

Lean Six Sigma Approaches Trend: A Bibliometric Review

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Abstract

Companies and organizations worldwide have used approaches based on Lean Six Sigma to improve the quality of their processes and products. Although there are literature reviews on this topic, the number of papers published on Lean Six Sigma has increased in recent years. Therefore, it is important to analyze the trends of the Lean Six Sigma approach to process improvement and locate the most relevant research centers, authors, and articles. This article presents a bibliometric review of the trends of the most used Lean Six Sigma approaches, analyzing 1,874 documents found in Scopus databases using PRISMA methodology and VosViewer software. The results indicate that the United States, the United Kingdom, and Brazil publish the most articles. Likewise, Heriot-Watt University is the institution with the most consolidated research groups. Antony, J., Does, R.J.M.M., and Cudney, E. A. are the most prominent authors in this topic. The most cited authors were Antony and Does. At the same time, the most published journals are the International Journal of Lean Six Sigma, Proceedings of the International Conference on Industrial Engineering and Operations Management, and the International Journal of Quality and Reliability Management.

Keywords

Lean-Six Sigma, Improvement, Bibliometric Review, Lean Manufacturing, Six Sigma.

1. Introduction

1.1. Lean Manufacturing

The Toyota Production System (TPS) provided the basis for what is now known as lean thinking. This approach to manufacturing began after the Second World War by Taiichi Ohno in the Toyota Motor Company because of capital and resource shortages. Eiji Toyoda instructed his workers to eliminate all waste, which was defined as "Anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely necessary to add value to the product. (Guleria et al. 2022).

Lean Manufacturing is considered an improvement philosophy in which the main objective is to eliminate or reduce waste to reduce the Lead Time of the manufacturing processes. Waste is categorized as follows:

- 1) MUDA: Refers to the eight forms of waste: over-production, defects, inventory, overprocessing, transportation, waiting, motion, and human talent.
- 2) MURA: Refers to all non-scheduled changes made to the production schedule that generate non-value-added activities.
- 3) MURI: Includes all the poor manufacturing station designs that result in operator fatigue, increasing the manufacturing lead time.

1.2. Six Sigma

Six Sigma was developed at Motorola by Bill Smith in the 1980's. Six sigma can be considered a philosophy or set of techniques with the purpose of improving business and manufacturing processes. Six Sigma main goal is to reduce the variation of the process through statistical techniques reaching a quality level of 3.4 parts per million defectives. Six Sigma uses the DMAIC methodology, which consists of the following stages: Define, Measure, Analyze, Improve and Control (Surange 2015).

1.3. Lean Six Sigma

Lean Six Sigma (LSS) integrates both philosophies "Lean" and "Six Sigma" with the purpose of improve quality, reduce variation and to reduce the Lead Time through waste reduction. LSS approach differentiates from Six Sigma methodologies in the time to provide results to the company, while six sigma are projects that takes more than six months, LSS works at lean speed "Just Do It" giving results faster (4 to 6 weeks) (Belu, et al. 2018).

Based on the results and benefits that companies can obtain by using LSS approaches and that today companies need to improve their processes to be more competitive, a bibliometric review is needed. This paper reports an LSS bibliometric analysis that allows any student or institution interested in this area to quickly identify the main authors, institutions, and sponsors, and where they are located.

2. Methodology

2.1 Documents Identification

This investigation was performed using databases such as Scopus and EBSCOhost. The following search equation was used: TITLE-ABS-KEY ("Lean Six Sigma") OR TITLE-ABS-KEY ("Lean-Six Sigma") AND TITLE-ABS-KEY ("Improvement") and open to the industrial or services sector. This research will help to analyze better and understand the current trends and approaches of Lean Six Sigma. The next step was to obtain the RIS and CVS extension files to apply the PRISMA methodology to perform a bibliometric review. It is essential to mention that PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes) has been accepted to conduct systematic reviews; for example, Cisneros et al. (2023) apply the PRISMA to analyze and explain the Fuzzy Optimization for business analytics trends and approaches. On the other hand, Alcaraz et al. (2022) used this methodology to analyze the system Dynamics in Supply Chains through a bibliometric review.

Figure 1 shows the PRISMA methodology in its four stages, as Ortiz-Martinez et al. (2019) recommended. In the first stage, all documents were obtained from the databases using the search equation described above in the two databases used for this bibliometric analysis open to any sector. In the first stage, 1,973 articles were obtained; in the second stage, after removing duplicates, the quantity was reduced to 1,873. In the third stage, thirty-four articles from 2023 were excluded, with 1,839 articles included in the bibliometric analysis. Thus, the search equation is as follows: (TITLE-ABS-KEY ("Lean Six Sigma") OR TITLE-ABS-KEY ("Lean-Six Sigma") AND TITLE-ABS-KEY ("Improvement")) AND LIMIT-TO (LANGUAGE," ENGLISH") AND EXCLUDE(PUBYEAR,2023)).

