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# Aplicación del SMED en la industria: Revisión sistemática de la literatura a través de VOSviewer

## Application of SMED in Industry: Systematic Literature Review through VOSviewer

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**RESUMEN**

En la actualidad, el análisis bibliométrico juega un papel fundamental en la búsqueda de métodos cuantitativos para identificar las tendencias e impacto a nivel científico de campos de investigación. Este análisis, se realizó para la herramienta SMED (Single Minute Exchange of Die) en el sector industrial identificando mapas de red de co-ocurrencia, co-citación y co-autoría de palabras claves, autores y países, respectivamente en el software bibliográfico conocido como VOSviewer. El presente documento tiene por objeto implementar un análisis bibliométrico a través de la literatura para conocer las características e impacto en el paso del tiempo del SMED. Para la ejecución del documento, se ha tenido en cuenta una ecuación de búsqueda en la base de datos de Scopus, encontrándose 433 artículos relacionados con el SMED en sectores industriales. Con este fin, la herramienta puede ser aplicada en el sector automotriz, textil y metalmecánico tanto en líneas de producción como en máquinas y los países que lideran la producción científica son India, China y Estados Unidos; en contraste, no se ha identificado producción científica en Colombia. Finalmente, las organizaciones del sector industrial requieren de la herramienta SMED que permitan reducir costos y a la vez, aumentar la productividad en un proceso de cambio de herramentales.

**Palabras clave:**

SMED,
Single Minute Exchange of Die,
sector industrial,
VOSviewer

**ABSTRACT**

At present, bibliometric analysis plays a fundamental role in the search for quantitative methods to identify trends and impact at the scientific level of research fields. This analysis was carried out for the SMED (Single Minute Exchange of Die) tool in the industrial sector, identifying network maps of co-occurrence, co-citation, and co-authorship of keywords, authors, and countries, respectively, in known bibliographic software. Like VOSviewer. The purpose of this document is to implement a bibliometric analysis through the literature to know the characteristics and impact of the SMED over time. For the execution of the document, a search equation has been taken into account in the Scopus database, finding 433 articles related to SMED in industrial sectors. To this end, the tool can be applied in the automotive, textile, and metalworking sectors both in production lines and in machines, and the countries that lead scientific production are India, China, and the United States; in contrast, no scientific production has been identified in Colombia. Finally, organizations in the industrial sector require the SMED tool to reduce costs and at the same time increase productivity in a tool change process.

**Keywords:**

SMED,
Single Minute Exchange of Die,
industrial sector,
VOSviewer

## Introduction

The SMED tool, known by its acronym Single Minute Exchange of Die, translates to the rapid change of tooling in less than ten minutes [1], [18]. The Japanese, Shigeo Shingo, was the pioneer in 1950 in the creation of the tool in the automotive sector, which is based on reducing internal and external operations in a change of tooling in die-cutting machines [14]; in addition, to improve and optimize resources at maximum efficiency-seeking to reduce time, costs and movements in the metalworking industry [1].

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SMED has divided into internal and external operations; the internal operation consists of performing activities when the machine is stopped such as disassembly and assembly. On the other hand, the external operation consists of performing tasks when the machine is in operation, such as performing maintenance, enlisting, and preparing to tool [10]. The above, so that the internal operation reduces the time, making the tooling change a flexible process with the necessary resources and at the right time for the proposed method [4].

Additionally, the tool with 3 general stages for the application: 1) identify and separate internal and external operations, 2) convert internal operations into external, 3) optimize internal and external operations; it is there where the improvements had tested so that there is a significant saving in aspects of time and costs compared to the current method and the proposed method [7]. Through the antecedents, the SMED has evolved in the application, finding use in footwear, aeronautical, electronic, food, among others. This evolution has also been reflected in die-cutting machines and production lines, achieving the fundamental criterion of the tool [2].

With the use of SMED, specific and effective methods are put into practice to reduce the times in the process of change in the industrial sector, starting with a study of production and indicators linked to the development of times in each of the processes that are executed in SMED [3]. The point to be carried out is the observation, followed by the evaluation and analysis that lead to characterize and standardize the soft and hard technology of the process under study [5]. Under this aspect, it is possible to determine the versatility and alignment of the tool with other improvement strategies and thus evaluate the effectiveness of the implementation of the SMED steps.

