

A Bibliometric Study of Lean Manufacturing and its Relationship with Sustainability

Um Estudo Bibliométrico sobre o Lean Manufacturing e sua Relação com a Sustentabilidade

Un Estudio Bibliométrico sobre la Fabricación ajustada y su Relación con la Sostenibilidad

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Abstract: *The need to reflect on the contributions that lean manufacturing offers through its application in industrial production management has motivated this paper. Also, the way in which academic research has been developed to understand the object of study in the parameters of citation, co-citation, the most influential countries, languages, keywords and evolution index amidst the temporality of the subject under study. Lean Manufacturing and the current panorama of research carried out in the last ten years were defined as objectives to analyze. In view of this, we carried out a bibliometrics research to generate results for the understanding and analysis of the main contributions of research on the relevant topic. Therefore, the main results achieved indicate there is a need to be further explore the topic in the national scenario to enable greater knowledge of its contributions to the industry and to the academic environment. Thus, it is understandable that the industry needs processes that are advantageous for its production process and human capital. It is necessary to innovate, invest and organize management models which offer better performances in the production, as well as in the value passed on to the consumers in a way that lean manufacturing offers answers to the production process, directed to the lean production originated from the Toyota Production System, enabling the management of the production process balanced for the real consumption demand, providing the conscious use of inputs, as well as providing opportunities for sustainability through economic, social and environmental factors.*

Keywords: *Lean Production; Balanced; Consumption; Sustainability.*

Resumo: Este trabalho foi motivado pela necessidade de refletir sobre as contribuições que o lean manufacturing oferece através de sua aplicação no gerenciamento da produção industrial e a forma de como as pesquisas acadêmicas estão se desenvolvendo para compreensão do objeto de estudo nos parâmetros de citação, cocitação, países mais influentes, idiomas, palavras-chave e índice de evolução em meio a temporalidade do tema em estudo. Assim como, definiu-se como objetivo analisar o lean manufacturing e sua relação com a sustentabilidade no atual panorama das pesquisas realizadas nos últimos dez anos. Diante disso, realizou-se pesquisa na plataforma Web of Science com análise de dados bibliométricos para gerar resultados para compreensão e análise das principais contribuições de pesquisas realizadas para o pertinente tema. Assim sendo, os principais resultados alcançados mostram que o tema precisa ser mais explorado no cenário nacional,

possibilitando maior conhecimento de suas contribuições para a indústria e para o meio acadêmico; de certa forma, o estudo também mostrou que existem uma alta escassez de publicações brasileiras voltadas para o lean manufacturing para com a sustentabilidade, além disso as principais pesquisas empíricas em cenário global são pertencentes a Journals internacionais com conteúdos pagos. Contudo, o lean manufacturing oferece respostas para o processo produtivo, direcionado para a produção enxuta originada do Sistema Toyota de Produção, possibilitando o gerenciamento do processo produtivo equilibrado para a real demanda de consumo, proporcionando o uso consciente dos insumos, assim como oportunizando a sustentabilidade através dos fatores econômicos, sociais e ambientais.

Palavras-Chave: Produção Enxuta; Eliminação de Desperdícios; Sustentabilidade.

Resumen: *Este trabajo estuvo motivado por la necesidad de reflexionar sobre las aportaciones que ofrece el lean manufacturing a través de su aplicación en la gestión de la producción industrial y cómo está evolucionando la investigación académica para comprender el objeto de estudio en términos de parámetros de citación, co-citación, países más influyentes, idiomas, palabras clave e índice de evolución en medio de la temporalidad del tema objeto de estudio. El objetivo era también analizar el lean manufacturing y su relación con la sostenibilidad en el panorama actual de las investigaciones realizadas en los últimos diez años. Para ello, se realizó una búsqueda en la plataforma Web of Science, analizando los datos bibliométricos para generar resultados que permitieran conocer y analizar las principales aportaciones de las investigaciones realizadas sobre el tema en cuestión. Así, los principales resultados alcanzados muestran que el tema necesita ser más explorado en el escenario nacional, permitiendo un mayor conocimiento de sus contribuciones a la industria y a la academia; de cierta forma, el estudio también mostró que existe una alta escasez de investigaciones brasileñas enfocadas en lean manufacturing para la sustentabilidad, además de las principales investigaciones empíricas en el escenario global pertenecientes a revistas internacionales de contenido pago. Sin embargo, la manufactura esbelta ofrece respuestas para el proceso productivo, orientadas hacia la producción esbelta originada en el Sistema de Producción Toyota, posibilitando la gestión del proceso productivo de forma equilibrada a la demanda real de consumo, proporcionando el uso consciente de los insumos, así como brindando oportunidades de sostenibilidad a través de factores económicos, sociales y ambientales.*

Palabras clave: Lean Production; Eliminación de residuos; Sostenibilidad.

Introduction

The pursuit for better working methods has been a goal aimed by all economic sectors, among these - the industry - which seeks to structure in its processes better production tools to achieve continuous quality through routine activities.

