Journal of Operational and Strategic Analytics
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Bibliometric Analysis of Data Envelopment Analysis in Supply Chain Management

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Received: 02-05-2023 **Revised:** 03-10-2023 **Accepted:** 03-18-2023

Citation: Ç. Sıcakyüz, "Bibliometric analysis of data envelopment analysis in supply chain management," *J. Oper. Strateg Anal.*, vol. 1, no. 1, pp. 14–24, 2023. https://doi.org/10.56578/josa010103.

Abstract: A bibliometric analysis is presented in this paper to examine the use of Data Envelopment Analysis (DEA) in the domain of Supply Chain Management (SCM). The research trends on DEA in SCM from 2000 to 2023 are explored, using data obtained from the Web of Science database (WoS) and VOS viewer software for detailed mapping of the articles. The numerous articles that use DEA in SCM worldwide are analyzed and summarized in this bibliometric study, producing a complete assessment of DEA in the field from 352 academic papers published in high-ranking publications. The articles are classified according to the year of publication, countries of the author(s), working areas, journals, and content of studies. Based on the findings of this research, tremendous potential is shown for DEA as a suitable evaluation instrument for future studies on sustainability concerns in SCM.

Keywords: DEA; Supply Chain Management; Bibliometric Analysis; VOSviewer

1 Introduction

The contemporary form of Data Envelopment Analysis (DEA) was first proposed in 1978 and has since greatly benefited both research and application [1]. This analytical approach is essentially a linear programming method for analyzing performance characteristics of different organizations, where multipl e inputs and outputs complicate comparisons [2]. DEA uses this information to develop efficiency frontiers across the data of accessible organizational units.

However, this efficiency method cannot be immediately applied to assess the effectiveness of supply networks since some measurements associated with supply chain (SC) components cannot be simply defined as "outputs" or "inputs" of the system. Disputes among SC participants are likely to arise concerning these measures. For example, suppliers' income is an output that suppliers want to maximize, but also an input that manufacturers wish to minimize. Merely reducing overall SC costs or increasing the entire SC profit does not adequately model and address the underlying tensions [3]. Hence, many studies have focused on performance measurement in different components of SCM in various sectors using varying models. For example, Mishra [4] used DEA to quantify internal SC efficiency in the pharmaceutical sector, while Hahn et al. [5] examined company value related to operational SC performance parameters from a financial sector viewpoint. Different models have been proposed, such as the SC assessing index system based on four factors: financial, process, service, and innovation, using DEA and Analytic Hierarchy Process (AHP) approaches [6]. Tavana et al. [7] extended the Epsilon-Based Measures (EBMs) approach by introducing a novel Network EBM (NEBM) technique that integrates radial and non-radial efficiency measures into a coherent structure to address network DEA applications.

DEA has been reviewed extensively in the literature. Comprehensive research has been conducted to investigate DEA's efficiency [8, 9], while several studies have examined DEA in the energy and environment area [10, 11] from different aspects and time spans. Liu et al. [12] examined DEA in methodological and application publications. Soheilirad et al. [13] conducted a systematic and meta-analysis approach to review DEA in SCM examination, but their review only covers 75 published works from 1996 to 2016. A bibliometric analysis was conducted on DEA in sustainable supplier selection [14], while Cikovic et al. [15] performed an exhaustive literature assessment of research utilizing DEA in supply chain management from 2017 to August 2021. However, no comprehensive bibliometric analysis has been conducted for DEA in SCM.

Bibliometric analysis has been widely used in business research, which can be attributed to (1) the development, presence, and ease of access of bibliometric software such as Leximancer, Gephi, VOSviewer, and scholarly databases such as WoS and Scopus, and (2) the cross-disciplinary pollination of bibliometric research methods. More importantly, the popularity of bibliometric analysis in business research is not a passing trend but reflects its value in (1) dealing with vast amounts of scientific information and (2) creating high scientific value [16].

Therefore, this study aims to provide a comprehensive bibliometric analysis of 352 articles on Data Envelopment Analysis (DEA) in Supply Chain Management (SCM) from 2000 to 2023. The study seeks to answer the following research questions:

(1): What is the percentage of papers conducted in the SCM domain within the DEA literature?
(2): How widespread is the application of DEA in different areas of SCM?
(3): Which are the most frequently cited articles related to DEA in SCM applications?
(4): What are the growth trajectories for each subject area within the field?

