Design of a comprehensive methodology for the lean manufacturing implementation in the colombian context

Diseño de metodología integral de implementación de manufactura esbelta en el contexto colombiano

Desenho de uma metodologia abrangente para a implementação da manufatura enxuta no contexto colombiano

Cesar Amílcar López Bello[1]
Luz Ángela Ospina Jiménez[2]

Received: June 5th, 2021
Accepted: August 25th, 2021
Available: September 6th, 2021

How to cite this article:
C.A. López Bello, L.A. Ospina Jiménez. "Design of a comprehensive methodology for the lean manufacturing implementation in the colombian context," *Revista Ingeniería Solidaria,* vol. 17, no. 3, 2021.
doi: https://doi.org/10.16925/2357-6014.2021.03.10

Research article. https://doi.org/10.16925/2357-6014.2021.03.10

[1] Maestría en Ingeniería, Facultad de Ingeniería. Universidad Distrital Francisco José de caldas. Bogotá, Colombia

Email: clopezb@udistrital.edu.co

ORCID: https://orcid.org/0000-0001-7123-0469

CvLAC: http://scienti.colciencias.gov.co:8081/cvlac/visualizador/generarCurriculoCv.do?cod_rh=0000166618

[2] Maestría en Ingeniería, Facultad de Ingeniería. Universidad Distrital Francisco José de caldas. Bogotá, Colombia

Email: laospinaj@correo.udistrital.edu.co

ORCID: https://orcid.org/0000-0002-7442-1225

CvLAC: https://scienti.minciencias.gov.co/cvlac/visualizador/generarCurriculoCv.do?-cod_rh=0001732059

Abstract

Introduction: This article is a product of the "Design of a comprehensive methodology for the Lean Manufacturing implementation in the Colombian context" research, carried out during 2019, 2020 and 2021 in Bogotá, Cundinamarca.

Challenge: Existing Lean Manufacturing implementation methodologies do not take into account the organizational culture aspects of the country in which it is being developed, making it difficult for its full implementation.

Objective: Present a comprehensive implementation methodology that increases the successful Lean Manufacturing application in the Colombian industry.

Methodology: This article presents the review and analysis of the existing implementation methodologies and the results of the analysis of problems in implementation processes in the Colombian industry, as well as the comprehensive implementation methodology designed.

Results: To achieve a successful Lean Manufacturing implementation in the Colombian context, it's necessary to carry out an adequate implementation process' follow-up, the company's Senior Managers commitment, the definition of appropriate leaders for the implementation process and the adequate personnel training.

Conclusion: This project seeks to develop a flexible methodology that adapts to organizational conditions.

Originality: This research integrates key success factors associated with the Colombian context in the implementation's methodology.

Limitations: The size of the sample to diagnose the Lean Manufacturing implementation degree in the Colombian industry, from which the key success factors are taken to be included in the methodology.

Keywords: Methodology, Implementation, Lean Manufacturing, Production Management.

Resumen

Introducción: El presente artículo es producto de la investigación "diseño de metodología integral de implementación de manufactura esbelta en el contexto colombiano", realizada durante los años 2019, 2020 y 2021 en Bogotá, Cundinamarca.

Problema: Las metodologías de implementación de Manufactura Esbelta existentes no tienen en cuenta los aspectos organizacionales propios de la cultura del país en el cual se está desarrollando, dificultando así su completa implementación.

Objetivo: Proponer una metodología integral de implementación que permita incrementar la aplicación exitosa de la Manufactura Esbelta en la industria colombiana.

Metodología: En este artículo se presenta la revisión y análisis de las metodologías de implementación prexistentes y los resultados del análisis de problemáticas en procesos de implementación en la industria colombiana, así como la metodología integral de implementación diseñada.

Resultados: Para lograr la implementación exitosa de la manufactura esbelta en el contexto colombiano se requiere un adecuado seguimiento al proceso de implementación, el compromiso de los altos mandos de la compañía, la definición de líderes apropiados al proceso de implementación y el entrenamiento adecuado del personal.

Conclusión: Este proyecto busca proponer una metodología flexible que se ajusta a las condiciones organizacionales.

Originalidad: Esta investigación realiza la integración de factores claves de éxito asociados al contexto colombiano en la metodología de implementación.

Limitaciones: El tamaño de la muestra del diagnóstico del grado de implementación de la Manufactura Esbelta en la industria colombiana de donde se toman los factores claves de éxito a incluir en la metodología.

Palabras clave: Metodología, Implementación, Manufactura Esbelta, Gestión de Producción.

Resumo

Introdução: Este artigo é o produto da pesquisa "desenho de uma metodologia abrangente para a implementação da manufatura enxuta no contexto colombiano", realizada durante os anos de 2019, 2020 e 2021 em Bogotá, Cundinamarca.

Problema: As metodologias de implementação do Lean Manufacturing existentes não levam em consideração os aspectos organizacionais da cultura do país em que está sendo desenvolvido, dificultando assim sua plena implementação.

Objetivo: Propor uma metodologia de implementação abrangente que permita aumentar a aplicação bem-sucedida do Lean Manufacturing na indústria colombiana.

Metodologia: Este artigo apresenta a revisão e análise das metodologias de implementação existentes e os resultados da análise de problemas nos processos de implementação na indústria colombiana, bem como a metodologia de implementação integral desenhada.

Resultados: Para alcançar o sucesso da implementação da manufatura enxuta no contexto colombiano, é necessário um acompanhamento adequado do processo de implementação, o comprometimento da alta direção da empresa, a definição de líderes adequados para o processo de implementação e a formação adequada dos pessoal. .

Conclusão: Este projeto busca propor uma metodologia flexível que se ajuste às condições organizacionais.

Originalidade: Esta pesquisa integra os principais fatores de sucesso associados ao contexto colombiano na metodologia de implementação.

Limitações: O tamanho da amostra do diagnóstico do grau de implementação do Lean Manufacturing na indústria colombiana, a partir do qual são retirados os principais fatores de sucesso a serem incluídos na metodologia.

Palavras-chave: Metodologia, Implementação, Lean Manufacturing, Gestão da Produção.

1. INTRODUCTION

Globalization has managed to make companies adopt technologies that allow production costs to be reduced, improve productivity and flexibility, broadening their value chain by optimizing resources and activities. This is because resources are not being used efficiently and most of the activities carried out are not sufficiently effective, as they generate waste, which creates problems that result in higher costs.

As the contemporary market is becoming increasingly competitive worldwide, manufacturing organizations are under immense pressure to pursue operational excellence and improve their performance in order to reduce their costs and provide higher quality products in shorter time frames. Lean manufacturing principles and techniques have been widely used by manufacturing organizations to gain a

competitive advantage over their rivals [1]. Lean manufacturing is an approach to manufacturing management that strives to make organizations more competitive by increasing their efficiency and decreasing costs by eliminating non-value-added steps and inefficiencies from the process [2]; [1].

Lean Manufacturing tools are independent, but they have a common goal; they seek to improve profits and eliminate as much waste as possible. These tools contain basic guidelines for their implementation, but it is essential that at the time of implementation not only the theory alone is understood, but also the particular processes of each company and the necessary adjustments are made to ensure the success of its implementation. This requires constant adaptation and learning [3], especially in Colombian companies where cultural behavior directly affects their improvement systems.

The Colombian manufacturing industry is no stranger to the need of remaining competitive at a global level since the import and export index in Colombia increased 8.5% in annual percentage average from 2001 to 2019 [4]. Colombian companies, in their eagerness to be competitive and meet the needs of their customers, have innovated processes to reduce production costs, increase productivity, improve flexibility and expand the value chain, among others. Likewise, changes have been observed in relation to social and institutional aspects, which go beyond the company itself, and these have adopted philosophies that allow the continuous improvement of all the links that make up its value chain.

