System Dynamics in Supply Chains: A Bibliometric Review

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Abstract

Supply chain simulation has been used to analyze possible scenarios, and one of the most used techniques is system dynamics, and although there are some literature reviews on this topic, the number of papers has increased in recent years, so it is necessary to analyze trends, locate the most relevant research groups, authors, and papers. This article reports a bibliometric review on the dynamic system applied to the supply chain on engineering and analyzes 519 documents found in the Scopus and Web of Science databases using PRISMA methodology and VosViewer software. Findings indicate that China, the United States of America and the United Kingdom are the countries that produce the most papers, although Cardiff University is the institution with the most consolidated research groups. The most productive authors are Towill, D.R., Naim, M.M. and Rabelo, L., although the most cited are Towill, D.R., Naim, M.M. and Wikner, J., while the Journals that most publish this topic are the International Journal Of Production Research, International Journal Of Production Economics and the Journal of Cleaner Production.

Keywords

Literature review, supply chain, dynamic systems, simulation.

1. Introduction

A supply chain (SC) is a set of processes involved and aimed to customer satisfaction that is consuming goods or services, integrating suppliers in the raw materials procurement, the manufacturer who transforms them into finished or intermediate products, distributors who bring them to the place where they are required, and consumers in the final stage (Agarwal, Shankar, & Tiwari, 2007). The integration of all these actors in the supply chain makes it dynamic, not static and reacts to parties' actions, and it is an open system (Abdullah, Hishamuddin, & Bazin, 2019). In this

article, it is understood that a system is a set of objects or ideas that are interrelated with each other as a unit for the construction of an end, although some authors define it as the portion of the universe which is the object of study (Mula, Campuzano-Bolarin, Díaz-Madroñero, & Carpio, 2013).

Given the above concepts, as the SC is an open system, it is possible to have several scenarios with probabilities of occurrence, so it is necessary to evaluate them before being applied. One of the most widely used tools is simulation. Simulation is understood as designing a model of a real system and carrying out evaluations and experiences to understand and comprehend the system's behavior, which allows evaluating various strategies of operation management (Song, Cui, & Wang, 2019).

One of the most widely used simulation methodologies in SC is system dynamics (SD) since it allows modeling and analyzing the temporal behavior in complex environments (Tian, Govindan, & Zhu, 2014). This methodology is based on identifying feedback loops between all components of the system, where the delays of information and materials are analyzed. Its high acceptance level is because it allows analyzing and studying complex systems with several components as it happens in an SC and where there is feedback or loops between them (Sánchez-ramírez, Ramos-hernández, Fong, Alor-Hernández, & García-alcaraz, 2020). It always seeks to structure the dynamics and behavior of the systems through mathematical models, which is sometimes not easily possible.

There are several specialized software for analysis and simulation using the system dynamics methodology, such as AnyLogic, Evolution, iThink/Stella, Powersim, Simile and Vensim, all of which have different versions and updates advantages, disadvantages, and costs. The SD-SC has been widely reported in the literature, where it has been applied to different industrial sectors, including different environments. For example, Roci et al. (2022) and Tombido, Louw, van Eeden, and Zailani (2022) apply it in manufacturing areas, Bajomo, Ogbeyemi, and Zhang (2022) in the construction sector, van Oorschot, Akkermans, Van Wassenhove, and Wang (2022) in the digital services area; however, as mentioned by Lin, Zhou, Spiegler, Naim, and Syntetos (2022), all SD applications in SC help in the decision-making process.

Similarly, literature reviews of SD applications in SC in different sectors have been conducted. For example, Brailsford, Eldabi, Kunc, Mustafee, and Osorio (2019) reports a state of the art of simulation as a widely used technique in operations research, which indicates that system dynamics is one of the most accepted methodologies, Rebs, Brandenburg, and Seuring (2019) performs a literature review regarding DS-SC to sustainable SC modeling and indicates that systems thinking is a new trend that should be adopted, also Saavedra M, de O. Fontes, and M. Freires (2018) analyze DS applications to the sustainability of renewable energy SC.