This research makes several contributions to the DEA field. First, it distinguishes the publications between SCM and the entire collection of DEA literature. Second, it lists the most frequently referenced scientific publications within the field. Finally, it identifies outstanding articles and authors in the essential historical development route of the field using primary analysis.

2 Methodology

For this study, data was collected from the Web of Science (WoS) database, and all selected articles and journals were authored in English. To ensure that the articles obtained were relevant to various aspects of Data Envelopment Analysis (DEA) and Supply Chain Management (SCM), specific keywords such as ”supply chain management” and ”data envelopment analysis” had to be present in the title, keywords, or abstracts. This systematic literature search yielded 419 publications published between 2000 and March 2023. From all publication types, including conference proceedings, papers published in trade journals, books, and book chapters, a total of 352 articles were selected for bibliometric analysis.

3 Results

These 352 articles were cited a total of 10,445 times, with 9,526 references excluding self-citations. The estimated H-index for the selected articles is 54. The average citation per article was calculated to be 29.67.

3.1 Articles Statistics

3.1.1 Publication years

Figure 1 illustrates the number of articles on supply chain management utilizing the DEA method between 2000 and 2023. From 2000 to 2010, the number of publications remained below 10, but it doubled in 2010 and 2011. From 2016 to 2018, there was a significant increase in the number of publications, with the majority being published in 2021. However, the number of articles decreased in 2022. As of now, only 5 articles have been published in 2023, but it is expected that the number will increase by the end of the year.

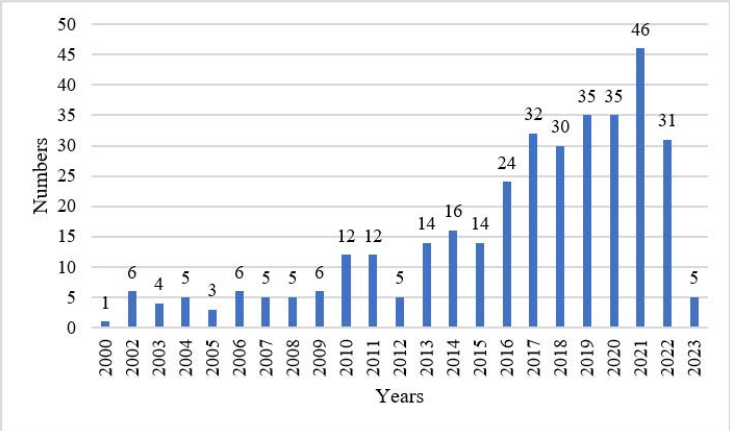

Figure 1. Published article numbers between 2000 and 2023

3.1.2 Research areas

The researchers have published articles on supply chain management utilizing DEA in various fields. Figure 2 below illustrates the distribution of research areas covered in the selected articles between 2000 and 2023.

Out of 34 research areas, 25 are represented in Figure 2. The majority of studies were conducted in Business Economics and Engineering, with 119 articles. The second most represented field is Operations Research and Management Science, followed by Environmental Sciences and Ecology, which together account for approximately 16% of all publications. Around 13% of the articles are in the field of Computer Science.