One of the main objectives in strategy formulation and implementation is the creation of sustainable advantages for companies. De Oliveira and Fensterseifer [5] argue the need to understand why some companies perform better than others operating in similar market and competitive situations. These performance differences can be attributed to differentiation in internal factors, such as knowledge and other strategic assets, which have an impact on the overall company's performance. This mindset is embodied in the "Resource-Based View" (RBV) approach that considers companies as different amalgamations of both productive and strategic resources as well as capabilities that lead to different performance potentials.

Since each company has its characteristics, it is viable to design a production management model that includes the fundamental theoretical concepts and the variations required to achieve an implementation methodology tailored to the needs of each company. Therefore, with the objective of adapting the principles, approaches, and tools of Lean Manufacturing to the Colombian context, the idea of proposing a methodological process that takes into account pre-existing methodologies and success and failure factors in the implementation processes in the Colombian industry

arises, thus achieving a complete implementation of the Lean Manufacturing philosophy in Colombian companies.

Therefore, in order to support Lean Manufacturing implementation processes, this work presents a methodology for Lean Manufacturing implementation that understands each company's particular processes and adapts to them to guarantee its successful implementation in the Colombian industry.

1.1 Literature review or research background

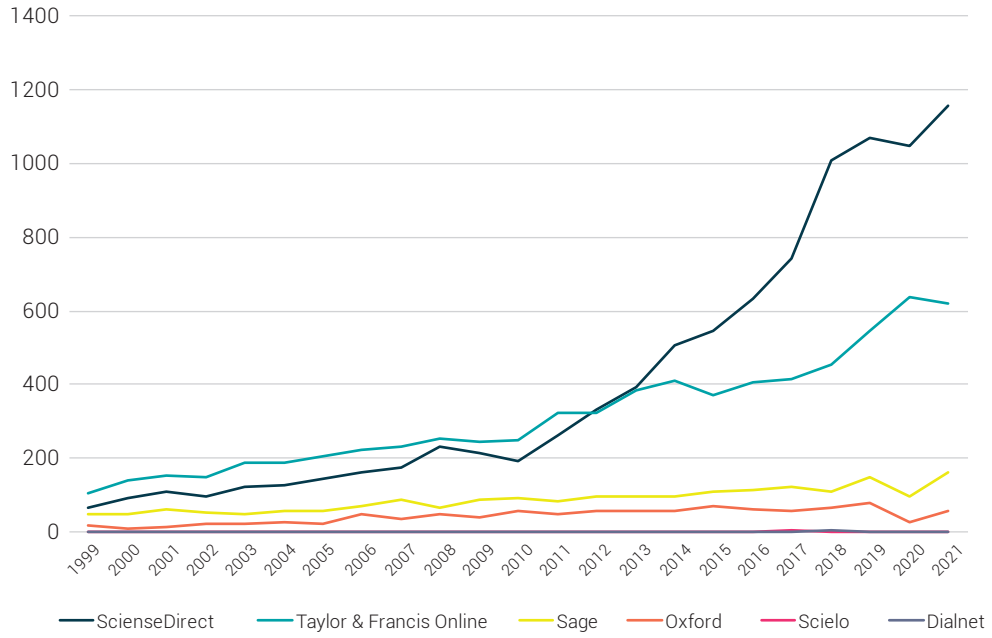
A systematic literature review involves the study of selected articles searched in different databases and sources [6]. According to Hong and Easterby-Smith [7], the literature review is a necessary step in structuring a field of research and progressing our understanding of any emerging research area.

1.1.1. Methodology

In order to search for information related to the review of the state of the art, the following keywords were established: methodology, lean manufacturing, implementation, and Colombia. The following electronic databases were used to search for information: Sciens Direct, Taylor & Francis Online, Sage, Oxford, Scielo, and Dialnet

Two search processes were carried out between 1999 and 2021; in the first process the words: methodology, Implementation, and Lean Manufacturing were used and a total of 19,646 results were identified in databases; in the second process the words: methodology, Implementation, Lean Manufacturing, and Colombia were used and a total of 750 results were identified.

Within the results obtained in the two search processes carried out, it was possible to identify that there is a great variety of information related to the subject and that this has increased in the last 10 years, as shown in the graph below.



Graph 1. Historical search result 1999 – 2021 . 5.
Reference: the authors

A pre-selection of articles presenting information on Lean Manufacturing implementation methodologies in the title, summary, or keywords fields was made from the totality of the results obtained. Then, articles that could be repeated in the 6 databases consulted were eliminated. A total of 29 articles were identified in this exercise.

Finally, each of the selected articles was read from the abstract, followed by the introduction and general reading to determine if it described the Lean Manufacturing tools included in the implementation methodologies and the general aspects to develop a successful implementation methodology. In this last step, a total of 18 articles that could serve as a reference were identified.

The literature review process took time and effort. Six databases were considered and a 20-year period was reviewed for each of them with 2 search processes, totaling 46 different searches. In this search exercise, 20,402 results were retrieved, and the preselection and selection process explained above was applied to them. Finally, 18 articles with content describing Lean Manufacturing implementation methodologies were obtained, and for this reason, they were considered suitable for the development of the research background review, which is presented below.

1.1.2. Lean Manufacturing

The term "Lean" was introduced by a study group of the Massachusetts Institute of Technology to analyze the manufacturing methods of companies in the automotive industry worldwide [8], this philosophy emerged as Toyota's Production System (TPS) in 1950 [9]. Its main objective was to carry out operations with minimum cost and zero waste [10]. The TPS is represented by a house whose foundations are given by operational stability and continuous improvement. The walls, on one hand, are represented by the Just In Time system: "the right part, at the right time, in the right quantity" [11]; and on the other hand, the quality in the process, or "Jikoda" is stated with the control of line stops, poka-yoke, visual factories, efficient work, and machinery. With these foundations and walls, we have the house's roof, which represents high quality, lower cost, and shorter delivery time goals.

In Colombia, the context of incorporating the model of economic openness since the early nineties; the national government policy of the first decade of the 21st century, which favors the signing of international free trade agreements and treaties with different countries of the world; and the closing of trade relations with Venezuela in between 2008-2010; are factors that have encouraged entrepreneurs in the sector to gradually incorporate into their production processes the administrative and operational adjustments that enable them to meet the quality requirements and gain share in international markets [12].

1.1.3. Lean Manufacturing Implementation Methodologies

Regarding implementation methodologies, the literature is very vast; however, we will try to describe some of them, showing their techniques and results. The first one is the one proposed by Carreras and Sanchez [13], in which they suggest a model dividing it into three levels:

First level: Identifying and defining the key factors of the model: Leadership, communication, planning, training, operational, continuous improvement, monitoring, and measurement.

Second level: Group identified key aspects, classify them under each key factor, and prioritize them for each of the phases in which a company is in the implementation process.

Third Level: Defining the strategies/good practices for each of these key aspects to follow in order to achieve a consolidated Lean implementation. The first is associated with the vital aspect defined by the commitment of the management, for which it was determined that all Lean implementation must be endorsed by the support and

commitment of the organization. The second refers to the facilitator as responsible for monitoring the implementation of the Lean strategy; and the third focuses on the visualization that should be given to the company as a value chain so that each department's objectives become common objectives, which leads to a radical change in the functional structure.