Although the above literature reviews provide much knowledge regarding the DS-SC applications in the engineering area, some of them are very specific, focus only on certain industrial sectors and do not answer questions such as: what is the trend in DS-SC applications on engineering? Where are the main research groups that apply it? Who are the main authors or gurus in this research area of DS-SC? Who are the most cited authors? What are the pioneering or most cited papers that serve as a reference for another research? What are the main institutions and countries where this methodology is most used?

Since the above questions have not been answered, it is considered that there is a need for a bibliometric review focus on DS-SC applications, regardless of the industrial or service sectors in which it is applied. Our paper aims to report a bibliometric analysis that allows answering the previously raised questions so that students and scholars in this area can quickly identify the main authors, educational institutions where they are located, and the most important documents given rise to these applications.

2. Methodology

2.1 Documents identification

A search was performed in the Scopus and Web of Science databases with the following equation: TITLE-ABS-KEY ("supply chain") AND TITLE-ABS-KEY ("dynamic systems") limited to the area of engineering, which guarantees that a combination of both keywords are used and in that specific sector is obtained as a response. From each of these databases, a RIS and CSV extension files are downloaded for further analysis according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) methodology, which is defined as a guide for the systematic reviews and meta-analyses publications, and which has been widely accepted in various sectors. For

example, de Paula Ferreira, Armellini, and De Santa-Eulalia (2020) use it to conduct state of the art on simulation in Industry 4.0 and Zanker, Bureš, and Tučník (2021) use it in a systematic review associated with commercial environmental and health conditions.

Figure 2 illustrates the PRISMA methodology in its four stages as proposed by Oláh, Krisán, Kiss, Lakner, and Popp (2020). In the first stage, the different documents are identified according to the keywords described above in the two databases consulted and only focused on the engineering area. 510 documents were identified on Scopus and 311 in WOS; the files were downloaded in RIS extension to be read in Endnote, so in the second stage, the duplicated documents were identified, and in the end, a total of 577 were obtained. However, in the third stage, 37 documents not in English or Spanish were excluded since it is not our domain, leaving 540 and, 13 documents from 2022 were excluded. Thus, the search equation is as follows: (TITLE-ABS-KEY ("supply chain") AND TITLE-ABS-KEY ("system dynamics")) AND (EXCLUDE (PUBSTAGE , "aip")) AND (LIMIT-TO (SUBJAREA, "ENGI")) AND (LIMIT-TO (LANGUAGE, "English") OR LIMIT-TO (LANGUAGE, "Spanish")) AND (EXCLUDE (PUBYEAR, 2022)).