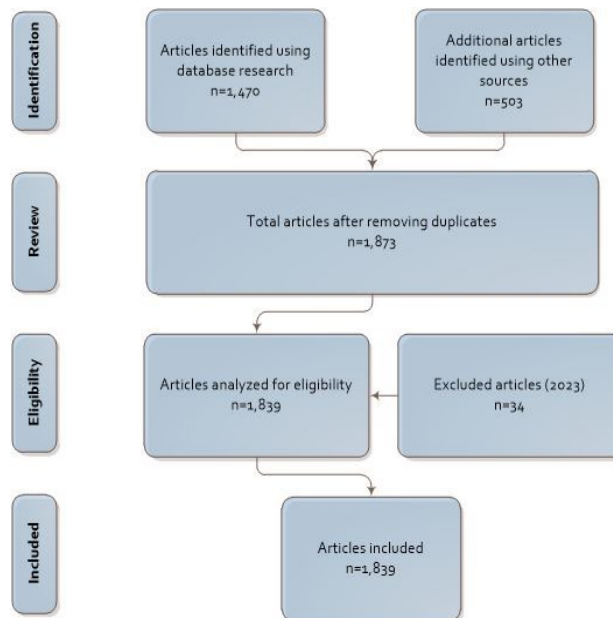


Figure 1. Methodology

2.2 Document Analysis

The total of documents included are analyzed using the software VOSviewer 1.6.17 since it has been used by many authors for bibliometric reviews, such as Alcaraz et al. (2022), to analyze trends for the Dynamic Systems in Supply chain and by Goli and Haghhighinasab (2022) to analyze the prices of the essential products.

This bibliometric review focuses on the following topics:

1. Trends in articles published on Lean Six Sigma topics.
2. Most cited authors on Lean Six Sigma Topics.
3. The most important research groups were located.
4. Countries and institutions with the most published.
5. Most frequently cited documents.

3. Results and Discussion

3.1 Trends of Lean Six Sigma

Figure 2 shows the trend of Lean Six Sigma used to improve the processes. It can be noted that the first articles about this topic are: by Palmer (2001), Brady (2001) and Winiarz et al. (2001), so it can be concluded that these three authors can be considered as the initiators in this research topic.

The Lean Six Sigma trend, as shown in Figure 2, exhibited an excellent trend; the first articles were published in 2001; in the first three years, the number of papers per year was limited to nine, but this dramatically changed three years after 2004, and the number of papers increased up to 40 per year. Thus, in the following years, the number of papers will increase to a maximum of 196 articles per year in 2021. Unfortunately, in 2022, the COVID-19 pandemic affecting the home office affected the chance to conduct Lean Six Sigma projects in many organizations; thus, the number of articles per year dropped to 144.

All the analyzed information and statistics can be found in a spreadsheet in the following link: [10.6084/m9.figshare.22411453](https://www.figshare.com/figure/22411453).



Figure 2. Trends in Lean Six Sigma Publications

3.2 Type of documents in Lean Six Sigma

Figure 3 illustrates the documents published in the Lean Six Sigma area. As described above, 1,839 documents were analyzed: 55.5% were articles, 29.3% were conference papers, and 7.06% were reviews, the top three types of documents. After reviewing these percentages, it can be noted that more than half of the documents are articles; thus, Lean Six Sigma can be considered a mature topic with diverse ways to evolve this topic.