In this model, pre-operation is given special treatment, meaning that before implementing any Lean practice, the important thing is the motivation from management, the company's size, the determination of the complexity of the process, and the recognition of management's expectations. In this way, according to the proposed model, the implementation of Lean is not a short-term strategy but becomes a habit of continuous improvement. [13]

The implementation of the Lean methodology is extremely interesting and good contributions have been made for its implementation. The Massachusetts Institute of Technology (MIT), in a collaboration program they have with the US Air Force, presents a model that describes 7 phases with its main components or actions in order to make the transition to a Lean-type company [14]. The methodology is cyclical, which evokes basic continuous improvement methodologies such as PDCA (Plan-Do-Check-Act) popularized by Deming and developed by Shewhart in the 30's, only that in the MIT model the activities to implement Lean are particularized, such as the paradigm shift that the organization must have based on the managers' support, going on to establish a value flow map that clearly tells what the goals are, who is involved in them and then, in a team effort, implement the Lean thinking and culture through activities described in specific plans that over time allow seeing results that improve the company and that will be reviewed in strategic planning.

Another methodology called "Enterprise Lean Model" is derived from a study by MIT and Lean Aerospace Initiative in 2004 to enhance the best practices in the execution of this methodology in organizations. It provides a series of steps where the successful practices in aspects that are linked to the Lean implementation in the company are specified. The methodology suggests metrics to monitor the results of the changes made in the internal processes of the organization. This methodology attempts to optimize information, human and material workflows in the processes, providing us with metrics that respond directly to each of the 12 points to track in the methodology. The Enterprise Lean Model, unlike the previous one, which was used to initiate the implementation of Lean, is used more to refine and make processes work better based on Lean concepts.

It is also possible to identify 5 basic steps to have a Lean process [15] [16] [17]:

1. Defining what adds value in a given process.
2. Identifying the value stream, the chronological flow of how the process activities add value since people are visual by nature and can place the value activities when they can see their process flows.
3. Forcing activities to flow without interruption. Any non-value adding activities should be removed or minimized (in the case that non-value adding activities are required the impact to the process is minimized).
4. Enabling the customer to pull the product or service through the process.
5. Continually strive for process perfection by reviewing the above steps again to form a cycle and continually ensure that the process is improved.

Jing [18], in a conference for the IIE (Institute of Industrial Engineers), summarized the Lean methodology. This methodology shows how the tools are common to others previously presented, and the event called Kaizen stands out because it is under its continuous execution that improvements are produced in the organization.

The so-called Lean Production System is consolidated by applying most of these tools, being interdependent with each other. Arrieta, Muñoz, Salcedo, and Sossa designed a scheme that allows seeing the general effects of the implementation of different Lean Manufacturing tools in the Colombian Industry. [19].

According to Herrera, Herrera, González [20] various authors have shown the usefulness of lean tools in improving productivity, which is why it is necessary to identify the various implementation methodologies and the tools that were used in each one of them.

The following is a comparison of the research articles related to the development of Lean Manufacturing implementation methodologies. Table 1 shows the title of the article or document, the authors, the tools used in the implementation methodology designed, and whether organizational aspects are included in the methodology or not.

Table 1. Review of Lean Manufacturing implementation methodologies.

Document	Author	Tools used in the implementation methodology	Considers Organizational Aspects
Analysis and evaluation of the general elements of the Lean Manufacturing theory that can generate growth in a company of the plastics transformation sector. Case: UPR Ltda.	Serrano A; Suarez A. Pontificia Javeriana University. Undergraduate Monograph (2004) [21].	5's, JIT, SMED, KAIZEN, TPM, Manufacturing Cells.	Considers Organizational Aspects

(continúa)

(viene)

Document	Author	Tools used in the implementation methodology	Considers Organizational Aspects
Tools and control indicators to improve a process, according to Lean production principles.	Cuatrecasas A. Luís and Olivella Nadal J. (2005) [22].	Continuous improvement of cross-functional teams. Responsibility decentralization and function integration. Vertical information focused on processes.	Considers Organizational Aspects
Methodology for implementing Lean management in an independent, medium-sized industrial company.	Cuatrecasas A. Luís, (2006) [23].	Plant layout. Description of tasks. Job Positions. Balancing Operations-Work Station. Process workflow map.	No indication
Lean production: Current status and future research challenges.	Alarcón C. and Fuentes M., (2007) [24].	Functions, processes and inventories. Cost structure and bureaucracy. Manufacturing cycles, quality and innovation.	Considers Organizational Aspects
Evaluation procedure for manufacturing strategy: Applications in the metal-mechanical industry.	Sarache Castro, Cárdenas Aguirre, Giraldo García and Parra Sánchez, (2007) [25].	Competitive priorities. Production systems. Valuation. Improvement actions.	Considers Organizational Aspects
Organizational and technological trends in the global Agri-Food industry and their manifestation in Venezuela.	Mercado, A.; Córdova, K.; Testa, P. (2007). [26].	Technological innovation process control. Focuses on business creation.	No indication
Lean material system for GM Colmotores. Performance audit.	Muñoz, A. (2015) [27].	Company's quality costs. Analyses the causes and factors that generate quality costs.	No indication
Applying Lean Manufacturing Tools to Improve the Production Process of the Company. Tampografic Ltda.	Mosquera, F., Cartagena, M. and Sánchez, W. Universidad Sanbuenaventura. (2010) [28].	Value Chain, 5's, JIT, SMED, KAIZEN, TPM, Manufacturing Cells.	Considers Organizational Aspects
Lean Manufacturing Tools Application to Improve the Value Chain of an Office's Chair Production Line.	Wilches, M. J., Cabarcas, J. C., Lucuara, J. and Gonzalez, R. (2013) [29].	Value chain, productivity, flow, waste.	No indication
Conceptual justification of a Lean Manufacturing implementation model.	Rivera Cadavid Leonardo. (2013) [30].	Value chain, 5's, JIT, SMED, TPM, Flexible Manufacturing Systems, Standard Work, Jikoda, Heijunka, KAIZEN, Little's law.	Considers Organizational Aspects
Applying the Lean-Sigma methodology to problem solving in manufacturing processes: Case Study	Celis, O., Estrada, F., and Hermosillo, F. (2015) [31].	Lean Sigma, Problem Solving, Experiment Design, Six Sigma.	Considers Organizational Aspects
Lean Manufacturing implementation: An evaluation method regarding the adoption of socio-technical and ergonomic practices.	Tortorella, G., Lupi, L., Pereira, E. Ernani, C. (2016) [32].	Productivity, wastage.	Considers Organizational Aspects

(continúa)

(viene)

Document	Author	Tools used in the implementation methodology	Considers Organizational Aspects
Leadership's role in the Lean Manufacturing implementation.	Alefari, M., Salonitis, K., and Xu, Y. (2017) [33].	Lean leadership principles and practices that can lead to improvements in employees' performance.	Considers Organizational Aspects
Wooden pallet manufacturing process improvements. Case study.	J. C. Herrera Vega, G. Herrera Vidal, and C. I. González Polo (2017) [34].	5's, Standard Labor.	No indication
Lean Manufacturing tools implementation diagnose, based on the operations strategy in some Colombian textile and apparel companies: case report.	González, H., Marulanda, N., Echeverry, F. (2018) [35].	Kanban, 5S, Kaizen, Just-in-Time, Overall Quality Management.	Considers Organizational Aspects
Production line improvement for the automotive industry via the Lean philosophy.	Azevedo, J., Sá, J., Ferrerira, L., Santos, G., Cruz, F., Jimenez, G. and Silva, F. (2019) [36].	Lean Sigma, Problem Solving, 7 Wastes.	Considers Organizational Aspects
Lean manufacturing model for production management to increase SMEs' productivity in the non-primary manufacturing segment.	Flores, S., Limaymanta, J., Eyzaquirre, J., Raymundo, C., and Pérez, C. (2019) [37].	5´s, KANBAN	Considers Organizational Aspects
Methodology design to incorporate Lean Manufacturing tools in risk management in order to reduce occupational accidents in service companies.	Tortorella, G., Cómbita, J., -Monsalvo, J., Vidal, L., -Herrera, Z. (2020) [38].	5's, visual management, Standard Labor and KANBAN	No indication

Reference: the authors

During the last few years there has been progress in the design of Lean Manufacturing implementation methodologies. Different variants have been generated, but generally, common tools are used, such as: Kaizen, Value Chain Maps, 5's, Just-in-Time, SMED, Total Productive Maintenance, Heijunka, Six Sigma, Poka-Yoke, among others.