Consequently, the search for answers to the improvement in production processes arises in the year 1990 with the Toyota Production System that through temporality gave way to the lean manufacturing management philosophy or lean manufacturing, which according to Stone (2012) is an extension of the 14 principles of the Toyota System; thus, industrial activities begin to seek innovations, and lean manufacturing, henceforth LM, arises with the objective of variability, reduction of production time, improvement of the productive flow and the elimination of waste (Boyle & Rathje, 2009).

Concerning to the subject presented, Liker (2004) and Shingo (1996) emphasize that the LM offers the industrial sector different tools for adapting the production system, stimulating the giving up of old habits and adapting new standards for a more competitive and sustainable business performance. Thus, the authors consider such tools: 5s; Kanban; Takt time; Value stream mapping; (VSM); Standard work; Kaizen; Total quality control; Visual management; Error proof devices or Poka Yoke; Continuous flow; Andon; Single Minute Exchange of Dies - SMED; Heijunka; Total Productive Maintenance - TPM; Lean product development and improvement; Integration with suppliers; and Flexibility of

labor.

In this context, lean manufacturing tools emerge to offer new performance to industries, and at the same time challenge the researcher to explore researches in order to understand the study, making it pertinent to search for approaches by different authors such as Singh et al. (2010), Godinho Filho and Barco (2015), Camacho (2013), Bhamu (2014) and Womack, Jones and Roos (2004), who present important views on the investigated theme, the evaluation models and the appropriate production tools for each need identified in the industrial sector.

This article aims to analyze lean manufacturing and its relationship with sustainability in the current view of research carried out in the last ten years. As well as, it aims to achieve answers through bibliometric survey and contemporary studies that reveal authors, co-authors and keywords that provide answers to the questions of the theme under study.

However, this article directs the discussion guided through productions recognized in the academic universe, in addition to addressing analyzes through journals for discussion and approximation of the contemporary reality of today's world; being a support for students, researchers, organizations and other interested parties to know and also contribute to the advancement of the explored theme.

Therefore, understanding the research object presented in a contextualized way through scientific studies, is justified by the need to understand the importance of organizing industrial processes in a way that allows production in a standardized and balanced way for production stages consistent with the demand to be met, in addition to the permanence of the valuation of the real cost to the consumer, leading to the use of inputs in a conscious way to minimize impacts on the environment and sustainability for all parties involved.

Theoretical elements of the research

Lean Manufacturing: Historical Study

Lean manufacturing management originated from the Toyota Production System and is a work philosophy that emerged with the purpose of reducing waste and valuing the real cost to the consumer. According to Womack et al (2004), with activities originating in the automotive sector of Toyota—a Japanese company located on the island of Nagoya—lean production rose through the decline of mass production conceived by Fordism, which was becoming a factor generating losses and the depletion of social welfare.

For Vesentini (2004), in the 1970s, the Fordist work model began to lose ground in industrial production processes, as well as in social welfare conditions, which were being depleted in all operational scenarios. This gave rise to a new production process that reinvigorated capitalist production models: Toyotism or post-Fordism.

According to Womack et al (2004), Toyotism spread across a wide range of social segments, providing new opportunities to society through forms of work not restricted to the factory with lean or flexible production, where instead of mass consumption as found in Fordism, post-Fordism offered just-in-time production to meet only the demand necessary to satisfy consumption.

Thus, lean manufacturing is a work management philosophy focused on eliminating waste that emerges as support for management in various production line sectors, developing techniques that

"when combined and matured, reduce production time and cost, maximize customer value, and minimize waste. (Mastrapa; Assumpção & Campos, 2021).

In addition, LM makes significant contributions in relation to sustainability, offering a balance between social, economic, and environmental factors, as "it requires a commitment to management that must be visible, through mechanisms that encourage autonomy from the outset of gains and in ongoing evaluation. (Silva et al, 2024, p. 9).

According to João P. Pinto, president of the National Board of the Lean Thinking Community, the term or concept of lean was first used by James P. Womark and Daniel Jones in 1996. These authors studied management styles and working methods in Japan in the 1980s and conducted seminal research on lean production in 1990 in their book *The Machine That Changed the World*, which is now considered a pioneering work on lean thinking.

For Taddeo et al (2019), lean manufacturing is one of the most efficient models in industry, with the potential to increase business competitiveness, contributing to the reduction of any non-value-added activities, improving productivity and quality.

Thus, Lean manufacturing (LM) has been widely perceived by industry as a response to these requirements because LM reduces waste without additional resource requirements. This has led to a surge in LM research worldwide, mainly through empirical and exploratory studies that have resulted in a multitude of LM definitions with divergent scopes, objectives, performance indicators, tools/techniques, and elements. (Bhamu & Singh Sangwan, 2014).

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Understanding the Principles of Lean Manufacturing

The knowledge of the structuring of the principles of certain management is necessary in order to follow organized processes. According to Herzog and Tonchia (2014), the organization of the principles of the Toyota System are the pioneers in the results of the broader communities of Japan, as a proposal for changes against mass production that was had by most American and European companies after World War II.