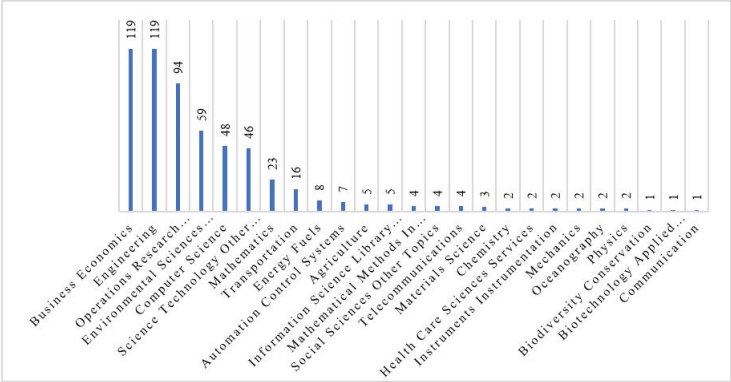

Figure 2. Articles in Research Areas

3.2 Most Impactful Studies

Table 1 lists the top ten articles on the topic of Supply Chain Management with DEA, based on their citation count. The majority of the highly referenced articles are related to outsourcing, supplier performance, and supplier selection. The paper with the highest number of citations, with 409, is by Kuo et al. [17] and was published in the Journal of Cleaner Production in 2010. The study focused on selecting green suppliers using a hybrid method of Neural Network (NN), DEA, and Analytical Network Process (ANP). Another study by Liu and Hai [18] on supplier selection with Analytical Hierarchy Method (AHP) used DEA to assess the performance of decision-making units.

Table 1. Highly cited articles

Authors	Year	Title	Journal	Number of Citation
[17]	2010	Integration of artificial neural network and MADA methods for green supplier selection	Journal of Cleaner Production	409
[18]	2005	The voting analytic hierarchy process method for selecting a supplier	International Journal of Production Economics	292
[11]	2017	A literature study for DEA applied to energy and environment	Energy Economics	279
[19]	2015	A new fuzzy DEA model for evaluation of efficiency and effectiveness of suppliers in sustainable supply chain management context	Computers & Operations Research	245
[20]	2014	A comprehensive environment-friendly approach to supplier selection	Omega-International Journal of Management Science	198
[21]	2006	Vendor performance with supply risk: A chance-constrained DEA approach	International Journal of Production Economics	190
[22]	2014	A novel network data envelopment analysis model for evaluating green supply chain management	International Journal of Production Economics	188
[23]	2011	Structured methodology for supplier selection and evaluation in a supply chain	Information Sciences	180
[24]	2004	A methodology for strategic sourcing	European Journal of Operational Research	170
[25]	2002	A multi-phase mathematical programming approach for effective supply chain design	European Journal of Operational Research	157

One of the reviewed articles focused on the application of the DEA method in the areas of energy and sustainability, including green supply chain management [11]. Another study by Azadi et al. [19] concentrated on green supply chain management utilizing the fuzzy DEA model. Additionally, Kumar et al. [20] proposed a green DEA technique to monitor carbon footprint in supply chain management. Talluri et al. [21] presented a chance-constrained DEA approach in the presence of uncertain performance measures of vendors using data from a pharmaceutical company. DEA was used to screen potential suppliers, and Techniques for Order Preference by Similarity to Ideal Solution (TOPSIS) was applied for ranking them in the Taiwanese textile industry.

Furthermore, a study was conducted on the design of an effective supply chain et al. [22], while two articles provided a methodology for supply chain [23] or sourcing [24].

3.2.1 Citations to the document

To ensure the relevance and significance of the selected articles, a minimum citation count of 50 was applied. Out of the initial 352 articles, 57 met the condition and were selected for further analysis. The records with the highest links were then chosen, resulting in the largest cluster of 42 items. Figure 3 illustrates a citation density visualization mapping of the selected articles.

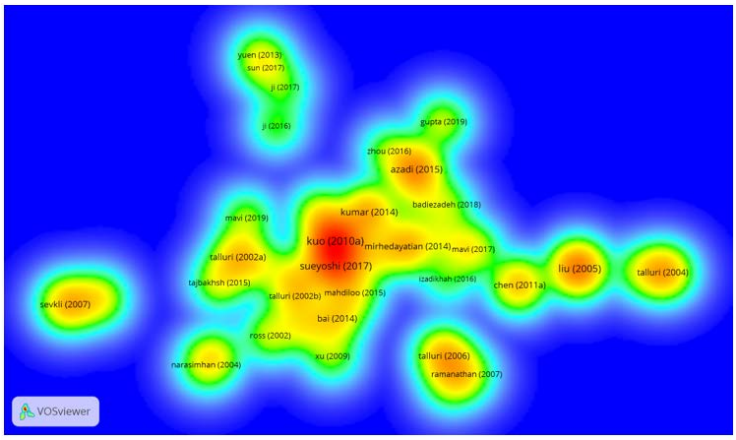

Figure 3. The density map of articles' citations

In the citation density visualization mapping shown in Figure 3, three primary colors are evident, namely green, yellow, and red. Green indicates low-density citation, yellow represents medium-density citation, and red represents high-density citation, reflecting the top articles. The color changes gradually as the proximity to the center of the weight grows, indicating that they are distant from heated themes, and the related groups are replaced with non-integrated ones.