The organizational aspects identified in the different methodologies are related to the organizational structure rather than to the strategic guidelines or the organizational culture factors.

1.1.4. Lean Manufacturing in the Colombian Context

Colombia was a late starter in the implementation of Lean Manufacturing tools within companies. According to Arrieta, Botero, and Romano [39], only implementation

initiatives have operations in the country, such as General Motors - Colmotores, Tetra Pak, Unilever Andina, and Siemens. These companies have implemented some of this philosophy's tools.

In the process of implementing Lean in Colombian companies, some of the initiatives have been successful, while difficulties have arisen for other organizations, with negative results or failure to meet expectations. Two reviewed case studies evaluating the level of implementation of Lean tools in SMEs in the Aburrá Valley [39], in the textile sector and in the industrial sector [40], found that companies have not developed a Lean culture and philosophy, and therefore, the use of tools is reduced. The least implemented tools are the Electronic Document or Information Exchange ("EDI"), supplier certification, Kanban, 5's, Six Sigma, SMED, and TPM. However, there are tools such as statistical process control and benchmarking that have been beneficial to companies.

Lean Manufacturing has been implemented in other continents, achieving continuous improvement of organizations for more than 40 years. Since it was implemented in Japan during the mid-1970's, there are few cases that have been implemented and documented in Colombia. According to Valencia & Plazas [41] in a certain way, the tools that have been successful in Japanese companies may face some barriers in Colombian companies, among which are the management of information systems, customer-supplier relationships, organizational culture, labor stability, and staff turnover. Moreover, such cases are limited to some industrial sectors.

The implementation methodologies reviewed have similar aspects, such as leadership, planning, continuous improvement, and follow-up. 63% of the reviewed methodologies take into account organizational aspects, however, none of them took into account the implementation success factors related to the country's context.

The Lean Manufacturing tools included in the most common implementation methodologies are: Kaizen, Value Chain Maps, 5's, Just-in-Time, SMED, Total Productive Maintenance, Heijunka, Six Sigma, and Poka-Yoke.

2. METHODOLOGY AND RESOURCES

2.1. Evaluation of the Implementation Level in Colombia

2.1.1. Survey

To evaluate the level of implementation and the tools applied in Colombian companies in order to identify the problems to be solved with the methodology designed for this document, a qualitative survey was conducted based on seven case studies of organizations located in Cundinamarca, which have implemented Lean Manufacturing philosophy tools.

The companies were selected from a list of names compiled out of the articles reviewed; the list had a total of 15 companies. It is important to keep in mind that sampling was non-probabilistic for convenience since the companies surveyed were the ones that made this study possible. Initially, they were contacted and only 7 companies agreed to participate. The survey was conducted by telephone with those directly responsible for the Lean tools' implementation process, who were familiar with it, its results, and the problems encountered during its implementation.

The survey was based on one previously applied by Leon, Marulanda, and Gonzalez [42] with some variations, this one has four sections.

1. Company's general information, Lean Manufacturing implementation status, tools applied, and benefits achieved.
2. Monitoring and control strategies information that enabled the implementation of Lean Manufacturing.
3. Requirements and characteristics prior to Lean adoption.
4. Problems encountered during Lean Manufacturing tools' implementation.

With the information collected, data was tabulated and the important and recurring aspects of successful implementations were identified. This information was supported by related bibliographic sources.

2.1.2. Results

Each of the companies surveyed had a variety of tools implemented, according to their particular needs. Not all the tools were implemented in their entirety, but they

were implemented in some of the company's processes. In this particular exercise, the visual factory was identified as the most generalized tool, followed by 5S's and Manufacturing Cells, as can be seen in Table 2.

Table 2. Lean Tool Implementation Ranking.

Tool	# of Companies that carried out the implementation	% of companies that carried out the implementation
Visual Factory	7	100%
5S's	7	100%
VSM - Value Stream Mapping	6	86%
Manufacturing cells	6	86%
TPM - Total Productive Maintenance	5	71%
Seis Sigma	4	57%
SMED – Single Minute Exchange of Dies	4	57%
Kanban	4	57%
Jidoka	4	57%
Kaizen	4	57%
Poka-Yoke	3	43%
Just in Time	3	43%

Reference: the authors

Just-in-Time is the least implemented tool in the companies interviewed because of the lack of delivery control from suppliers, which means that Kanban must be kept in the company's own facilities or in the suppliers' facilities.

According to the survey's results, in order to achieve success in a process of implementing the Lean philosophy in Colombian companies, it is necessary to have the commitment of investors and the organizations' top management. According to León, Marulanda, and González [42], "Regarding small and medium-sized companies, Lean experts should be consulted to train both owners, leaders, and supervisors in the Lean key aspects, and these latter should be the ones who carry out the training and coaching to operators and employees in general. Good leadership ensures and drives skills creation or improvement in work teams, allowing the implementation to be enhanced with available tools, generating innovative ideas, and integrating new technologies into the process. This is why in the Lean implementation, this ability should be trained and developed in supervisors and mid-level managers."

Each tool's implementation will depend on each company's capabilities and the resources' availability. Therefore, it is necessary to be clear about which resources

are available in order to define a work plan and adequately monitor the use of such resources.

Indicators must be managed to monitor and control the project's progress, as they are necessary to evaluate the implementation's efficiency and effectiveness.

Awareness and training processes are vital during the project's implementation; they should be carried out with the support of the organization's leaders to ensure the philosophy's adoption and appropriation.

3. RESULTS

A comparative table was developed as a result of the above reviews, comparing the lean manufacturing tools included in the research articles and those implemented in the surveyed companies.

Table 3. Results comparison.

Source	Most common tools	Organizational aspects	Key Success Factors
Literature review	Kaizen, VSM - Value Stream Mappin, 5's, Just-in-Time, SMED, TPM - Total Productive Maintenance, Heijunka, Six Sigma, Poka Yoke.	Organizational Structure Organizational context SWOT strategies	No indication
Survey	Visual Factory, 5S's, VSM - Value Stream Mapping, Manufacturing Cells, TPM - Total Productive Maintenance	Organizational Structure Organizational Culture	Senior Management Commitment Establish a work plan according to resources availability. Establish management indicators that allow project follow-up. Awareness-raising and training.

Reference: the authors

Based on the considerations of the previous chapters, one identifies that Lean tools can be implemented independently of each other and can be implemented at different stages of the project. Additionally, the need to take into account the cultural factors of each country was identified, since they determine some behaviors in the organizational culture that can prevent a successful Lean Manufacturing implementation.

The implementation methodologies reviewed have similar aspects, such as leadership, planning, continuous improvement, and follow-up. Some of them take into

account organizational aspects, however, none of them took into account implementation success factors related to the country's context.