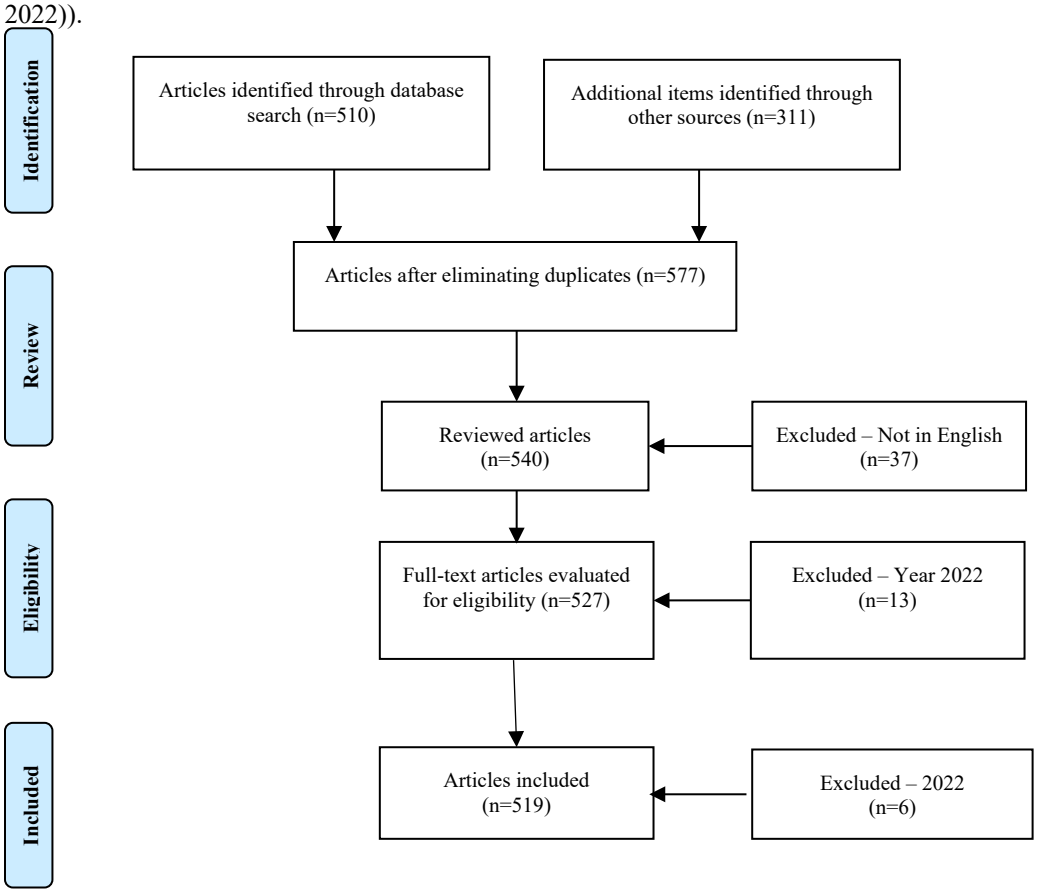

Figure 1. Methodology

2.2 Document analysis

Los documentos finales son analizados en el software VOSviewer 1.6.17, dado que su uso es gratuito y ha sido ampliamente usado en otras revisiones bibliométricas, tales como Gamage, Ayres, and Behrend (2022) para analizar las tendencias de uso de la herramienta Moodle en el proceso de enseñanza y aprendizaje, así como por Goli and Haghighinasab (2022) para analizar el dinamismo de los precios en productos básicos, por mencionar solamente algunas.

The bibliometric analysis focuses on determining the following:

1. Trends in documents publication on DS-SC applied to engineering.
2. The main research areas in which SD-SC are applied.
3. The main journals that publish SD-SC topics.

4. The main authors, research groups, institutions, and countries researching on SD-SC.
5. The most cited authors, institutions, and countries on SS-SC.
6. The most cited documents that serve for the development of new research.

3. Results and Discussion

3.1 Trend in SD-SC in engineering

Figure 2 illustrates the trend in SD-SC applications in the engineering area. It can be seen that the first time these two words are combined in the same report was by Towill (1991) and Wikner, Towill, and Naim (1991); however, the first author continued with the analysis of the dynamic behavior of SC two years later, and his work appears in Towill (1993b) and Towill (1993a), so it can be said that they are the precursors in this research area.

The evolutionary process of DS-SC can be said to comprise three different stages in different decades. The first decade is from 1991 to 2001 since it was in 1991 when the first papers appeared. Academic production was very scarce during this stage, limited to four papers per year. In other words, the combination of SD-SC concepts took approximately a decade to mature, perhaps because there was not as much specialized software as there is nowadays. The second stage comprises from 2002 to 2011, where an accelerated growth is observed in the first seven years, but then there is a drastic drop in the eighth year, to increase in 2010 and 2011. Finally, there is a drop in the first year in the third stage, but growth continues with ups and downs until 2021. However, in 2020, when the COVID-19 pandemic caused many SC to be insufficient and report problems, several simulations were conducted to improve them, which is why there was an increase in the number of documents.

It is important to mention that all the analyzed statistics can be found in a complementary Excel file in a repository and can be consulted at https://doi.org/10.6084/m9.figshare.19491878.v1.

