in the medium term. In order to have a better perspective of the root causes of the problems, it is recommended to use two tools, which although simple, are very effective for this activity, first, the cause-effect diagrams and then a mixture of what could be the quality circles, the juries of executive opinion or the Delphi method, making sure that in the execution of each activity of this phase both managers and workers are involved, since the latter can provide much valuable information that is not always available to managers.

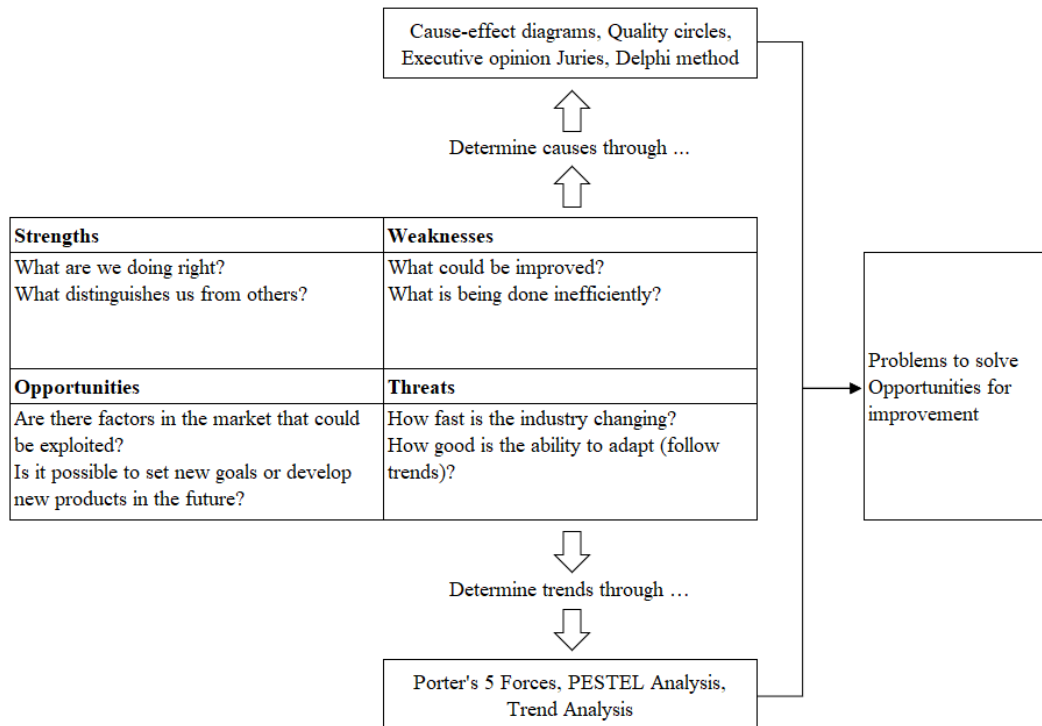


Figure 3. SWOT Analysis

In the second stage, once the problems and their causes have been detected, corrective measures are proposed to eliminate them. This can be done through a 4-stage procedure based on the PDCA cycle, the proposal begins with the planning stage where it seeks to propose plans that can mitigate the weaknesses or threats, as in the previous stage these plans can be conceived through meetings where the participation of all staff (not only managers) is encouraged, some techniques that are useful at this stage are brainstorming, quality circles, juries of opinion or the Delphi method. It is important at this stage to establish clear actions as well as measurable and achievable objectives, and to consider the resources needed to undertake the action as well as those responsible for the follow-up and fulfillment of the actions. The basic idea here is that the improvement actions can be continuously monitored so that they are carried out and do not remain mere intentions.

Plan Stage								
Problem/Threat:								
Objective:								
Improvement Action		Resources			Deadline	Responsible	Expected outcomes	Comments
Description	Tools	Human	Physics	Economic				
Action 1								
Action 2								

Figure 4. Plan Stage

In the doing stage (Figure 5), an improvement plan will be proposed to management that seeks to implement actions to eliminate the weaknesses and mitigate the threats identified in the previous stage, for this it is important to answer the following questions, what is being done, how is it being done, why is it being done? This is done in order to improve the processes that have recurring problems and provide assistance to the continuous improvement efforts in a clear and detailed manner. The idea of answering the questions is to have a guide on how to execute the improvement actions having a focus on results, this allows to propose orderly plans without losing the vision on the expected results, this avoids executing actions deviated from the objectives where time and resources would be wasted.