3.1. Methodology Proposal for the Implementation of Lean Manufacturing in the Colombian Context.

Considering the above, and according to the success cases of Lean implementation in the Colombian companies interviewed, we have defined the following methodology proposal for the implementation of Lean Manufacturing in the Colombian context:

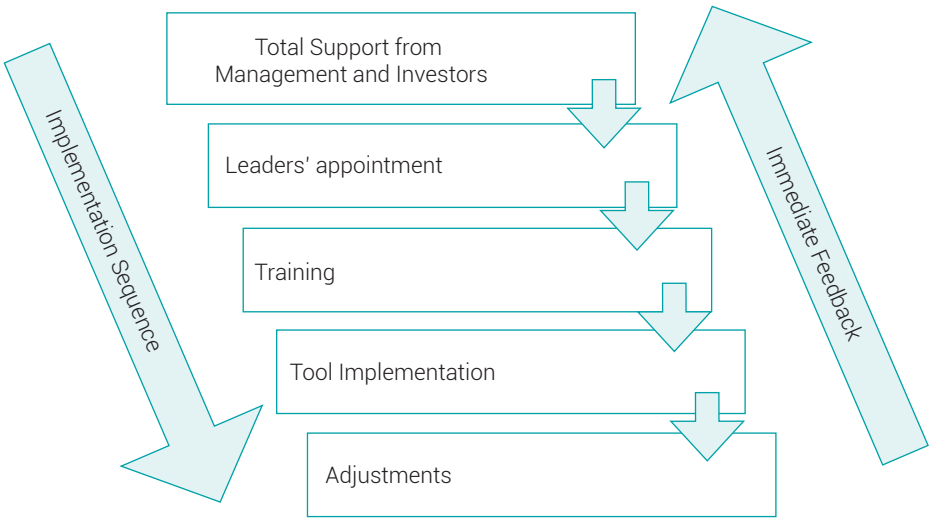


Illustration 3. Lean Manufacturing Implementation Methodology Proposal.
Reference: the authors

3.1.1. Full Management Support

The first step in this methodology, or steps to follow for the Lean implementation in the organization, is to have the unconditional support of the company's management.

e-ISSN 2357-6014 / Vol. 17, no. 3 / september-december 2021 / Bogotá D.C., Colombia
Universidad Cooperativa de Colombia

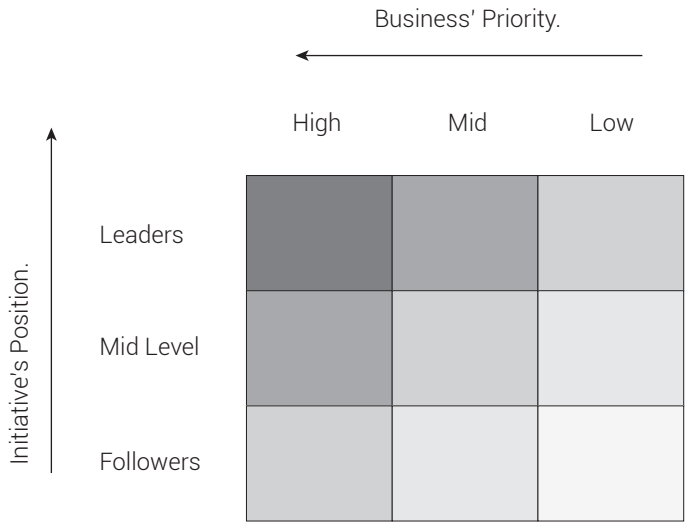


Illustration 4. The importance of the initiative for the organization.
Reference: the authors

As can be seen in Illustration 4, it is crucial to analyze where the organization is in relation to the initiative being taken. It is desirable to be at least in the lower left box, where the initiative is important to the business and therefore has 100% support from top management. To have a point of reference: Toyota would be in a great position in terms of the Lean initiative since they are pioneers of this production system.

3.1.2. Leader Appointment

Leaders play an extremely important role within organizations for implementing Lean at different company levels. To apply this methodology it is necessary to modify the organizational structure and create positions to lead and manage the implementation process.

The general leader of the process must have the knowledge of the tools, and their leadership is essential. These are the leader's main functions:

- Defining the vision and how to get there. (Strategy)
- Knowing that 85% of Lean Manufacturing is leadership is of utmost importance, the remaining 15% is nothing more than the correct application of the concepts.
- Adapting their behavior according to the working conditions, equipment, organization, etc.

- Learning with their team in the workplace (better known as Gemba by the Japanese) is also important for the leader to learn with their team.
- Using the tool of the ("5 whys") which consists of asking why 5 times in each situation.

Pick the Internal Team.

There are different models for work team selection; among them Gordon Raber mentions a series of steps that are important [43]:

1. Stating the requirement.
2. Analyzing the profiles that are needed.
3. Publishing the requirement.
4. Interviewing the candidates.5. Selecting the candidate for the team.

The team is critical to the success of the initiative within the organization. It is recommended to form a working team as follows:

- Lean Manufacturing Leader
- Lean Coordinator
- Lean Engineer
- Analysts (Research and Timing).

After an Action Work Out (AWO), it is very common to have additional people in the production lines. One of the initiatives adopted here is to take the person who best grasped Lean ideas and tools, they join the team. That way, the tacit knowledge created based on lived experience can be used to transmit it to new areas where the new AWO will be carried out.

Therefore, when selecting the internal team, it is very important to fulfill the following characteristics:

- Lean requires a team that is committed and willing to learn.
- They must be willing to work and understand that real learning takes place in the workplace.
- The team must be multidisciplinary and their roles have to be clearly defined.
- Goals should be clear for each of the team members.

3.1.3. Training

The next step is to train the entire organization, introducing the initiative and the benefits and challenges that the organization will face by implementing it. After defining the vision, objectives, and goals, developing a training plan for all levels of the organization is fundamental in order to start speaking the same language. Initially, a training sequence is defined, starting with department leaders, then employees, coordinators, supervisors and operators, so that the support of this initiative comes from management. The other people who join the list of trained employees start creating what is called the "snowball effect", which means that once the idea is approved and adopted by the organization, the initiative gains momentum and the benefits start growing exponentially.

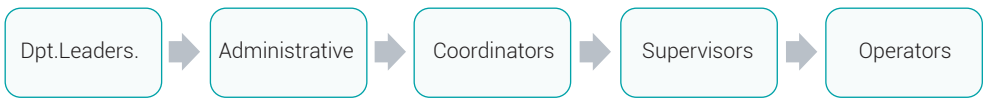


Illustration 5. Training Sequence.
Reference: the authors

The training plan should not only have a sequence. A training plan that contains all the tools that have been defined to be implemented should be established.

The following are some of the advantages of Lean training at all organizational levels:

- Ensure that the entire organization understands and speaks the same language.
- To obtain basic knowledge in the training room in order to execute more accurately in the workspace (Gemba).
- To explain the rules on which the methodology is based before implementation.

3.1.4. Tool implementation - Action Work Out

The next step of the methodology is the Action Work Out, which is going to the work area and applying the tools discussed in this paper. The steps to follow to perform the AWO are: - Familiarize yourself with the Process:

Becoming familiar with the Process.

It is very important that the team performing the AWO knows the process that will be carried out, for the team member to be able to identify the operations that add value and those that do not when observing operations and recording times. To do this it is necessary to read the procedures and instructions to see which operations are the ones that really need to be carried out, which are surplus, and which are not being carried out.

Identifying the 7 Wastages in the Workspace

Through process visualization and monitoring, the waste generated in diverse company processes will be identified.