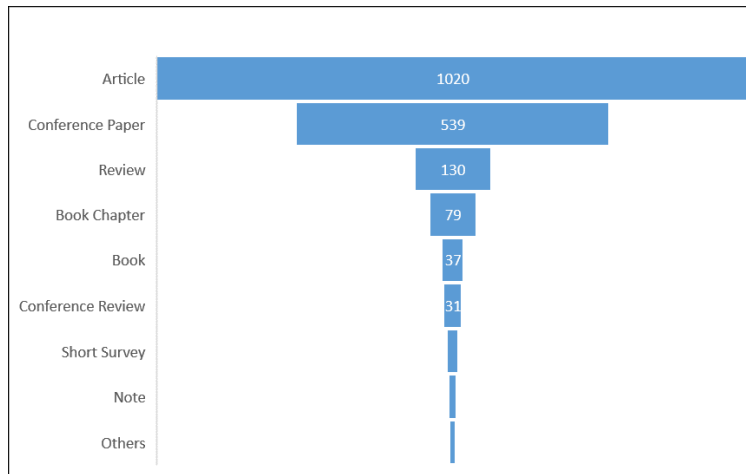


Figure 3. Type of documents on Lean Six Sigma topics

3.3 Lean Six Sigma research funding agencies

Several funding agencies are interested in lean six-sigma topics. As shown in Figure 4, the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior in Brazil is the institution that has funded the most projects in Lean Six Sigma, followed by Conselho Nacional de Desenvolvimento Científico e Tecnológico and Fundação para a Ciência e a Tecnologia, both located in Brazil. It can be concluded that the institutions in Brazil are the ones that funded the most in Lean Six Sigma.

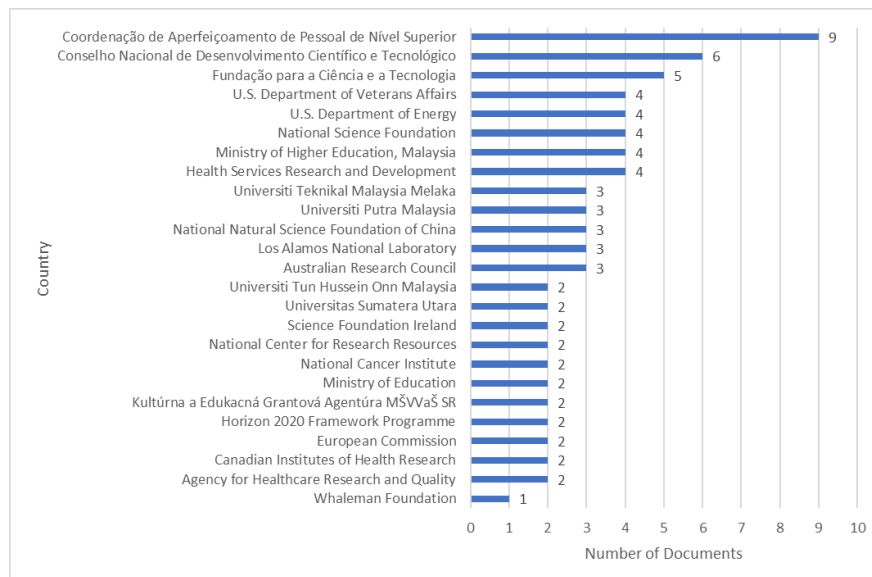


Figure 4. Funding institutions in the Lean Six Sigma topics.

3.4. Main authors, institutions, and countries involved in Lean Six Sigma research.

More than 80 countries have been identified where there is at least one document using Lean Six Sigma to improve manufacturing processes. Figure 5 presents the top 15 countries. The United Kingdom, Ireland, and the Netherlands lead European countries. At the same time, India, Indonesia, and Malaysia do so for Asia, and the United States, Brazil, and Mexico do so for the Americas.

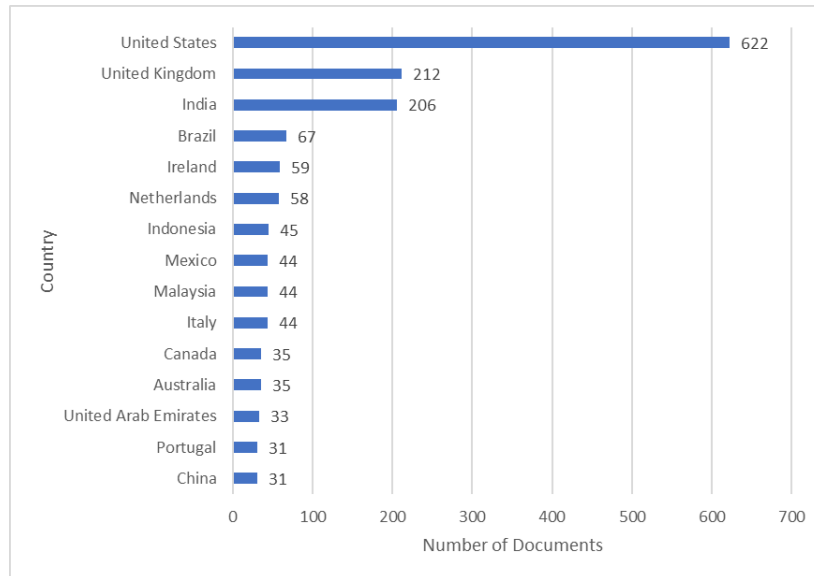


Figure 5. Main countries producing documents in Lean Six Sigma

Regarding the institutions that publish the most in Lean Six Sigma topics, 160 were identified. Figure 6 illustrates the list of institutions with at least 11 papers. Heriot-Watt University in the United Kingdom reports the most significant number of papers published, a total of fifty-four, followed by the Universiteit van Amsterdam in the Netherlands with 30 documents, University of Strathclyde, and the University of Galway in the United Kingdom, with a total of twenty-three papers, respectively. In conclusion, it can be said that the British Institutions are the most predominant publishers of Lean Six Sigma, followed by America and Brazil.