Pertinent to this, to understand the principles of lean manufacturing it is necessary to know the 14 Toyota Management Principles as pointed out by Liker (2004). They are:

Table 1-Toyota's 14 Management Principles

1 - Base management decisions on a long-term philosophy, even at the expense of short-term financial goals.
2 - Create a continuous process flow to bring problems to the fore.
3 - Use pull systems to avoid overproduction.
4 - Level the workload.
5 - Build a culture of stopping and solving problems so that the desired quality can be achieved on the first try.
6 - Standardized tasks are the basis for continuous improvement and employee training.
7 - Use visual control so that no problems are hidden.
8 - Use only reliable and fully tested technology that suits the employees and processes.
9 - Develop leaders who fully understand the work, live the philosophy and teach it to others.
10 - Develop exceptional people and teams who follow the company philosophy.
11 - Respect your network of partners and suppliers, challenging them and helping them to improve.
12 - See for yourself to fully understand the situation.
13 - Make decisions without haste and by consensus, fully considering all options and then implementing them quickly.
14 - Becoming a learning organization by relentless reflection and continuous improvement.

Source: adapted from Liker, 2004.

Therefore, the Toyota system had these principles minimized through the philosophy of the LM, where which assist in the management of the production of an industry. On the other hand, Womack et al (1996), defines that the principles of LM are developed to meet the total satisfaction of the customer, because they are the ones who receive and consume the products, thus indicating the corresponding value, in addition to the specification of the value from the perspective of the final consumer, integrated to the identification of the necessary steps for the production of a product with the clear establishment of a continuous flow, without delays or waits for the determination of a pulled flow, manufacturing only the quantities requested by the consumer, and ensuring continuous quality to perfection, eliminating rework and waste.

According to the aforementioned author, Womack, Jones and Roos (2004) point out the basic principles for an industry to become lean:

Table 2 - The 05 Principles of lean manufacturing

1 Value: Directed to the designation of the purchase of the product that generates a degree of satisfaction linked to the expectations and fulfillment of the needs through the acquisition of a product or service.
2 Value chain: It goes back to the process or set of distinct steps composed of processes where each product needs to pass to be completed.
3 Flow: As a sequential process, the flow is scaled throughout the value chain of continuous work, without the existence of problems that cause delays or reduction of an operation in certain activities of the chain.
4 Pulled System: This principle is also known as the pull system, it arises in sequence of the creation of the flow from it, production can be started properly and at the correct pace to meet the demand that the customer requests.
5 Perfection: Directed to the search for perfection, becoming a necessary objective for the value chain, as it is directed to continuous improvement. This principle has as its main objective the achievement of ideal conditions and the way to conduct the company's efforts.

Source: adapted from Womack, Jones and Roos, 2004.

When comparing the principles, it is clear that there was a new organizational structure, because Stone (2012) considers that LM encompasses the entire process of lean production as well as Toyota principles, remaining the essence of waste elimination and continuous quality throughout the product production process.

Lean Manufacturing Analysis Tools

The tools which make up the LM are flexible to adapt according to the structure of the organization. Thus, as pointed out in the productions of Vieira (2017), Womack; Jones (1996), Monden (1984) and Ohno (1997), the tools stand out:

- **5s**- this tool corresponds to five Japanese expressions beginning with the letter "S" they are named sense, which establish essential practices for visual vision, cleanliness and organization continuously. They are:
 - *Seiri*: sense of use, where it establishes that only the materials and tools necessary for the execution of the tasks should be in the work area, avoiding excesses of unnecessary tools in the place of activities.
 - *Seiton*: Sense of organization, aimed at avoiding unnecessary movement in the performance of the task, so it guides the identification and location of the necessary work tools close to the workplace.
 - *Seiso*: Sense of cleanliness, aimed at keeping the workstation clean, integrating all components pertaining to the environment;
 - *Seiketsu*: Sense of standardization, discipline / standardize work practices and organization according to the aforementioned senses;
 - *Shitsuke*: Sense of self-discipline, aimed at maintaining the standard of the other four "S" not allowing vicious cycles of old habits and maintaining a continuous systematic effort.
- **Kanban** - The term means "signal board" or "card" and is a system that offers instructions through green, yellow and red cards to signal the production or withdrawal of products according to the control board. This tool guides suppliers for material handling and process evolution for manufacturing products as requested by the customer. This ferment establishes the essence of the pull production system.
- **Takt time** - It is the establishment of a time value that standardizes the pace of production to meet the requested demand. It establishes the ratio between the time available for production to the final stage of units to be produced.
- **Value Stream Mapping (VSM)** - it turns to a diagram that informs all the related steps in the material flows with information needed to serve customers from order to delivery. The VSM is composed of two maps, where the first turns to the current moment that shows the current conditions, and the second that shows the identification of opportunities for improvement to improve performance in some type of failure.
- **Standard work** - with reference to the takt time, work procedures are established for each worker in the execution of production, having a sequence of work and standard stock.
- **Kaizen** - establishes the process of continuous improvement for all activities with the purpose of creating more value with elimination and reduction of waste. This process that all employees must be part of.
- **Total quality control** – it is a managerial methodological process where all levels (strategic, tactical and operational) of the company must be part of the applicability of continuous quality to its products and services through the PDCA cycle.
- **Visual management** - oriented to offer visualization of information of activities, production, products, performance indicators among other variables that provide access and understanding of the progress of activities in companies.
- **Error-proof devices or Poka Yoke** – a tool that guides operators not to practice error in the

execution of activities; this guidance can be done through electronic systems or complex monitoring structuring to ensure that the activity is performed rather than being forgotten.