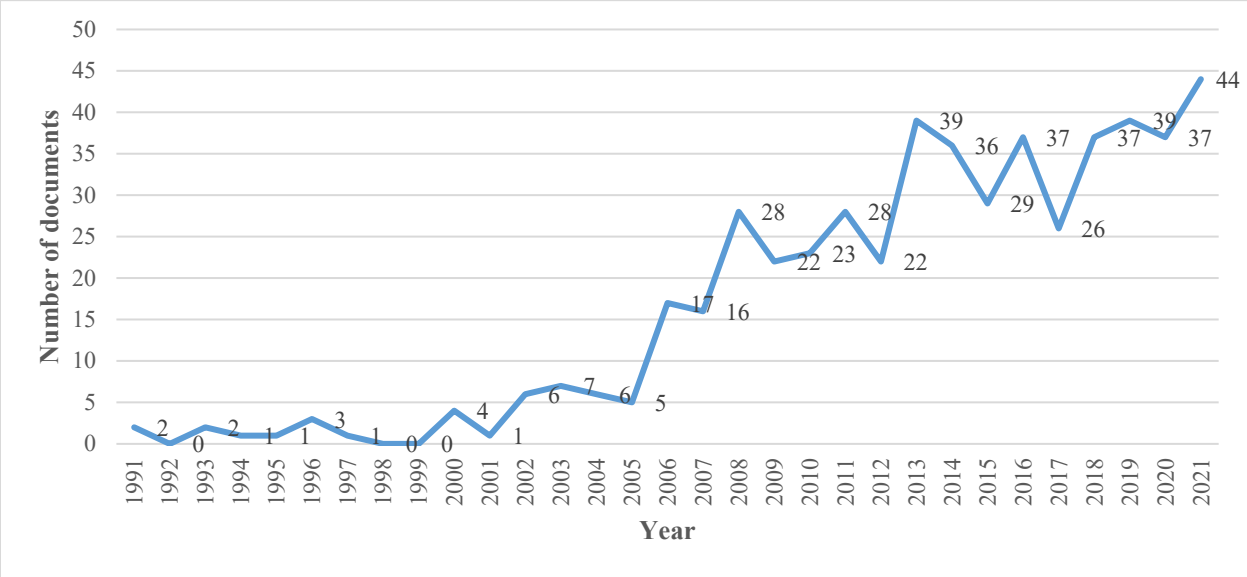

Figure 2. Trends in SD-SC publications applied to Engineering

3.2 Type of documents on DS-SC in engineering

Regarding the type of documents that have been published in the DS-SC area, 519 documents were analyzed, and the majority have been as articles 258 (49.7%), conference paper (40.84%), book chapter 26 (5.01%), conference review (3.85%) and review 3 (0.58%). A review of the percentages shows that the number of conference papers is very high, almost equal to the number of articles, indicating that the DS-SC combination is not fully mature and should continue to evolve.

3.3 DS-SC research funding agencies

Research associated with DS-SC in engineering is of interest to many funding agencies. Figure 3 shows the main entities that have funded some type of research associated with SD-SC, where it can be seen that the National Natural

Science Foundation of China has funded the most projects, followed by the National Council of Science and Technology of Mexico. However, when reviewing the names and countries in which these institutions are established, it can be seen that China is the country that provides the most resources for this type of research.