Do Stage				
Problem/Threat:				
Objective:				
Improvement Action		What is done?	How is it done?	What is it done for?
Description	Tools			
Action 1				
Action 2				

Figure 5. Do Stage

In the checking stage (Figure 6), the results of the actions implemented are evaluated, and the follow-up and monitoring are carried out to verify that the improvement actions are contributing to the fulfillment of the proposed objectives. This review must be carried out by the management together with collaborators who have expertise in the work area. Although the questions posed for this stage are similar to those of the previous stage, it should be taken into account that they are focused on verification, i.e., what is checked, how is it checked and what is it checked for, so these questions are closely related to the previous ones and cannot be distanced from each other, so the check is performed on the actions proposed in the planning and doing stages.

Check Stage				
Problem/Threat:				
Objective:				
Improvement Action		What is checked?	How to check?	What is it checked for?
Description	Tools			
Action 1				
Action 2				

Figure 6. Check Stage

Finally, in the action stage, the way in which to implement the improvement plans previously evaluated as a definitive (standard) practice within the organization is proposed. This stage leads to carrying out the necessary actions to close the gaps evidenced in the verification. Future plans or recommendations usually emerge during this stage, which is precisely what leads to continuous improvement. The standardization of the solution, its compilation or documentation on procedures and its subsequent dissemination are usually part of the act stage.

Act Stage				
Problem/Threat:				
Objective:				
Improvement Action		What is done?	How to proceed?	What is it done for?
Description	Tools			
Action 1			Administrative Level	
			Operational level	
Action 2			Administrative Level	
			Operational level	

Figure 7. Act Stage

In this last stage it is also necessary to propose plans that are focused on both the administrative and the operational part, since improvement actions that are proposed only at the plant level without the support of the management will hardly be sustained in the long term, thus becoming projects that can cause demotivation since sooner or later they will return to the original situation causing feelings of frustration and a low motivation for future initiatives. Although there is no standard and universal way to implement the improvement cycle, the following figure (Figure 8) proposes a series of tools (lean and administrative) that can serve as support when developing each of the stages, it should be remembered that the purpose of this article is not to teach in detail the use of each of the tools but to give a guide on how to approach a continuous improvement process, even so a group of tools have been selected that do not have a high technical complexity and that could be adopted by the vast majority of organizations regardless of their type and size.

PDCA cycle & Lean Tools							
Plan Stage		Do Stage		Check Stage		Act Stage	
Administrative tools	Lean Tools	Administrative tools	Lean Tools	Administrative tools	Lean Tools	Administrative tools	Lean Tools
Cause-effect diagram	5S	Benchmarking	SMED	Control Charts	KPI's	Six Sigma	SOS/JES
Interviews	VSM	AMEF	TPM	BSC	Gemba	Standardization	Hoshin Kanri
Pareto Analysis	Jidoka	Flow charts	Heijunka	Error Proofing	5S	Process documentation	Kaizen
Process Mapping	Visual management	Pilot testing	Kanban	Statistical process control	Visual management	BSC	Poka - Yoke

Figure 8. Improvement processes based on the PDCA cycle.

5. Conclusion

Process management and lean manufacturing tools are a great help to improve manufacturing processes in companies that use them, since they improve productivity, quality, and manufacturing systems in general. A big problem usually faced by SMEs is that sometimes they see limited opportunities for improvement for fear of getting complicated with highly technical models or high investment, however it can be seen that the mixture of these two tools, process management and lean manufacturing, facilitate the tasks of m, so its application allows microenterprises to carry out improvement actions with low investment.

It is recommended to the managers of the microenterprise Jotta Shoes to carry out the improvement plans in a meticulous way so that its application provides positive results and to be able to solve the existing problems in the best way. It is important to mention that, for the plans to give the best results, all the members of the microenterprise must work together and keep them constantly motivated to avoid the inertia of old practices. Another more technological help can be found in ERP software that can help monitor a company's processes. Although these solutions are usually expensive for SMEs, there are today low-cost, high-quality solutions like the one you mention by Astudillo Rodríguez et. al., (2020), this type of tools together with process management models cause great synergies and can substantially increase the performance of a company.

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