- **Continuous flow** – a tool that conducted by the method of production and movement of one item at a time in the production of a continuous series, that is, each step will be executed at the time it is requested by the sequential step.
- **Andon** - Visual management tool also called "lamp or signals with light", directed to show the operations in a single place, forming visual alerts through lights that emphasize where it is necessary to act in a certain place of production.
- **Acronym for Single Minute Exchange of Dies - SMED** - popularly known as set up it is directed to quick tool change in the shortest possible time with separation of internal operations with the machinery stopped or the external operations where the machinery continues in operation. It seeks to solve situations in an estimate of less than ten minutes to make the equipment available and not interfere with the delivery time of the product.
- **Heijunka** – a tool that establishes the balance of the type and quantity of production over a stipulated period of time. In this way it has stability of the process, elimination of time waste, elimination of excess inventory, reduction of costs and labor, in addition to the production lead time.
- **Total Productive Maintenance - TPM** - aimed at total productive maintenance, directing itself so that the machinery and the guarantee that they are always able to function to perform the tasks and the operators are the participative agents to care for the equipment.
- **Lean product development and improvement** - agile production for new products, with less work and elimination of waste. Develop principles of rapid model substitution, continuous expansion of product mix, participative supplier process, multidisciplinary teams and computerized design tools.
- **Integration with suppliers** - seeks to select suppliers that provide inputs that meet the needs of the production system related to quality, quantity, delivery times and cost.
- **Flexibility of labor** - turns to flexibility of labor, with the movement of employees to perform in other operations when production is changed. Flexibility is influenced by three factors: proper equipment layout design, well-trained operators, continuous evaluation and reviews, and standardized operations.

LM tools are structured to meet the diagnosis of each company according to the needs encountered. In a way, the execution takes place through combinations and structured strategies that industries establish in production processes to achieve quality standards and operational efficiency.

Lean Manufacturing Assessment Models

LM is a philosophy or method of production management measured through empirical studies or analysis of the industrial environment. However, the evaluation model for a given study requires the consistency of the analysis made through the selected object; Singh et al (2010), considers that there is no standardized way to achieve success, because every institution has several variants and different factors that are conditioned to the studies.

For Godinho Filho and Barco (2015), LM is a reference for the study of industrial production through its evaluation tools and principles that seek to meet concepts that add competitive performance to industries, seeking to adapt the evaluation according to the analysis performed and the applicability of its tools.

Therefore, Marodin and Saurin (2013) consider the same approaches to the evaluation method

of LM in industries, structuring itself in two perspectives: Evaluation by Practices or by Results. In this way, Walter and Tubino (2013) establish that the evaluation of practices turns to verify the commitment of the agents involved with the tools and methodologies proposed by lean manufacturing.

In another relevance, the evaluation of the results as addressed by Camacho et al (2013), is directed to the metrics of the production processes, that is, the improvements found through the application of the tools of the LM, which can be by qualitative or quantitative analysis through the operational reports arising from the maturity of a lean culture that must be analyzed in the strategic, tactical and operational spheres of an industry.

Methodological elements of the research

To achieve the objective of the present research study through temporal changes in patterns, natures and transformations in scientific productions, a bibliometric study research was adopted, using citation analysis, co-citation and bibliographic coupling techniques.

In a sense, the bibliometric method offers the researcher the opportunity to analyze the scientific quality of the publications of a certain theme, by means of quantitative evidence through parameters of sets of articles for the management of productions, information and scientific knowledge arising from a certain object under study. For this purpose, the identifiable parameters are: the selected articles, their references, authors, journals, countries, number of citations and co-citations, keywords and most relevant journals (Ensslin et al., 2010).

Therefore, the present work has mapped the scientific production in the national and international scenario of the last ten years (2011-2021), considering that the choice of this temporality was due to the fact that there are no relevant numbers of publications and citations prior to 2011. Thus, productions were sought on the Web of Science (WOS) research platform, where the choice of the platform was due to the fact that it has a greater number of articles related to the theme, in addition to the richness of information and the high extension of the collection when compared to other platforms.