Takt Time

The Takt Time of the operations should be measured in order to know how often a product unit should be produced, according to the demand. This Takt Time, understood as the rate at which a production line should be flowing depending entirely on the customer's demand and the time available for operation would explain how often a product should be produced in a specific process. For this purpose, the following formula should be applied:

Takt Time = (Time Available) ⁄ (Units required (demand))

Time Taking

Time taking is vital, because this is where we can detect other wastes in which operators incur and that do not add value to the product, such as crane time, transportation, defects, etc. It is important to make around 10 samples when taking times which will be taken 10% by the process' engineer, 10% by the area supervisor, and the remaining 80% by the Lean team that was previously appointed; the purpose of this is that the process owners of such areas can become aware of their wastes and activities that do not add value to the operation, and that many times, due to the blindness of the workshop, are not able to be detected.

Once the times are taken, it is necessary to analyze them and see the differences between operators.

At the same time, when times are taken, using tools such as spaghetti chart, standard work combination sheet, 7 ways, is important to analyze exactly which activities add value and which don't.

Identifying Operations

When taking operation times at workstations and performing the analysis, identify each of the operations that are carried out, these may be:

- Manual operations that add value. These are the ones that transform the product and for which the customer is paying. It is important that the time spent on this type of activity is the highest share.
- Manual operations that do not add value. These are the operations that the operator performs manually but do not transform the product and therefore do not add value. It is necessary to try reducing the percentage of time that is lost performing these operations.
- Machine time. These are the machinery operating times, and it is imperative to identify and separate these activities so that the operator can perform other operations while the machine is working.
- Walking does not add value. In many organizations, it is very common to see an operator leaving his workstation in order to go pick up material, look for a measuring instrument, and so on. This is one of the most common types of waste and it is important to be able to pinpoint it.

Therefore, when taking time, it is important to be able to analyze and try to eliminate all activities that do not add value. This is because, if the Takt Time is not being fulfilled, eliminating these activities can help in producing within it.

Eliminating Non-Value Adding Activities.

Once non-value-adding activities have been established, they need to be eliminated from our process. If, before the AWO we were not complying with the Takt time, once we eliminate all those operations that do not add value, we will be able to produce within it.

Defining Standard Operations

Once the operations that do not add value have been eliminated, we must determine the sequence of operations that each operator has to follow, in order to produce units consistently within the Takt Time. When defining the sequence of operations, we have to remember that the operators are the ones who carry out the operation and that they are the ones who know it deeply.

There are many purposes of following a sequence of operations, among them we can mention:

- Decreasing the number of malfunctioning parts.
- Facilitating the operation.
- To visually manage the operation.
- Improving and facilitating supervision.
- Make it easier to train other operators.

Once the AWO process has progressed, implementing tools should be carried out in the following way:

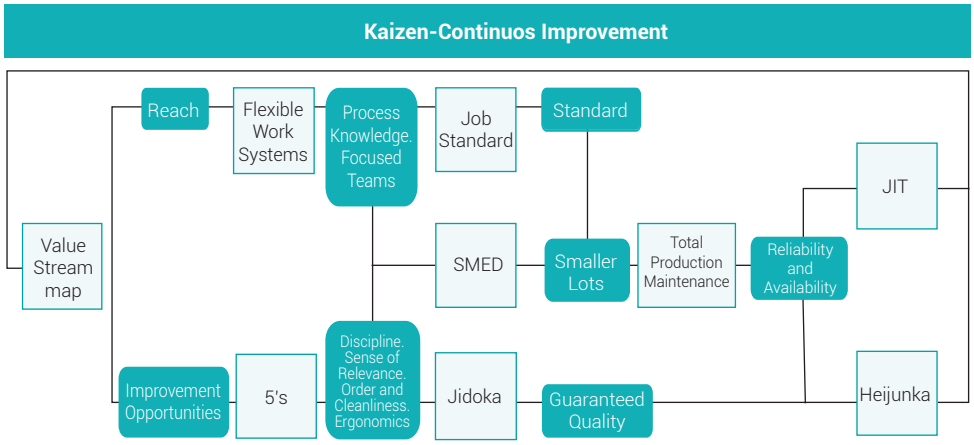


Illustration 6. Continuous Improvement. [30],

Just because we are producing below Takt Time and following a sequence of operations to standardize the process, we should not stop working to improve our process continuously, we must remember that a lot of discipline and continuous work is required to be able to maintain the right level. In the world of Lean Manufacturing, a metaphor is made using a diet. It is hard for a person to lose weight and be in shape; but once they do, they have to keep exercising and eating healthy in order to stay

at the desired level, and this is where it is very difficult to maintain. The same thing happens with Lean, in order to be able to work below Takt Time, we have to follow the standard operation routine (diet) while at the same time observing the operation to be able to detect any of the 7 wastes that appear in the process. That is why continuous improvement, better known by the Japanese as Kaizen, is of great importance in the organization to ensure success when implementing Lean.

3.1.5. Implementing Required Changes

"Mr. Ohno was passionate about TPS. He would say that he had to clean up and identify all the problems that existed in the workplace. He usually complained if he couldn't tell if there was a problem in a work area."[44], Fujio Cho, President, Toyota Motor Corporation.

All the areas of opportunity in a work area that have been found during an AWO must be addressed, and the necessary changes must be made in order to eliminate the problems' root cause. It is very common to see problems in organizations that are not aired, and are solved without letting the whole company know the reason or the cause of the problem. Normally they try to hide it, but in Toyota Production System (TPS) culture it is completely opposite, making it very important to visualize the problems so that they do not happen again.

So far, we have presented works from different authors that present methodologies to carry out an implementation, and we have also presented a proposal of a methodology that allows the implementation of Lean Manufacturing in the Colombian context. In addition, we have found a good compendium of experiences where, one or more Lean tools have been developed but now the question that arises is, how to determine the Lean strategy' development level in the companies, and how to know if the Lean Manufacturing methodology' execution process is being carried out correctly.

3.1.6. Results

Once the process previously mentioned in this work has been carried out, it is essential to be able to highlight the results obtained during the Lean tools' implementation. A visual way to show these results is by using a tool called the Objectives Sheet.

Date _____ **Takt Time** _____

Team´s name _____ **Work Area** _____

	Measurement Unit	Exit	Objective	Date 1	Date 2	Date 3	Date 4	Result	% of change
Area									
Inventory									
Route's Distance									
Walking Distance									
Cycle									
Volume									
# of Workers.									

Illustration 7. Objective Sheet.
Reference: the authors

The illustration above shows us all the parameters we should measure before starting a workout, and establishes a goal to achieve. At the end of the AWO, depending on the time frame, which can be a few hours or more than a week. Here we can see parameters such as: Cycle time, lead time, number of operators, inventory, travelling distance of a piece, liberated space, etc.

4. DISCUSSION AND CONCLUSIONS

The implementation methodologies reviewed have similar aspects, such as leadership, planning, continuous improvement and follow-up. The most common Lean Manufacturing tools included in these methodologies are: Kaizen, Value Chain Maps, 5's, Just-in-Time, SMED, Total Productive Maintenance, Heijunka, Six Sigma and Poka-Yoke.

63% of the methodologies reviewed take organizational aspects into account. However, none of them took into account implementation success factors related to the country' s context.

Each of the companies surveyed in Colombia had a variety of tools implemented, depending on their specific needs. Also, not all tools were fully implemented and only some of them had been implemented in some of the company's processes.

The implementation methodologies reviewed have similar aspects such as leadership, planning, continuous improvement and follow-up. Some of them take into account organizational aspects. However, none of them took into account the implementation's success factors related to the country's context.