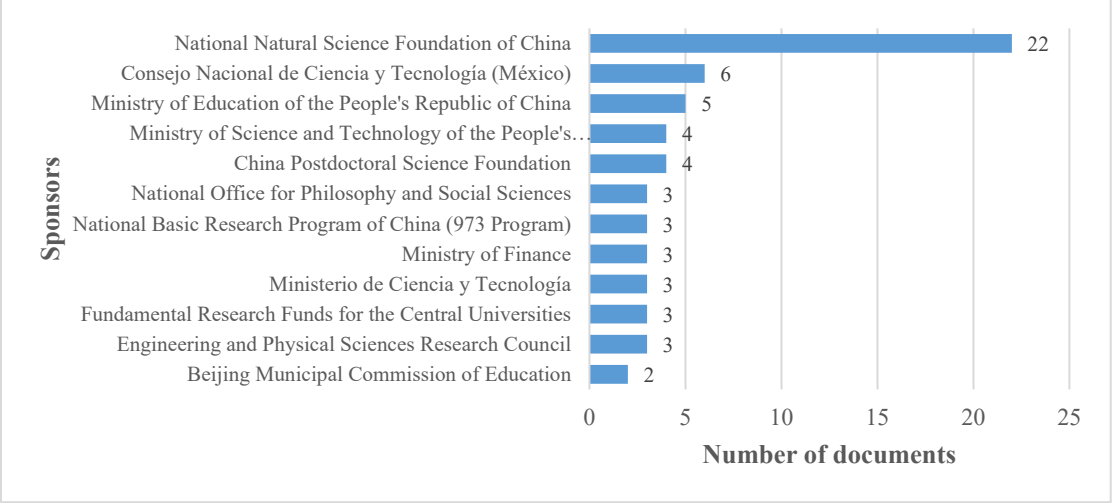

Figure 3. Funding and sponsors in SD-SC

3.4 Main authors, institutions and countries involved in SD-SC research

Sixty-one countries have been identified in which there is at least one document using the DS-SC binomial in engineering, and Figure 4 illustrates the main 15 countries. On this occasion, Germany and Italy lead the European countries, while China, India and Indonesia do so for Asia, and the United States, Colombia and Mexico for the Americas. To identify all countries and the number of documents generated, please refer to the supplementary material found in the repository at https://doi.org/10.6084/m9.figshare.19491878.v1.

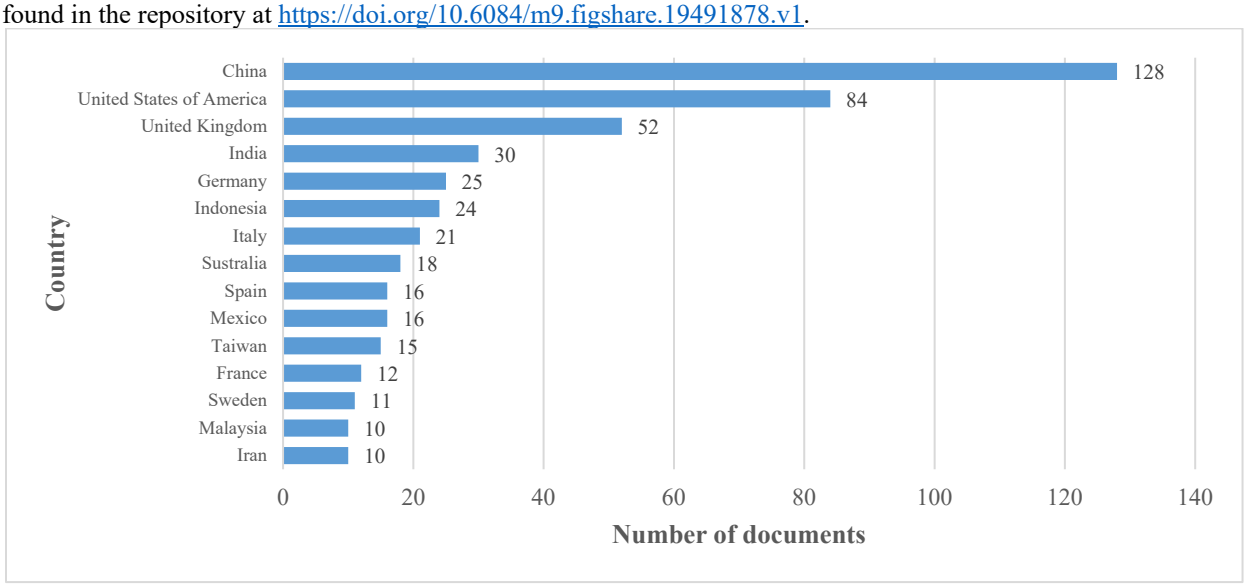

Figure 4. Main countries producing documents in DS-SC

Regarding the institutions that publish the most and certainly have research groups specialized in the DS-SC combination, 1590 have been identified. Table 1 shows a list of those with at least three papers. Cardiff University in the United Kingdom reports the largest number of papers, followed by Aristotle University of Thessaloniki in Greece, the Universitat Politècnica de València in Spain and the University of Central Florida in the United States of America. In general terms, it can be seen that various Spanish and Italian institutions are in this ranking and that the Chinese institutions, although as a country they occupy the first place, at the institutional level they begin to appear from the third place. See the complete list of institutions as supplementary material.