In this perspective, the systematization process advocated by Creswell (2010) was considered, establishing inclusion or exclusion criteria; the unit of analysis was defined in the months of January 2011 to December 2021, using as thermologies [TS] "lean manufacturing", [OR TS] "lean manufacturing and sustainability", [AND TS] "manufacturing and sustainability" and [OR TS] "manufacturing and lean production", obtaining a total of 1,857 articles found.

For the refinement of the data with the purpose of emphasizing the theme under study, the data were filtered only by the categories "Management" and "Business" resulting in 159 articles. For exclusion criteria, we considered research from areas not belonging to the knowledge of "Management" and "Business", as well as years prior to 2011, in addition to types of documents not belonging to the scientific article standard.

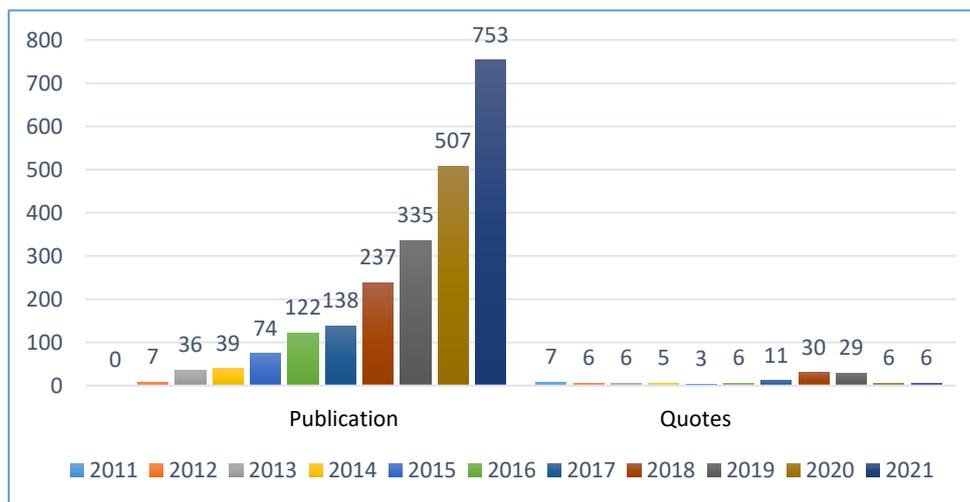
For data analysis, it was organized in two stages: the first focused on the use of Microsoft Office Excel tools for the elaboration of tables and graphs, and the second stage the use of Vosviewer software version 1.6.18 for technical and precise analysis of clustering and mapping, with the purpose of presenting a systematic analysis of the results achieved.

Results and Discussion

In order to meet the main objective of this article, which is to analyze lean manufacturing and its relationship with sustainability in the current panorama of research carried out in the last ten years, structured data were sought in bibliometric indicators aimed at: total publications by most influential countries, main journals with publications on the subject, main languages in publication, relevance of the main authors, bibliographic coupling of author keywords, analysis of author co-citation and coupling of keywords on a global scale.

Figure 01 shows the evolution of research developed on the object of study, considering the number of publications and citations made between 2011 and 2021:

Figure 01 - Evolution of research between 2011-2021



Source: own elaboration through Web of Science, 2022.

Through figure 01, it can be seen that investigations on LM and its expertise in the industrial world are becoming increasingly ascendant, so, as identified (graph 01) in 2011 there were no citations, only research production, but from 2012 the academic community begins to be interested in working on the theme. The greatest highlight is mainly in the year 2020 and 2021 where there were only 06 documents published respectively, but the citations reach an average of 105 citations per articles. It should be considered that external factors may have favored this interest in the study of LM, mainly due to environmental problems, economy looking for answers in the midst of the covid-19 pandemic, as well as solutions to produce more with less and establish more profits with cost reduction.

Table 04 shows the top 10 countries that have relevance in citations for the theme under study:

Table 04 - Most influential countries in publications

Countries	Documents	Cited
United States	20	617
England	14	579
Sweden	10	433
Brazil	30	376
Spain	10	259
India	22	248
Italy	9	224

Netherlands	5	171
Mexico	5	60
Malaysia	5	49

Source: Own elaboration from Vosviewer, 2022.

Table 04 shows that the most influential countries in the citations are found in the international scenario, and that the number of productions (documents) are not influential in the quality of the research, because visibly in the United States has 20 documents (617 citations) which is in first place in the ranking, having fewer documents than Brazil (30 documents) which occupies the fourth position. It is important to consider that of the 10 countries, only Brazil and Mexico belong to Latin America, reflecting the spaces of research focused on the theme under study and the importance of industrial development in developing countries or with an environmental dimension that need research for sustainable exploitation without degradation of the dimensions of sustainability.

On the other hand, it is important to highlight that the European continent has great representativeness with 05 countries that have research focused on LM, being England (579 citations), Sweden (433 citations), Spain (259 citations), Italy (224 citations) and the Netherlands (171 citations), which provide opportunities to discover new alternatives and the possibility of discussing less aggressive work on sustainable dimensions and environmental agreements.