With the use of the SMED tool, the verification of the losses caused in the plant is effective and the identification of the origin of the same [6]. Similarly, it generates the ability to identify each specific aspect in the execution of the processes and the implementation of each technological line of tooling in operation as well as in quality and safety.

With this in mind, a systematic literature review is conducted and bibliometric analysis of the literature in the Scopus database is implemented to understand its characteristics and impact over time. In that context, this article implements a literature analysis based on network maps in the VOSviewer software to analyze aspects of co-authorship, co-citation, and co-occurrence networks in the SMED tool [8]. The software allows a combination of quantitative methods through network map, density, and timeline methods.

It should be noted that bibliometric indicators allow for an evaluation of scientific and research production, measured through the publications of scientific articles, defining four factors: 1) who produces, being individuals, institutions, or countries. 2) How many documents do they produce. 3) How cited what they produce is. 4) How research networks or institutions collaborate.

## Methodology

This section presents the literature review that has developed on the topic of SMED in industrial sectors. In the review, it has been found that industries such as metalworking, electrical, food, automotive, textile, among the most prominent, used the SMED tool to improve their change processes. Similarly, different relationships in the SMED research field have been evidenced that allow a more successful approach to the analysis of the tool through bibliometric networks.

For the literature search review, the following equation has been defined in the Scopus database:


According to the above, the database yielded 433 articles, which were incorporated into the scientific visualization software of greater impact worldwide, VOSviewer 1.6.15, which is to perform bibliometric maps based on co-citation distance, co-authorship, co-occurrence of organizations, countries, authors, and keywords [17]. For this, the software visualizes the results through network, timeline, and density maps.

As methods, word co-occurrence analysis, co-citation of authors and references, and co-authorship of countries are implemented, which serve as the measurement patterns between the relationship of documents and structure of the SMED tool.  Co-citation is defined as the number of times with which two papers from previous literature are cited together in subsequent literature; the higher the co-citation, the higher the relationship [9]. The unit of analysis of co-citation results is between authors.

Keyword co-occurrence consists of the close relationship between two or more keywords that are mentioned within a document; the higher the frequency, the higher the relationship [11]. The unit of analysis of co-occurrence results is comprised of keywords. Additionally, co-authorship is related to the frequency in which 2 or more scientists write a paper together; the greater the collaboration, the greater the co-authorship [15]. The unit of analysis of co-authorship results is comprised of countries.

## Results

### Keyword co-occurrence analysis

The keyword co-occurrence analysis is based on the comparative study of the terms of all the SMED keywords to determine the close relationship between both concepts; in addition, to determine a baseline for a new field of research or, failing that, to deepen in the same field. Within the results obtained by the VOSviewer software, 2 visualizations of the keywords were generated, initially grouped by the co-occurrence analysis of the keywords globally as shown in Figure 1 and a co-occurrence analysis of the keywords of the industrial sector node as shown in Figure 2. It should be noted that the keywords provide an important meaning to the central content of the 433 articles, in such a way that they account for the research and knowledge topics.

According to Figure 1, there are 4 nodes in which SMED is present in the fields of industry and health; although the search equation was limited to the field of engineering. It is highlighted that the main node was "smed" with the highest number of occurrences with a total of 90 times, followed by "lean production" with 53 occurrences and "lean manufacturing" with 49 occurrences. Similarly, there is a strong relationship between the health node and expressions such as "drug carrier", "drug delivery system", "drug formulation" and "microemulsion", understanding that the acronym SMED is part of the name of classification of human cells.

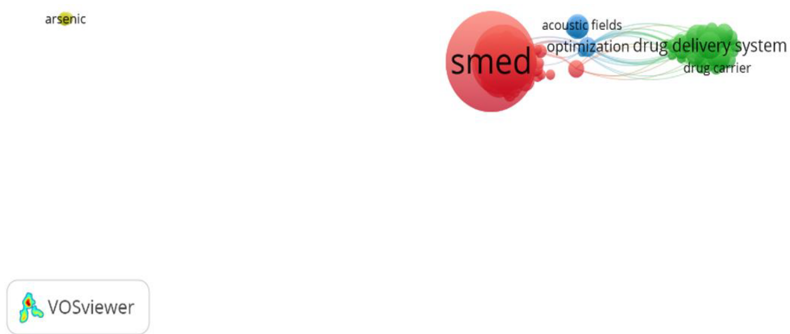


**Figure 1** Co-occurrence analysis of keywords globally
**Source:** VOSviewer

According to Figure 2, the co-occurrence analysis of the main node is observed, being that of the industrial sector. From there, it is emphasized that terms such as "manufacture", "productivity", "statistical energy analysis", "simulation", "cost-effectiveness", "manufacturing companies", "automotive industry", "metallurgy", "textile industry", among others, have a great relationship being keywords used to define and apply the SMED tool.