The success factors identified in the survey, according to the survey applied in the Lean Manufacturing implementation processes in the Colombian industry are: Top

Management Commitment, work plan according to the resources available, management indicators that allow the follow-up of the project and an adequate awareness raising and training process.

Lean tools can be implemented independently, and this implementation can be done at different stages of the project. Additionally, there is a need to take into account cultural factors in each country, since they determine some organizational culture behaviors that can be obstacles to a successful Lean Manufacturing implementation.

During this project, a methodology for Lean Manufacturing implementation was developed, based on pre-existing methodologies' literature and successful cases of Lean Manufacturing implementation in Colombia.

With the experience gathered, we can conclude that this methodology can help other organizations in the Lean Manufacturing implementation and above all, that the methodology outlined in this document is flexible rather than rigid, it will depend on the organization in which it is applied.

4.1. Future Research

During the research process, it became evident that there is a possibility of wasting the knowledge gained through experience. It is proposed as follow-up work to create a system in which knowledge management can be applied within the Lean Manufacturing implementation methodology for the Colombian context, so that expertise and insights gained by team members are not wasted, making them available for other members of the organization.

The results of the survey showed that the suppliers' development and the organizational culture modification are difficult aspects to deal with. Therefore, as a future research, we propose the characterization and adequate development for suppliers in the Lean Manufacturing implementation, starting from the country's logistic systems to achieve an adequate implementation of JIT in Colombia.

5. REFERENCES

[1] Ioannis Belekoukias, Jose Arturo Garza-Reyes & Vikas Kumar (2014) The impact of lean methods and tools on the operational performance of manufacturing organisations, International Journal of Production Research, 52:18, 5346-5366, . [Online]. Available: DOI: https://doi.org/10.1080/00207543.2014.903348

[2] Sohal, A.S. and Egglestone, A. (1994), "Lean Production: Experience among Australian Organizations", International Journal of Operations & Production Management, Vol. 14 No. 11, pp. 35-51. [Online]. Available: DOI: https://doi.org/10.1108/01443579410068639.

[3] E. Lander y J. K. Liker, «The Toyota Production System and art: making highly customized and creative products the Toyota way», *International Journal of Production Research*, vol. 45, n.º 16, pp. 3681–3698, Agosto de 2007. [Online]. Available: DOI: https://doi.org/10.1080/00207540701223519

[4] "DANE. Retrieved from Departamento Administrativo Nacional de Estadística." https://www.dane.gov.co/index.php/estadisticas-por-tema/comercio-internacional/ (accessed April 24, 2020)."

[5] De Oliveira Wilk, E. and Evaldo Fensterseifer, J. (2003), "Use of resource-based view in industrial cluster strategic analysis", International Journal of Operations & production Management, Vol. 23 No. 9, pp. 995-1009. [Online]. Available: DOI: https://doi.org/10.1108/01443570310491747

[6] Steven Michael Burgess, Jan-Benedict E.M. Steenkamp, Marketing renaissance: How research in emerging markets advances marketing science and practice, International Journal of Research in Marketing, Volume 23, Issue 4, 2006, Pages 337-356, ISSN 0167-8116, [Online]. Available: DOI: https://doi.org/10.1016/j.ijresmar.2006.08.001.

[7] Hong, J. F., & Easterby-Smith, M. (2002, April). Transfer of organizational learning practices. In Third European Conference on Organizational Knowledge, Learning and Capabilities. Athens April (pp. 5-6). [Online]. Available: DOI: https://doi.org/10.1016/j.intman.2006.09.005

[8] P. Reyes Aguilar, «Manufactura Delgada (Lean) y Seis Sigmaen empresas mexicanas: experiencias y reflexiones. » Contaduría y Administración, Vol. 205, pp.51-69, Junio de 2002. [Online]. Available: https://www.redalyc.org/articulo.oa?id=39520506

[9] J. P. Womack, *The machine that changed the world*. New York: Rawson Associates, 1990.

[10] M. Espejo Alarcón, y J. Moyano Fuentes, "LEAN PRODUCTION: ESTADO ACTUAL Y DESAFÍOS FUTUROS DE LA INVESTIGACIÓN." Investigaciones Europeas de Dirección y Economía de la Empresa, Vol. 13, no. 2, pp. 179-202, 2007. [[Online]. Available: https://www.redalyc.org/articulo.oa?id=274120280010

[11] A. Toledano De Diego, N. Mañes Sierra y J. García, "Las claves del éxito de Toyota". LEAN, más que un conjunto de herramientas y técnicas." Cuadernos de Gestión, vol. 9, no. 2, pp.113-122, 2009. [Online]. Available: https://www.redalyc.org/articulo.oa?id=274320565006

[12] S. Martínez, J. Vera, P. Márquez Rodríguez, C. De Oro Lajud y R. Ardila García, "Perfil de los empresarios colombianos a partir de los datos del Global Entrepreneurship Monitor." Forum Empresarial, vol. 22, no. 1, pp.1-21, 2017. [Online]. Available: https://www.redalyc.org/articulo.oa?id=63153388001

[13] M. Carreras Y J. L. Sánchez García, Lean Manufacturing, la evidencia de una necesidad. España: Ediciones Díaz de Santos, 2010.

[14] L.A. Initiative, Transitioning to a Lean Enterprise: A Guide for Leaders, Volume II, Transition-to-Lean Roadmap, 2000. [Online]. Available: DOI: https://dspace.mit.edu/handle/1721.1/81894

[15] D. Nave, "How to compare six Sigma, Lean and the theory of constraints", Quality Progress, Vol. 35 No. 3, pp. 73-78, 2002. [Online]. Available: https://www.lean.org/Search/Documents/242.pdf

[16] R.D. Snee, "Weave six Sigma into the fabric of an organization", Quality Progress, Vol. 37 No. 9, 69-72, 2004.

[17] J. P. Womack, "Value stream mapping", Manufacturing Engineering, Vol. 1, pp. 45-56, Mayo de 2006.

[18] G. Jing, "IIE Conference", en *A Comprehensive Comparison Between Lean And Six Sigma And A Tier-based Mutually Inclusive Integration Model*, 21 de mayo de 2008.

[19] J. G. Arrieta, J. D. Muñoz, A. Salcedo y S. Sossa, Aplicación Lean Manufacturing en la industria colombiana. Revisión de literatura en tesis y proyectos de grado. Ninth LACCEI Latin American and Caribbean Conference (LACCEI'2011), Engineering for a Smart Planet, Innovation, Information Technology and Computational Tools for Sustainable Development, Agosto 3-5, 2011, Medellin, Colombia. [Online]. Available: http://laccei.org/LACCEI2011-Medellin/RefereedPapers/PE298_Arrieta.pdf

[20] J. C. Herrera Vega, G. Herrera Vidal, y C. I. González Polo, «Mejora del proceso de fabricación de estibas de madera: Un caso de estudio», ing. Solidar, vol. 13, n.º 23, pp. 40-55, sep. 2017. [Online]. Available: DOI: https://doi.org/10.16925/in.v23i13.2004

[21] A. Serrano y A. Suarez. "Análisis y evaluación de los elementos generales de la teoría de Manufactura Esbelta que pueden generar desarrollo en una empresa del sector de transformación de plásticos. Caso: UPR Ltda.", Pontificia Universidad Javeriana. Monografía de grado, 2004. [Online]. Available: http://hdl.handle.net/10554/7131