Following the studies, table 05 presents the 12 most relevant journals, taking into account the order of citations from largest to smallest:

Table 05 - Main journals with publications on the theme

Journals	Qtd. Documentos	Qtd. Citações
Internacional Journal of Operations & production Management	19	738
Total Quality Management & Business excellence	16	381
Benchmarking-an Internacional Journal	13	220
Management decision	4	223
Supply Chain management -an international journal	4	213
Internacional Journal of Productivity and Performance Management	10	77
International Journal of human resource management	4	60
Internacional Journal of Quality & Reliability Management	5	52
quality innovation Prosperity-Kvalita Inovacia prosperita	4	19
Journal of advances in management research	4	10
Independent Journal of Management & Production	4	9
Quality-access to seccess	4	2

Source: Own elaboration from Vosviewer, 2022.

So, analyzing table 05, it can be seen that the International Journal of Operations & production Management appears first in the ranking, presenting the highest number of citations when compared to the others (738 citations). However, it is noted that the Journal Total Quality Management & Business excellence (223 citations) and the Journal Benchmarking-an Internacional Journal (213 citations) appear ahead of the International Journal of Productivity and Performance Management (77 citations) and the International Journal of Quality & Reliability Management (52 citations), making it understood that the number of documents is not a factor that guarantees the strength of the citation of relevant research, considering that the Journal Total Quality Management & Business excellence and the Journal Benchmarking-an Internacional Journal have only 04 documents, respectively; It is

important to emphasize that the information of most of these journals is through paid subscriptions to access the content.

In continuity with such analysis criteria, it is possible to perceive through table 06 the languages that researchers use for bibliographic production, as follows:

Table 06 - Main languages in publication

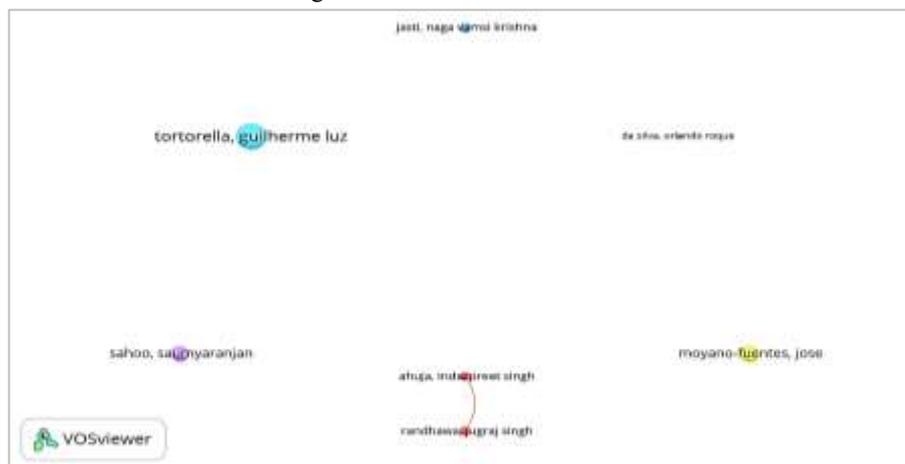
Languages	Qty of documents
English	151
Portuguese	5
Spanish	2
Croatian	1

Source: Own elaboration from, 2022.

The reflection of the publications when analyzing the language for main productions, it is perceived that the English language has great relevance among researchers, therefore, when comparing table 06 with table 05 (Main journals with publications on the theme), we identify that many of the countries do not use their mother tongue to write research giving priority to the English language that is predominant in most continents.

Figure 02 shows the mapping of authors who form networks with common co-citation, as well as authors who do not have networks more expressive in co-citations.

Figure 02 - Co-citation of authors



Source: Own elaboration from Vosviewer, 2022.

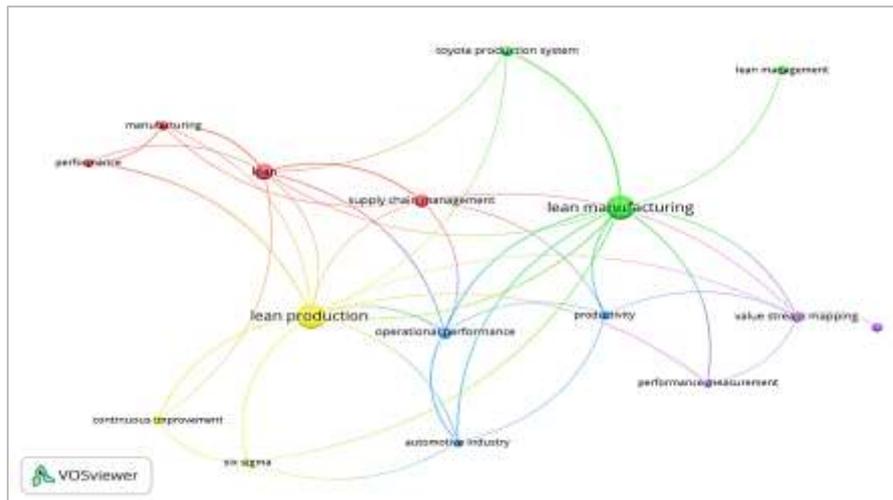
Through the co-citation networks (Figure 02), it can be seen that the most cited authors do not have a network relationship between them, with an isolated mapping. Thus, it is understood that for this study, researchers still do not explore the research developed in a shared way, implying that works are carried out without socialization of readings between texts that work on the same theme. Among the 06 clusters, it is verified that the red color turns to authors who are cited in common in some works, being Ahuja and Randhawa each having 03 documents and 35 citations respectively.