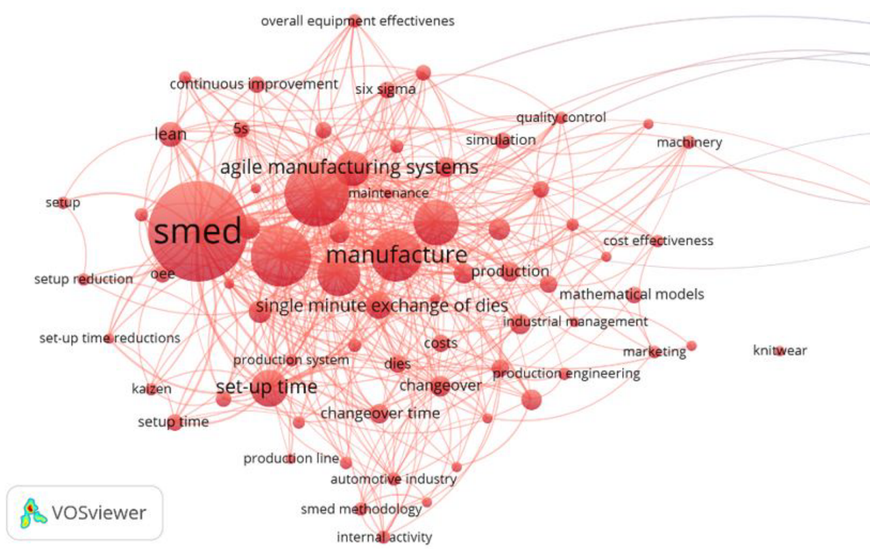


**Figure 2** Keyword co-occurrence analysis by industry sector

**Source:** VOSviewer

Similarly, it is related to the preparation of time and quick changeover, known as "setup time", "setup reduction" "setup" and "quick changeover"; as well as with other Lean Manufacturing techniques such as Six Sigma, 5S, among others and with mathematical software to analyze the data as WITNESS software, simulation program LMTTS-SMED, iGrafx program, Rasch method, Taguchi method, to name a few [13].

Finally, the keywords mentioned above, refer to terms used in the last 5 years, evidencing a successful evolution of the tool since its inception in 1950 in the manufacturing sector [12], [16] as shown in Figure 3.