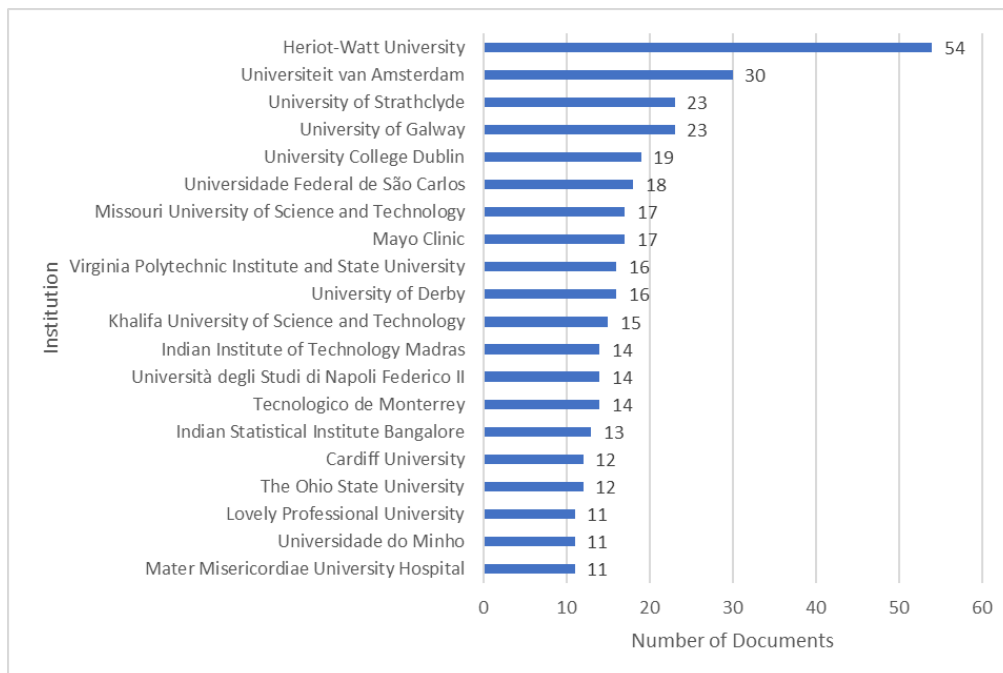


Figure 6. Institutions with Lean Six Sigma documents.

One-hundred and fifty-nine authors were identified who generated papers in Lean Six Sigma for process improvement were identified. Table 1 shows the top ten authors and the total number of documents published. As can be seen, Antony, is the author with the highest number of papers published and thus can be considered a world leader in Lean Six Sigma applications since he is leading the number of documents generated.

Table 1. Main Authors in Lean Six Sigma

Author Name	Number of Documents
Antony, J.	88
Does, R.J.M.M.	24
McDermott, O.	16
Garza-Reyes, J.A.	15
Cudney, E.A.	14
Sony, M.	14
Teeling, S.P.	13
Sunder M, V.	12
Improta, G.	11
Kumar, M.	11

3.5 Main Journals publishing about Lean Six Sigma

Approximately 863 scientific journals publish topics related to Lean Six Sigma. Figure 7 shows the ten journals with the highest number of documents published. The main journals are The International Journal of Lean Six Sigma, Proceedings of the International Conference on Industrial Engineering and Operations Management, the International Journal of Six Sigma and Competitive Advantage and the International Journal of Quality and Reliability Management; all of them focus on Lean Six Sigma and Quality approaches to either improve or solve problems in different production and service enterprises.

It is important to mention that these journals publish theoretical and applied approaches and Lean Six Sigma, having an exceptionally low quantity of articles that sustain their conclusions with a data approximation of 30% of the documents.



Figure 7. Main sources publishing Lean Six Sigma.

3.6 Main Keywords used by authors in Lean Six Sigma

Authors used total of 7,709 keywords in their research papers related to Lean Six Sigma. The most common words were: six sigma (813), lean six sigma (707), work simplification (451), process engineering (373), lean production (372), process monitoring (339), lean (301), total quality management (299), human (273), quality improvement (272), humans (239), process improvement (209), article (177), continuous improvement (158). Figure 8 shows a distribution of the keywords.