The findings of the analysis reveal four distinct articles on Supply Chain Management with DEA: Kuo et al. [25] and Sueyoshi et al. [26] are among them.

3.2.2 Co-citations to the reference

To further analyze the relevance and impact of the selected articles, a minimum citation count of 25 for cited references was applied. Out of the 14,834 cited references, 22 met the condition and were selected for analysis. The total co-citation links with other cited references were analyzed, and the ones with the highest total strength were selected, resulting in the creation of three clusters with 220 links. The full link strength of the clusters was found to be 2167. The network diagram of the clusters is shown in Figure 4.

The network diagram in Figure 4 reveals three distinct clusters of studies referenced according to the most significant work in a relevant area. The red cluster represents the most significant contribution, with the authors citing papers such as [27–35].

The green cluster was the second most significant contribution, containing references to [3, 23, 36–40]. The blue cluster covers the works of [41–46].

3.3 Most Impactful Authors

3.3.1 Authors

The most active researchers in the field of Supply Chain Management with DEA are Saen RF, with 47 articles, accounting for approximately 13% of the total reports. The second most active researcher is Wang CN, with 25 articles, followed by Talluri S with 24 articles. Other highly productive authors in this area include Dang TT, Izadikhah M, Sarkis J, Hsu HP, Nguyen NAT, and Yousefi S.

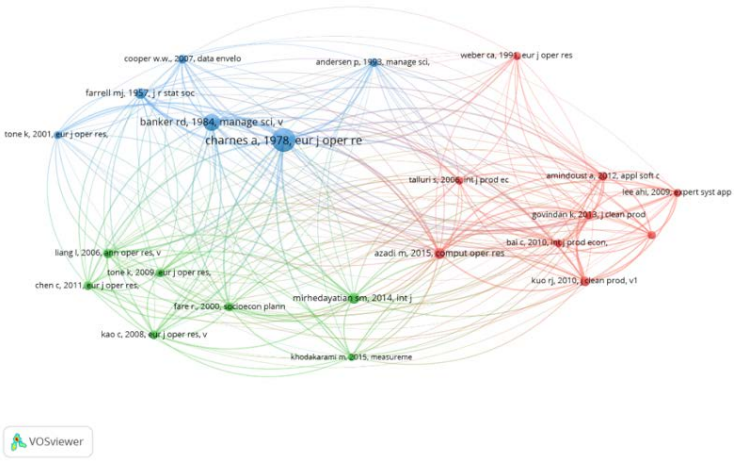

Figure 4. The network diagram of co-citations of articles

To determine the most influential authors in this domain, bibliographic coupling analysis was conducted. A minimum article count of 5 by an author and a minimum citation count of 20 per author's article were set. Out of 798 authors, 15 met these thresholds, and their bibliographic coupling was analyzed to determine the total link power with other authors. The results of the bibliographic coupling analysis and the total connection strength are detailed in Table 2 below.

Table 2. Most prominent authors in this area

Author	Articles	Citations	Total link strength
Saen, Reza Farzipogr	43	1326	11943
Izadikhah, Mohammad	11	190	7054
Wang, Chia-Nan	24	215	5736
Thanh-Tuan Dang	11	118	3206
Hsu, Hsien-Pin	10	63	2764
Talluri, S	13	1056	2641
Azadi, Majid	6	567	2484
Ngoc-Ai-Thy Nguyen	7	84	2268
Talluri, Srinivas	10	177	1966
Shabani, Amir	6	199	1688
Dang, Thanh-Tuan	6	55	1617
Narasimhan, R	5	546	1304
Sarkis, J	5	327	1182
Sarkis, Joseph	6	243	1114
Min, Hokey	5	238	925

The results of the bibliographic coupling analysis in Table 2 indicate that Saen, RF is the most prominent author in the field of Supply Chain Management with DEA. Wang, CN is the second most productive author, but in terms of bibliographic coupling, Izadikhah M was the second most co-cited author in the field. Additionally, the articles of Min, H were among the articles that met the conditions for inclusion, with a total link strength of 925.