Through this analysis, the most influential authors were also identified in general, having the

greatest strength of citations among themselves, being them: Tortorella (258 citations), Moyano-Fuentes (114 citations), Sahoo (90 citations), Jastin (37 citations), Da Silva (11 citations); For such authors, their works are relevant in numbers of citations, however they have no common relationship with any work as seen in the image Figure 01.

Next, figure 03 is presented with bibliographic mapping of keywords most used by the authors in their productions of abstracts or titles of articles, in order to understand what surrounds the theme worked by them:

Figure 03 - Author keyword linkage



Source: Own elaboration from Vosviewer, 2022.

In Figure 03, the co-occurrence of the formation of the most used keywords that are contained in titles or abstracts of the articles belonging to the sample under study is exposed, which through this were found 05 clusters.

The first cluster represented by the red color with the words lean, manufacturing, performance and supply chain management are the most repeated by the authors in their productions to direct the production line and productive impacts, considering what Liker (2004) and Shingo (1996) affirm about the LM about its adequacy to the productive systems and the offer of adaptations to the activities developed for change and improvement of the most competitive business performance.

Therefore, the second cluster represented by the green color and organized in a network of three words, being lean management, lean manufacturing and Toyota production system, turns to the direction of the theme related to the Toyota Production system as found in Womack et al (2004) and Stone (2012) who report this relationship between both working methods mediated by lean production and quality in processes.

For the third cluster, represented by the blue color, there is an agglomeration of words automotive industry, operational performance and productivity showing contextualization for industrial research, operational performance and productivity; making it clear the existence of the search for industrial performance and continuous improvements as stated in the bibliography of Bhamu et al (2014).

In the formation of the fourth cluster, represented by the yellow color and the words continuous improvement, lean production and six sigma, there is a tendency to direct research towards quality

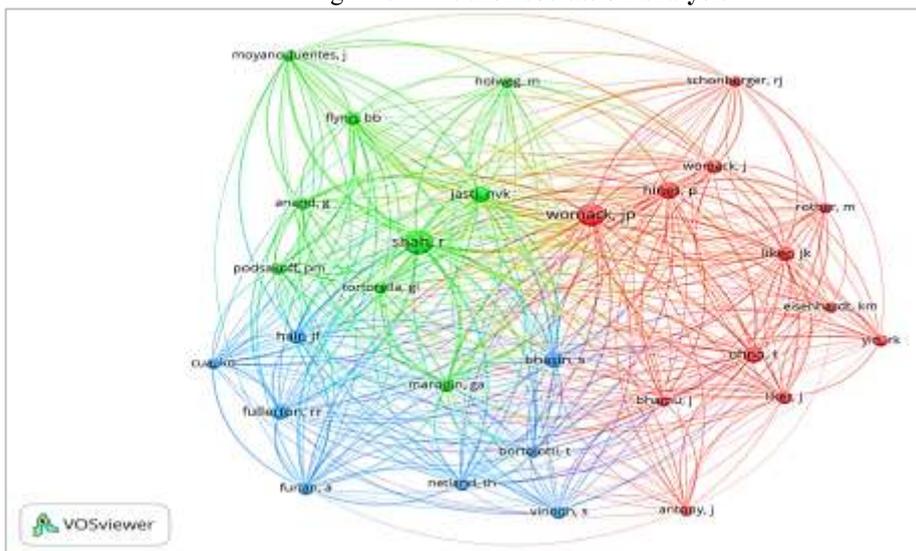
through continuous improvement that offers the search for more dynamic and competitive processes for the industry. This is also found in the fifth cluster, represented by the lilac color that has keywords for lean six sigma, performance measurement and value stream mapping contextualized by the form of mapping that exists in industries and throughout the value stream necessary for the sustainability of operational life.

Thus, it is expressed in figure 04 mappings referring to the data collected for co-citation of authors. Analyzing the co-citation networks of figure 04, it is identified that the red cluster is the most prominent among the 03 clusters formed, therefore, the author Womack has high in this group, where such researches are directed to contexts directed to lean manufacturing, waste, value flow, quality and bottlenecks found in the industry, as well as possible hypotheses for more effective and sustainable solutions.

To this end, for the green color cluster with representation for Shah's authorship, the works are based on research aimed at lean manufacturing, industrial waste, improvement of LM and sustainable conditions.

However, for the blue color cluster, author Fullerton among others who make up this group, have researches bypassed for lean manufacturing, structure modeling, lean accounting and industrial stability.