Table 1. Institutions with documents in DS-SC

Institution	Documents
Cardiff University	32
University of Central Florida	10
Universidad Politecnica de Cartagena National Institute of Standards and Technology	7
Universiti Teknologi Malaysia, Massachusetts Institute of Technology, South China University of Technology, Universitas Indonesia	6
The University of Johannesburg, Dalian University of Technology, Northern Illinois University, Politecnico di Torino, Indian Institute of Technology Bombay, Aristotle University of Thessaloniki, Beijing University of Posts and Telecommunications, Nankai University, Nanjing University of Aeronautics and Astronautics, Dalian Maritime University, Institut Teknologi Sepuluh Nopember, Tianjin University of Technology and Education	5
Indian Institute of Technology Kharagpur, The University of Hong Kong, Hong Kong Polytechnic University, RMIT University, Universitat Politècnica de València, National Chiao Tung University, Beijing Institute of Technology, Tilburg University, Harbin University of Commerce, Tianjin University, Georgia Institute of Technology, University of Botswana, Aalborg University, Wuhan University of Technology, Università Degli Studi di Genova, Hochschule für Wirtschaft und Recht Berlin, Hiroshima University, Instituto Tecnologico de Orizaba, Universitas Islam Indonesia Rutgers University-New Brunswick	4
The Royal Institute of Technology KTH, Weifang University, Southeast University, Tecnologico de Monterrey, CNRS Centre National de la Recherche Scientifique, Purdue University, The University of Arizona, Högskolan i Skövde, University of Windsor, LUT University, Lodz University of Technology, Central South University, National University of Singapore, Fuzhou University, National Tsing Hua University, Universität Kassel, Harbin Institute of Technology, Heriot-Watt University, Texas A&M University, Brunel University London, Beijing Jiaotong University, Industrial Technology Research Institute of Taiwan, Chongqing University, Shanghai Jiao Tong University, Huazhong University of Science and Technology, Manipal Institute of Technology, UNSW Sydney, University of Cambridge, Universidad de Sevilla, Universidad Nacional de Colombia, Universitas Sebelas Maret, Berner Fachhochschule, St. Petersburg Federal Research Center of the Russian Academy of Sciences, Brunel Business School	3

Concerning the authors who generate more papers in this DS-CS on engineering, Table 2 illustrates those with at least three papers. It is observed that Towill, D.R., Naim, M.M., Rabelo, L., Jones, A., Cagliano, A.C., Campuzano-Bolarín, F. and Wang, Y. top the list with more than five for each of them and more specifically, Towill was the author that initiated the use of SD applied to CS Students interested in carrying out a project associated with DS-CS must consult these authors, who are world leaders in its application because they are leading the number of documents they have generated in their professional careers.

Table 2. Main authors in DS-SC

Author name	Documents
Towill, D.R.	11
Naim, M.M., Rabelo, L.	10
Jones, A.	6
Cagliano, A.C., Campuzano-Bolarín, F., Wang, Y.	5
Besiou, M., Cedillo-Campos, M.G., Georgiadis, P., Ghadge, A., Ivanov, D., Morikawa, K., Mula, J., Mutingi, M., Rafele, C., Revetria, R., Spiegler, V.L.M., Sudarto, S., Sánchez-Ramírez, C., Takahashi, K.,	4
Ashayeri, J., Briano, E., Bueno-Solano, A., Caballini, C., Dutta, P., Díaz-Madroñero, M., Ekinci, E., Fan, C.Y., Gao, T., Giribone, P., Gruchmann, T., Gu, Q., Helal, M., Hisjam, M., Luxhøj, J.T., Mbohwa, C., Moraga, R., Orji, I.J., Sarmiento, A.T., Sokolov, B., Sun, K., Trappey, A.J.C., Trappey, C.V., Venkateswaran, J., Vlachos, D., Wang, W., Wangphanich, P.	3

3.5 Main journals publishing DS-SC

The above authors must publish some document where they share their findings with the scientific community as a product of their research. In the case of publications associated with DS-SC, the main scientific journals are the International Journal Of Production Research, International Journal of Production Economics, and the Journal of Cleaner Production, all of them focused on the analysis of operation management, including those performed in the SC from a practical and applied point of view and Figure 5 resumes those journals.