3.3.2 Co-citations to authors

To identify the most prominent authors in the field of Supply Chain Management with DEA, a minimum citation count of 100 was set for authors. Out of the 9,956 authors, 12 met the condition and were selected for analysis. The density map of their co-authorship network is visualized in Figure 5 below.

The density map in Figure 5 represents authors who have been cited at least 100 times in studies related to Supply Chain Management with DEA and who have referenced each other jointly. Two distinct clusters emerged from the analysis.

The first cluster includes seven authors, namely Charnes A, Cooper WW, Banker RD, Talluri S, Sarkis J, Saen RF, and Weber CA. Charnes A is the most cited author in this cluster with 331 citations and a total link strength of 1,777. Cooper has 143 citations with a total link strength of 1,135, and Banker has 172 citations with an absolute link power of 1,048.

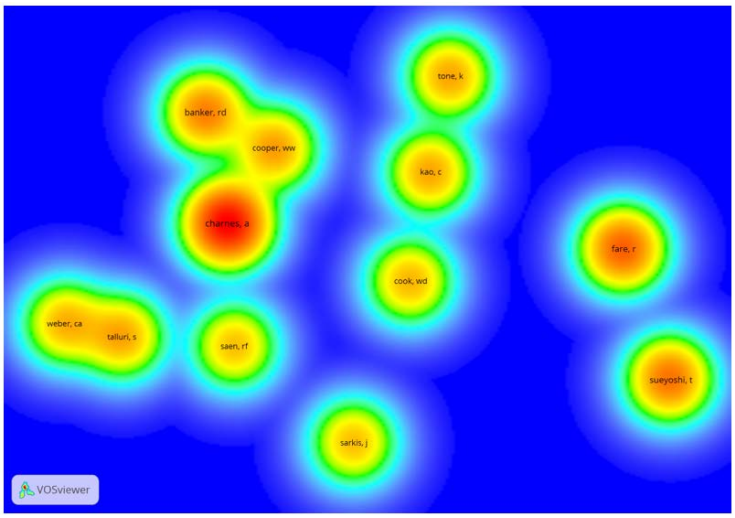

Figure 5. The density mapping of authors to co-citations

The second cluster contains authors Fare R, Sueyoshi T, Cook WD, Tone K, and Kao C. Fare R has the highest total link power among the 12 authors on the map with 208 citations and a total link power of 2,577. Sueyoshi T has the second-highest total link strength (1,923) and 143 citations.

3.3.3 Countries of authors

To examine the bibliographic coupling between countries, we limited the number of articles per country to 10, resulting in 14 countries meeting the threshold out of 57. We calculated the total power of bibliographic coupling connections for these 14 nations and selected the ones with the highest power, categorizing them into four groups. The overlay diagram of these groups is depicted in Figure 6 below.

The first cluster includes Australia, Canada, Iran, Malaysia, Oman, and China. The second cluster consists of England, India, South Korea, Turkey, and the USA. Taiwan and Vietnam constitute the third group, while Germany is in the fourth category.

Iran is the most productive country in terms of the number of articles published, with 91 articles and a total link strength of 44,015, which have received 1,955 citations. The USA is the second most productive country, with 86 articles having received 3,805 citations. Malaysia, South Korea, and Germany have the same number of articles (11), while Vietnam and England have 21 publications with different citation numbers.