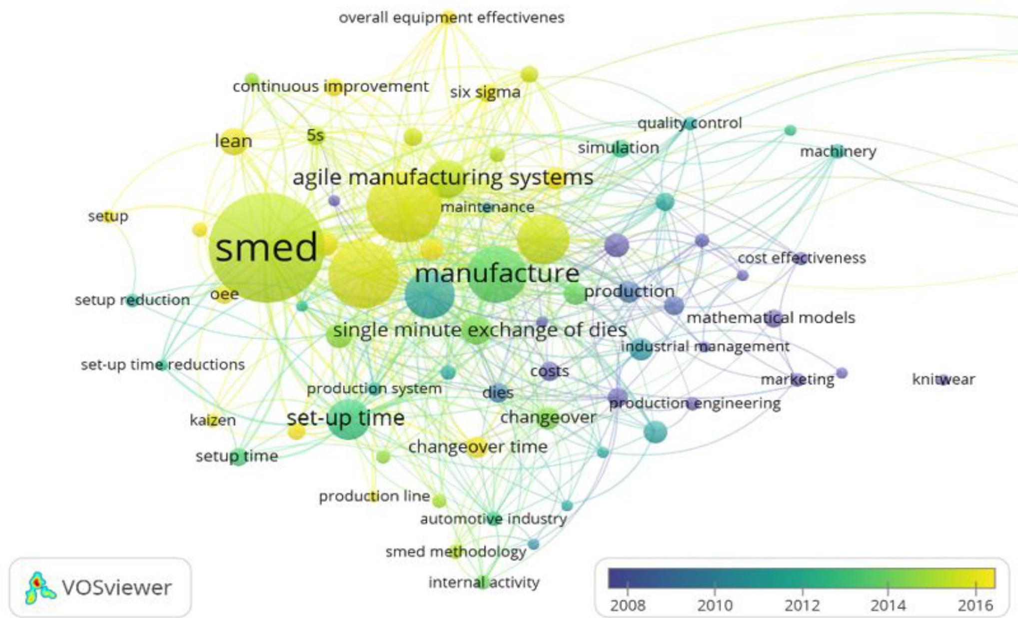


**Figure 3** Timing map for industry sector keywords
**Source:** VOSviewer

## Author co-citation analysis

Through the visualization of co-citation, it is possible to determine the correlation between the most cited authors through the software proximity distance observed in Figure 4, indicating that the smaller the distance between authors, the greater the strength of co-citation and the probability that they are semantically related. The analysis of the co-citation of authors consists of the relationship of 2 documents that were cited in the same, observing the frequency in which they were referenced.

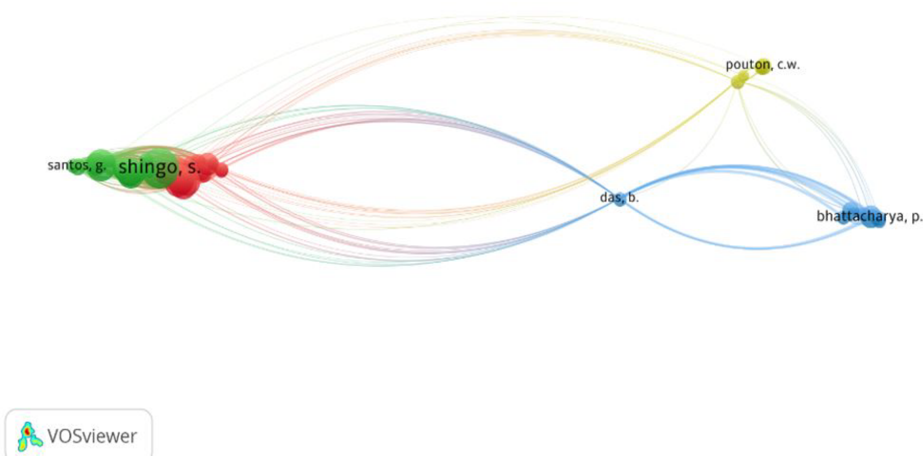


**Figure 4** Author co-citation analysis
**Source:** VOSviewer

This network analysis yields 50 authors and 621 co-citation links divided into 4 clusters represented in colors, the first cluster and the second cluster identified by the colors red and green, respectively. Each cluster was composed of 18 authors and these were the most relevant for SMED concerning the other two clusters.

The above refers to the fact that the first two clusters are the strongest, as it is observed that they are the ones with the largest nodes, which means that they are the ones with the highest number of citations from the authors. The Japanese author and engineer, Shigeo Shingo, is presented as the author of greater centrality with 121 citations and means that he is the pioneer in the implementation of the change of tooling in manufacturing companies.

Table I shows that the first five authors have the highest number of citations: Shingo, S. with 121 occurrences, Maxit. L. with 93 occurrences, Silva, F. with 84 occurrences, Guyader, J. with 83 occurrences, and Mileham, A. with 76 occurrences. The above translates that, the author Shingeo is the first with the highest link strength in scientific and research journals such as Journal of Sound and Vibration with 157 occurrences and Procedia Manufacturing with 85 occurrences.

**Table I** List of Authors with the Highest Co-Citation Rate

| Authors | Subpoenas | Total bond strength |
|---|---|---|
| Shingo, S. | 121 | 1111 |
| Maxit. L. | 93 | 1692 |
| Silva, F. | 84 | 2032 |
| Guyader, J. | 83 | 1388 |
| Mileham, A. | 76 | 1880 |
| Mcintosh, R. | 75 | 1870 |
| Jones, D. | 74 | 784 |
| Womack, J. | 73 | 834 |
| Culley, S. | 71 | 1832 |
| Owen, G. | 68 | 1750 |
| Totaro, N | 62 | 1184 |

## Co-authorship analysis in countries

The country co-authorship network for the SMED tool has 23 countries. This analysis yields 7 clusters represented in colors; the first cluster identified by the red color, the second cluster identified by green color; being the most relevant. According to Figure 5, it is observed that the countries Portugal, China, United States, and India, lead the scientific production of the SMED; although the distance between these countries is distant (geographically distant), they are intellectually related.