It is important to mention that many other journals publish on the SD-SC binomial. However, many of them are very theoretical in their approach to both SD and SC, and it is demonstrated by the fact that there are no specialized journals in the list of the first fifteen. However, they are more focused on production systems applications.

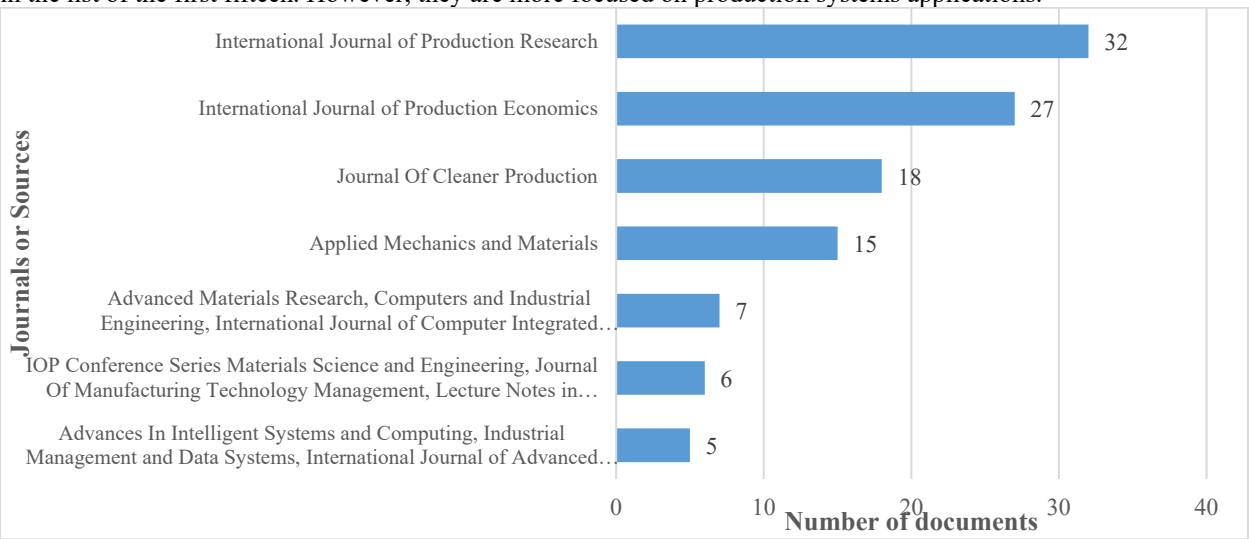

Figure 5. Main sources publishing on SD-SC

3.6 Main keywords used by the authors in SD-SC

Authors used 1146 keywords in their research papers applying SD-SC. Among the most common words were: system dynamics (276), supply chain (97), simulation (62), supply chain management (62), whiplash effect (43), supply chain dynamics (16), reverse logistics (13), sustainability and system dynamics (11), risk management (10), logistics and remanufacturing (9), information sharing, optimization and supply chains (8). Figure 6 illustrates a distribution of these keywords.