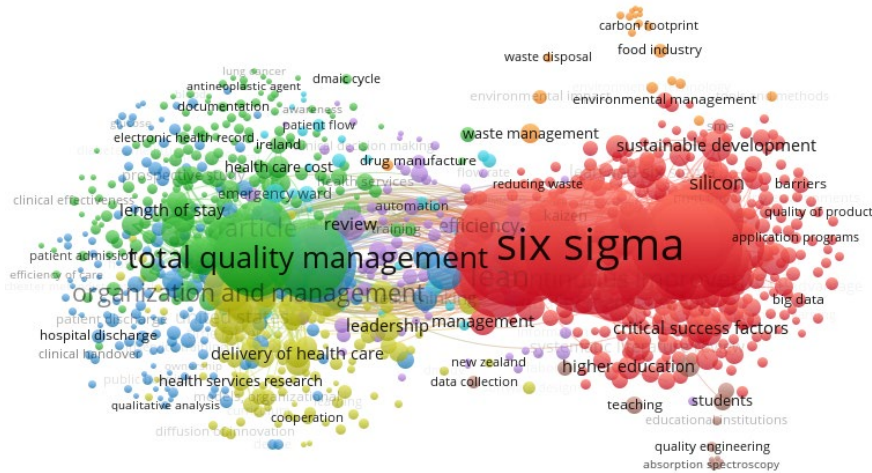


Figure 8. Keywords used by the authors in Lean Six Sigma research.

3.7 Most cited authors in Lean Six Sigma

A total of 159 authors have been identified worldwide that research Lean Six Sigma approaches, but not all of them have had the same impact on the scientific community; for example, Cooper, R.G. has published only one paper and has received a total of 808 citations. On the other hand, authors such as Antony have published eighty-eight articles and have received only 360 citations. Table 2 shows the authors with over 300 citations received on this topic, which refer to the total number of papers published, not to a specific paper.

Table 2. Most cited authors

Article	Cited By
Cooper R.G.	808
Dahlgard J.J., Dahlgard-Park S.M.	471
Snee R.D.	448
Arnheiter E.D., Maleyeff J.	411
Bhuiyan N., Baghel A.	391
Pepper M.P.J., Spedding T.A.	375
Antony J.	360
Andersson R., Eriksson H., Torstensson H.	352
Kumar M., Antony J., Singh R.K., Tiwari M.K., Perry D.	347
Albliwi S., Antony J., Lim S.A.H., van der Wiele T.	329

3.8 Most cited documents

Table 3 shows the documents that have been cited the most, in descending order. It can be noted that the Cooper R.G. article was the most cited, with over 800 citations.

It is important to mention that the trends in Lean Six Sigma papers are more focused on theoretical approaches; as discussed previously, only two of the most cited articles are implementations of Lean Six Sigma for improvement or problem-solving.

Table 3. Most cited documents in Lean Six Sigma.

Article	Cited By
Perspective: The stage-gates® idea-to-launch process - Update, what's new, and NexGen systems	808
Lean production, six sigma quality, TQM and company culture	471
Lean Six Sigma – getting better all the time	435
The integration of lean management and Six Sigma	411
An overview of continuous improvement: From the past to the present	391
The evolution of lean Six Sigma	375
Similarities and differences between TQM, six sigma and lean	352
Implementing the lean sigma framework in an Indian SME: A case study	347
Critical failure factors of lean Six Sigma: A systematic literature review	329
Use of lean and six sigma methodology to improve operating room efficiency in a high-volume tertiary-care academic medical center	316

4. Conclusion

A total of 1839 documents related to the Lean Six Sigma Improvement Approach were identified and analyzed, and it has been noted that there is a positive trend in the number of papers published related to this topic, which began in 2001 with only four papers, but in 2021, there were 196 papers. When analyzing funding agencies, it was noted that Brazil provides the most economic funds. The countries that publish the most in Lean Six Sigma topics are the United States, followed by the United Kingdom and India, where the educational institutions that published the most are Heriot-Watt University and the Universite Van Amsterdam.

It was found that the authors that are leading on this topic are: Antony, J., Does, R.J.M.M. and McDermott, O. These authors published in journals related to quality and operational management such as the International Journal of Lean Six Sigma, Precedings of the IEOM and the International Journal of Six Sigma and Competitive Advantage.

The most cited authors are Cooper R.G., Dahlggaard J.J., and Snee R.D. Finally, the most cited countries were Brazil, the United States, and the United Kingdom.

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