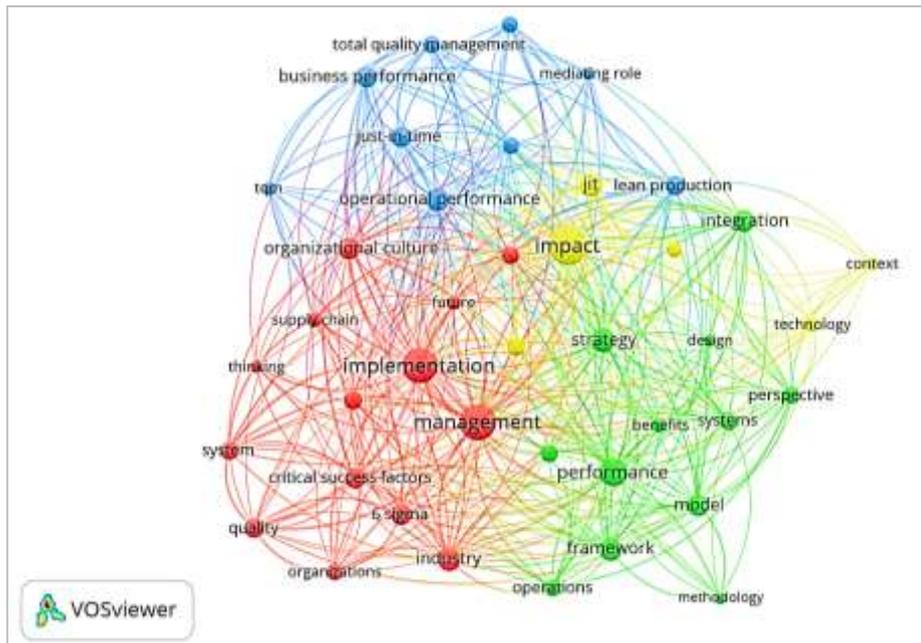
Figure 04 - Author cocitation analysis



Source: Own elaboration from Vosviewer, 2022.

In figure 05, the analysis is directed to the study of the repetition of the main keywords in the global scenario, providing the formation of 04 clusters; where the first red color (14 words) has high representation by the words implementation and management, which are highlighted in a larger spiral. For cluster 02, identified by the green color (12 words), the words performance, strategy, model and fragework are highlighted.

Figure 05 - Global keyword coupling



Source: Own elaboration from Vosviewer, 2022.

For cluster 03 signaled in blue (09 words), the words operational performance and business performance are highlighted. However, for the yellow cluster (06 items), impact and jit are the most relevant. Thus, it can be seen that the context that these keywords have around the approaches worked on by each author, are structured directly for work models with higher business performance in order to achieve quality in operational processes.

Final Thoughts

Lean manufacturing proposes the standardized use of its production control tools in order to reduce and eliminate waste that must be controlled in industries for greater use of inputs and human resources.

However, the relevance of the studies of the analyzed researches, point out that the practicality of the LM in companies arises through considerable effects and greater contribution to profitability factors, cost reduction and increased quality in manufactured products, causing potential variables for the achievement of sustainable levels in the economic, social and environmental areas of industries.

In a way, that even though there are tools in lean manufacturing for production processes, it is still necessary to invest in technology for innovation and advances in financing on the part of the public interest, so that industries go through modifications and the production system is changed to greater sustainable achievements in their extensions of cleaner production levels; such actions need to be discussed in the corporate layers and by public management so that it can reach all industries in an accessible way to make them competitive in today's market.

However, the scarcity of Brazilian research becomes a worrying factor in the national scenario, considering the advance of studies since 2011 that have an upward trend among these institutions,

Brazil is among the least influential countries in studies of the referred theme, considering its industrial and environmental potential for the development of processes in sustainable dimensions and future notes for industrial solutions in interfaces with sustainability; It is necessary to reinforce that the main studies and empirical research in the global scenario belong to journals with paid content and their access through subscriptions, thus, few bibliographies are open to the public, being them in the format of journals or more extensive productions, tapering access to the general public and restricting researchers to access innovations or strengthening hypotheses for the implementation of lean manufacturing with sustainable and promising aspects for regional development.

In this conception, it comes to the consonance that the deficiency in research as verified in the analysis of bibliometric data, reflect directly in possible economic and environmental diagnoses that influence in an "aggressive" way in less developed regions, mainly in South America, where companies are unable to develop the LM culture due to lack of investments in innovation, public interest, development in research and the absence of the implementation of sustainable projects in the economic, social and environmental dimensions that makes it difficult to find solutions for transforming the industrial scenario through its relationship to regional development.

Therefore, this work contributed to reflect on the evolution of lean manufacturing and its contributions over the past ten years, in addition to its relationship in research developed in relation to sustainability for cleaner production processes, through the tools of work and waste reduction method that are conducive to offer lower economic, social and environmental impacts. This study also contributed to researchers, academics and professionals can understand and know more about the subject under study, providing the opportunity for the emergence of new research and academic work of access to students and the general community.

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