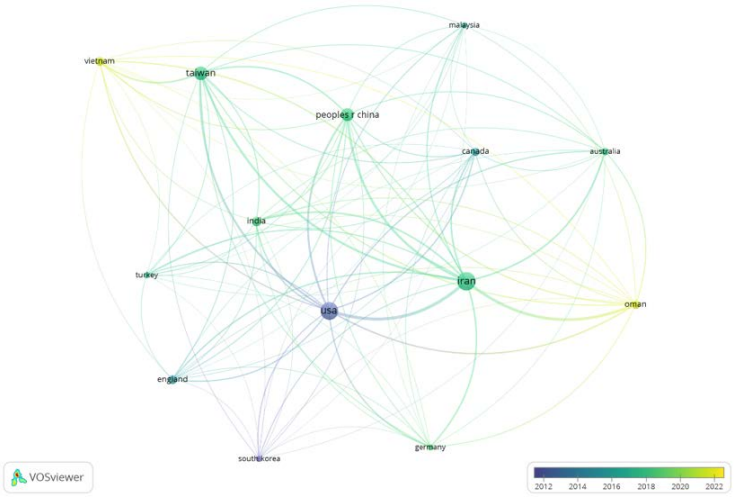

Figure 6. The overlay diagram of authors' countries

In recent years, the USA has been the most prolific country in terms of publishing articles on Supply Chain Management with DEA, with a majority of the publications being released after 2012. While Turkey, India, Canada, Australia, and England have also published more than 10 papers, Taiwan, Iran, and China have mainly published articles between 2016 and 2018. Recently, Oman and Vietnam have also published articles on DEA in the SCM area.

3.4 Most Impactful Authors

3.4.1 Co-occurrence of keywords

To examine the occurrences of authors' keywords, the minimum number of co-occurred keywords was set to 5, resulting in 35 keywords meeting the condition. The total power of co-occurrence connections with other keywords was estimated to be 35, and the keywords were categorized into five groups, as shown in the network diagram in Figure 7 below.

The red cluster is mainly related to MCDM in the renewable energy sector, including keywords such as DEA, decision-making, MCDM, performance, renewable energy, supplier selection, supply chain, sustainable development, and TOPSIS.

The green cluster contains keywords such as DEA, efficiency evaluation, network data envelopment analysis (NDEA), sustainable supplier selection, sustainable supply chain management (SSCM), and undesirable outputs, indicating studies focused on sustainable supply chain network design.

The blue group represents the DEA method with fuzzy logic to increase the performance efficiency of supply chain management, while the yellow category concentrates on data analytics on purchasing in supply chain management.

In the purple cluster, most articles integrate DEA with the AHP method for supplier evaluation.

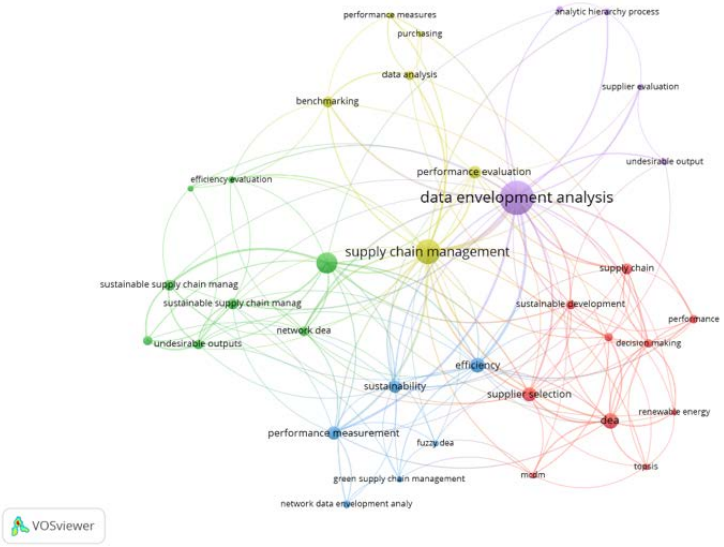

Figure 7. The network diagram of keywords to their occurrences

3.4.2 Co-occurrence of terms

To examine the most frequent terms in the title and abstract of articles, a minimum occurrence count of 25 was set. Out of 7,741 terms found, 78 met the condition, and 47 of them were deemed the most relevant. The overlay diagram in Figure 8 visualizes these relevant terms and their connections with other terms.

The analysis of the most frequent terms in the title and abstract of articles revealed that around 2015, the most relevant terms were design methodology approach, originality value, methodology, firm, practice, and operation. This indicates that articles during this time period focused on firms' operational level using DEA or hybrid models.

Between 2016 and 2017, the articles shifted their focus to analysis methods for measuring the performance of companies or suppliers. In recent years, from 2017 to the present, authors have proposed models and their applicability to case studies, with a focus on input and output parameters to aid in better decision-making in SCM.