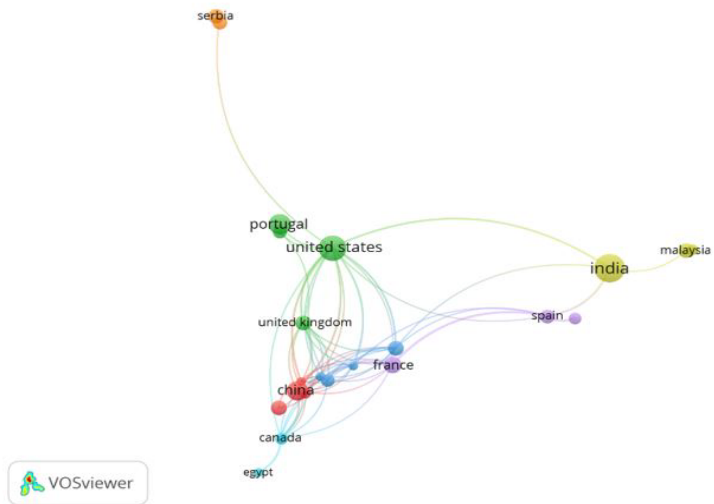


**Figure 5** Country co-citation analysis

**Source:** VOSviewer

In addition, the United States has more links with countries such as Turkey, Portugal, India, China, Canada, United Kingdom, Italy, Spain, France, among others. Also, it is identified that the countries mentioned above except for the United States, Canada, and the United Kingdom have recent scientific production, from 2014 to 2020. Next, it is identified that Brazil has collaboration with Portugal and the United States and Peru has scientific partnerships with Canada, being the only Latin American countries in research on the SMED tool; being emerging countries.

Table II shows the top ten countries with the highest scientific production of the SMED. The most relevant are: India with 282 citations, France with 206 citations, Belgium with 194 citations, Italy with 185 citations, and with 170 citations corresponds for United States. This indicates that European countries are the most collaborative for the production of research articles in the industrial sector.

**Table II** List of Countries with the Most Co-Authorships

| Countries | Documents | Subpoenas | Total bond strength |
|---|---|---|---|
| India | 51 | 282 | 21 |
| France | 18 | 206 | 25 |
| Belgium | 6 | 194 | 15 |
| Italy | 11 | 185 | 40 |
| United States | 41 | 170 | 16 |
| Portugal | 28 | 165 | 60 |
| United Kingdom | 14 | 145 | 31 |
| Turkey | 13 | 137 | 44 |
| China | 26 | 104 | 30 |
| Germany | 15 | 100 | 32 |

## Conclusions

This work is based on an analysis of bibliometric data related to 433 scientific articles found in the Scopus database from 1938 to 2020. Co-occurrence, co-citation, and co-authorship network map analysis methods were performed in the bibliometric software VOSviewer to identify the characteristics and scientific impact of the SMED tool.

The analysis of the keywords allowed to explore the evolutionary content of the tool, application sectors, research branch, diagnostic and analysis techniques, and main contributions. This indicates that it is a Lean Manufacturing tool that can be applied to the textile, automotive, and metalworking sectors, and in which it can be diagnosed and analyzed through efficiency costs, productivity indicators, and simulation programs. Likewise, it can be analyzed in production lines and machines to achieve savings in costs and time, regardless of the compliance that the change of tooling is carried out in only 10 minutes.

The analysis of co-citation represents the networks that connect authors and journals. The main authors in developing research on the application of SMED in the industrial sector were: Shingo, S., Maxit. L. Silva, F., Guyader, J. and Mileham, A. and in scientific and research journals such as Journal of Sound and Vibration and Procedia Manufacturing.

The analysis of country co-authorship represents strong research linkages. The countries that lead the SMED research were: Portugal, China, India, and the United States; although they are geographically distant countries, they have a high intellectual relationship. On the other hand, it was identified that there is a great opportunity to promote and implement this type of tool in Colombia to minimize existing gaps in the agriculture and construction industry, which represents 36% of employment in the city of Manizales. Finally, SMED is part of the strategy par excellence for the reduction of time in a change of configuration.

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