[22] A. Cuatrecasas y J. Olivella, “Herramientas e indicadores de control para la mejora de un proceso de acuerdo con los principios de la producción Lean”. IX Congreso de Ingeniería de Organización, septiembre 8-9, 2005. [Online]. Available: http://www.adingor.es/Documentacion/CIO/cio2005/items/ponencias/117.pdf

[23] J. Fortuny-Santos, A. Cuatrecasas, O. Cuatrecasas-Castellsaques, J. Olivella-Nadal, “Metodología de implantación de la gestión lean en plantas industriales”. Universia Business Review, Vol. 20, pp. 28-41, 2018. [Online]. Available: https://www.redalyc.org/articulo.oa?id=43302003

[24] M. Alarcón y J. M. Fuentes, “Lean production: Estado actual y desafíos futuros de la investigación”. Investigaciones Europeas de dirección y economía de empresa Vol. 13 No. 2, pp. 179-202, 2007. [Online]. Available: https://www.redalyc.org/articulo.oa?id=274120280010

[25] W. Sarache, J. Parra Sánchez, “Procedimiento para evaluar la estrategia de manufactura: Aplicaciones en la industria metalmecánica.” Cuadernos de Administración, vol. 20, núm. 33, pp. 103-123, 2007. [[Online]. Available: https://www.redalyc.org/articulo.oa?id=20503305

[26] A. Mercado, K. Córdova y P. Testa, “Tendencias organizativas y tecnológicas de la industria agroalimentaria global y su manifestación en Venezuela.” AGROALIMENTARIA. Vol. 13, Nº 24, pp. 85-103, 2007. [Online]. Available: https://www.redalyc.org/articulo.oa?id=199216580007

[27] A. M. Muñoz Skinner, «Sistema Lean material para GM Colmotores, auditoría al funcionamiento», *Tekhnê*, vol. 2, No. 1, pp. 18–24, jun. 2015. [Online]. Available: https://revistas.udistrital.edu.co/index.php/tekhne/article/view/8866/10221

[28] F. Mosquera, M. Cartagena y W. Sánchez, “Propuesta De Aplicación De Herramientas De Manufactura Esbelta Para El Mejoramiento Del Proceso Productivo De La Empresa Tampografic Ltda.” Universidad San buenaventura. Monografía de grado, 2010.

[29] M. Wilches, J. Cabarcas, J. Lucuara y R. Gonzalez, “Aplicación De Herramientas De Manufactura Esbelta Para El Mejoramiento De La Cadena De Valor De Una Línea De Producción De Sillas Para Oficina”, Dimensión Empresarial, Vol. 11, No. 1, pp. 126-136, 2013. [Online]. Available: https://econpapers.repec.org/article/col000461/011162.ht

[30] L. Rivera, “Justificación Conceptual De Un Modelo De Implementación De Lean Manufacturing.” Heurística, Vol. 15, pp. 91-106, 2013. [Online]. Available: http://hdl.handle.net/10893/6139

[31] O. Celis, F. Estrada y F. Hermosillo, “Aplicación de la metodología Lean-Sigma en la solución de problemas en procesos de manufactura: Caso de Estudio.” Cultura Científica y Tecnológica, Vol. 12 No. 57. [Online]. Available: http://erevistas.uacj.mx/ojs/index.php/culcyt/article/view/848

[32] G. L. Tortorella, L. G. L. Vergara y E. P. Ferreira, "Lean manufacturing implementation: an assessment method with regards to socio-technical and ergonomics practices adoption", The International Journal of Advanced Manufacturing Technology, vol. 89, n.º 9-12, pp. 3407–3418, agosto de 2016. [Online]. Available: DOI: https://doi.org/10.1007/s00170-016-9227-7

[33] M. Alefari, K. Salonitis y Y. Xu, "The Role of Leadership in Implementing Lean Manufacturing", Procedia CIRP, vol. 63, pp. 756–761, 2017. [Online]. Available: DOI: https://doi.org/10.1016/j.procir.2017.03.169

[34] J. C. Herrera Vega, G. Herrera Vidal y C. I. González Polo, "Mejora del proceso de fabricación de estibas de madera. Un caso de estudio", Ingeniería Solidaria, vol. 13, No. 23, pp. 40–55, septiembre de 2017. [Online]. Available: DOI: https://doi.org/10.16925/in.v23i13.2004

[35] H. H. González Gaitán, N. Marulanda Grisales y F. J. Echeverry Correa, "Diagnóstico para la implementación de las herramientas Lean Manufacturing, desde la estrategia de operaciones en algunas empresas del sector textil confección de Colombia: reporte de caso", Magazine School of Business Administration, Vol. 85, noviembre de 2018. [Online]. Available: DOI: https://doi.org/10.21158/01208160.n85.2018.2058

[36] J. Azevedo et al., "Improvement of Production Line in the Automotive Industry through Lean Philosophy", Procedia Manufacturing, vol. 41, pp. 1023–1030, 2019. [Online]. Available: DOI: https://doi.org/10.1016/j.promfg.2019.10.029

[37] S. Flores-Meza, J. Limaymanta-Perales, J. Eyzaquirre-Munarriz, C. Raymundo-Ibañez y M. Perez, "Lean Manufacturing Model for production management to increase SME productivity in the non-primary manufacturing sector", IOP Conference Series: Materials Science and Engineering, vol. 796, p. 012019, Abril de 2020. [Online]. Available: DOI: https://doi.org/10.1088/1757-899x/796/1/012019.

[38] Tortorella, G., Cómbita-Niño, J., Monsalvo-Buelvas, J., Vidal-Pacheco, L., & Herrera-Fontalvo, Z. (2020). Design of a methodology to incorporate Lean Manufacturing tools in risk management, to reduce work accidents at service companies. *Procedia Computer Science*, *177*, 276-283[Online]. Available: DOI: https://doi.org/10.1016/j.procs.2020.10.038

[39] J. G. Arrieta, V. E. Botero y M. J. Romano, "Benchmarking sobre Manufactura Esbelta (Lean Manufacturing) en el sector de la confección en la ciudad de Medellín, Colombia". Journal of Economics, Finance and Administrative Science, Vol. 15, No. 28, pp. 141-170, 2010. [Online]. Available: http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S2077-18862010000100007&lng=es&tlng=es

[40] Rave, J. P., Rodríguez, C. P., & Manco, O. Ú. (2010). Uso de herramientas de mejoramiento y su incidencia en costos, fallas y factores de éxito de grandes y medianas empresas industriales del Valle de Aburrá. *Gestão & Produção*, *17*, 589-602. [Online]. Available: DOI: https://doi.org/10.1590/S0104-530X2010000300012

[41] D. J. Valencia y J. A. Plazas, "Análisis de la implementación del Lean Manufacturing en las pymes Colombianas." Obtenido de XVI International Conference on Industrial Engineering and Operations Management.12-15 Octubre 2010.

[42] G. León, N. Marulanda, y H. González, Factores claves de éxito en la implementación de Lean Manufacturing en algunas empresas con sede en Colombia, RTend, vol. 18, No. 1, pp. 85-100, feb. 2017. [Online]. Available: DOI: https://doi.org/10.22267/rtend.171801.66

[43] G. Raber, "Good Selectíon: Great Team." New Zealand Management. Vol. 48; No. 7, 2001.

[44] J. Liker y G. L. Convis, "The Toyota way to Lean leadership: Achieving and sustaining excellence through leadership development. New York, Chicago, San Francisco, Athens, London, Madrid, Mexico City, Milan, New Delhi, Singapore, Sydney, Toronto: McGraw Hill Professional. 2012. [Online]. Available: https://www.accessengineeringlibrary.com/content/book/9780071780780