3.5 Most Prominent Journals

Out of 184 journals, the top 25 journals that published articles on Supply Chain Management with the DEA method are listed in Table 3 below. The journal Sustainability has published the most papers in this field.

Among the top 25 journals that published articles on Supply Chain Management with the DEA method, notable journals include the Journal of Cleaner Production, the International Journal of Production Economics, the International Journal of Production Research, and Annals of Operations Research.

In the top ten journals, we find the European Journal of Operational Research, Computers Industrial Engineering, Benchmarking: An International Journal, Supply Chain Management: An International Journal, Axioms, and Omega: The International Journal of Management Science.

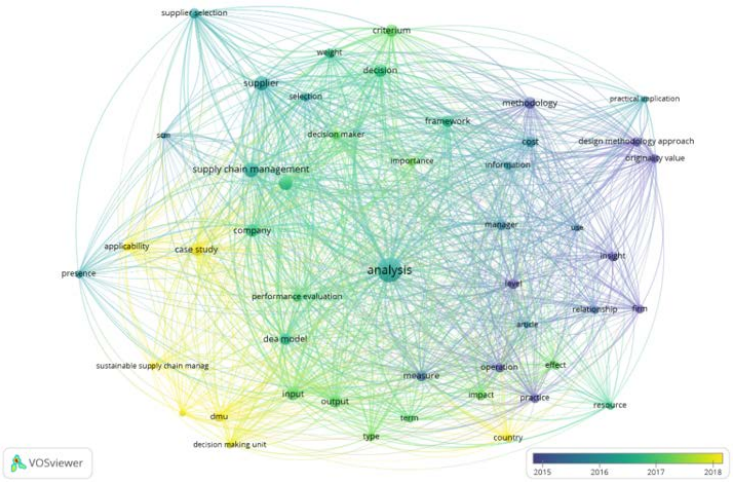

Figure 8. The overlay diagram of relevant terms to the years

Table 3. Publications of DEA papers

Publication titles	Article number	% of 352
Sustainability	19	5.398
Journal of Cleaner Production	15	4.261
International Journal of Production Economics	14	3.977
International Journal of Production Research	14	3.977
Annals of Operations Research	11	3.125
European Journal of Operational Research	9	2.557
Computers industrial engineering	8	2.273
Benchmarking: an international journal	7	1.989
Supply Chain Management an International Journal	7	1.989
Axioms	6	1.705
Omega: The International Journal of Management Science	6	1.705
IEEE Transactions on Engineering Management	5	1.42
Industrial management data systems	5	1.42
Neural computing applications	5	1.42
Environmental Science and Pollution Research	4	1.136
International Journal of Advanced Manufacturing Technology	4	1.136
International Journal of Industrial Engineering Theory Applications and Practice	4	1.136
Journal of Operations Management	4	1.136
Transportation Research Part D Transport and Environment	4	1.136
Clean Technologies and Environmental Policy	3	0.852
Computers operations research	3	0.852
Decision sciences	3	0.852
International Journal of Information Systems and Supply Chain Management	3	0.852
International Journal of Logistics Research and Applications	3	0.852
International Journal of Operations Production Management	3	0.852

4 Conclusions

This study has found that the majority of studies on DEA with SCM were conducted in the areas of Business Economics, Engineering, and Operations Research and Management Science. The bibliometric analysis identified the most productive authors in this field as Saen RF, Wang CN, Talluri S, Dang TT, Izadikhah M, Sarkis J, Hsu HP, Nguyen NAT, and Yousefi S.

The highly cited articles in this field were written by authors [26, 27]. The top five journals that have published articles on DEA in SCM are Sustainability, Journal of Cleaner Production, International Journal of Production Economics, International Journal of Production Research, and Annals of Operations Research.

Recent articles in this field have focused on sustainable or green SCM, with DEA being recognized as one of the approaches for determining sustainability. Scholars are now working to overcome challenges related to energy

and the environment, as growth is often associated with air, water, and soil pollution, which can lead to human health problems and climate change. It is important to balance business prosperity and environmental protection to maintain a high degree of social sustainability worldwide.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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