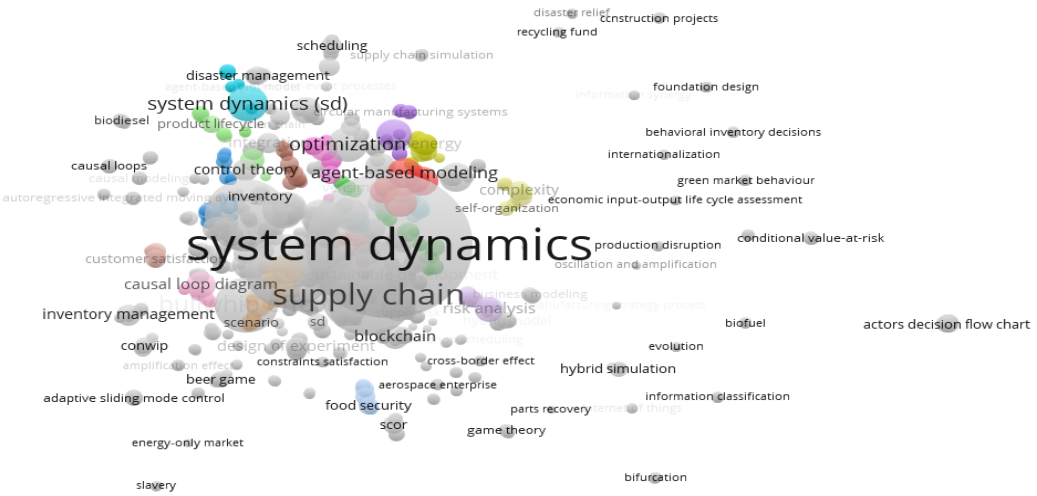

Figure 6. Keywords used by the authors in SD-SC

3.7 Most cited authors, institutions and countries in DS-SC

Twenty-eight countries were identified that have been cited in the SD-SC topic; however, they are led by the United Kingdom (2383), United States (1397), China (939), Germany (525), Greece (432), India (361), Denmark (344), Sweden (334), Italy (317), Mexico (282), Australia (271), France (271), Russian Federation (200), all of them with at least 200 citations. These results contrast with the main countries that publish on this topic, where China occupies the first place, followed by the United States of America in second place and the United Kingdom in third place, the same country that occupies the first place as the most cited country.

Figure 7 illustrates the most cited institutions, where it can be seen that Cardiff University in the United Kingdom has the highest value with a total of 427 citations, and three other institutions have values greater than 300, such as the Aristotle University of Thessaloniki, University of Wales and California State University. In summary, it can be seen that European universities have been the pioneers in this topic, and it is there where the main research groups are located.

Additionally, a total of 1130 authors around the world who research and apply SD-SC were identified; however, not all of them have had the same impact on the scientific community; for example, Towill, D.R. has published 11 papers and has received 791 citations in total, but authors such as Wilson, M.C. have published only one paper and have 317 citations in it. Figure 8 illustrates the top 15 authors with the most citations in this topic, which refer to the total of the papers they have published and not to a specific paper.

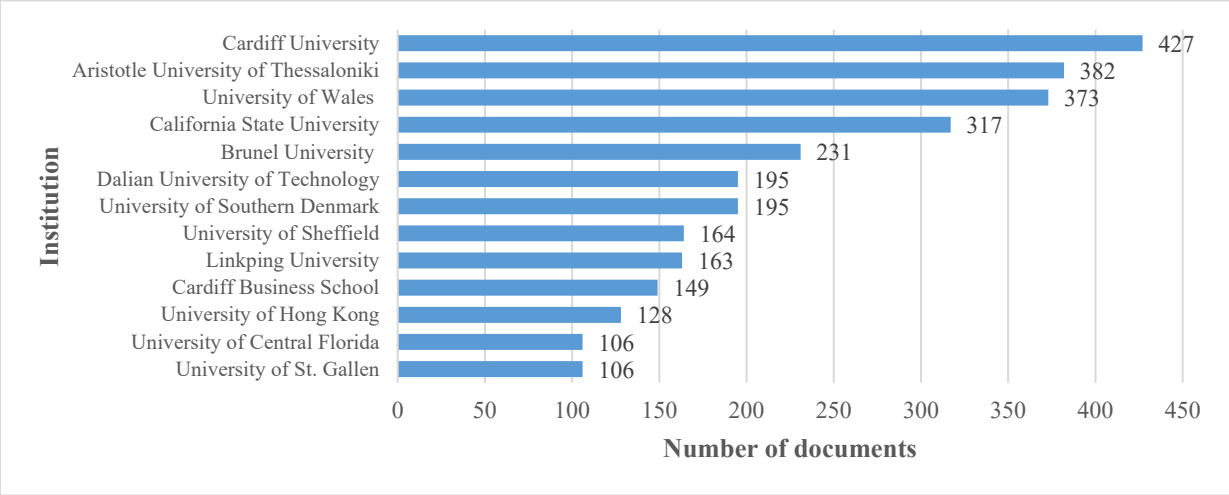

Figure 7. Most cited institutions in DS-SC

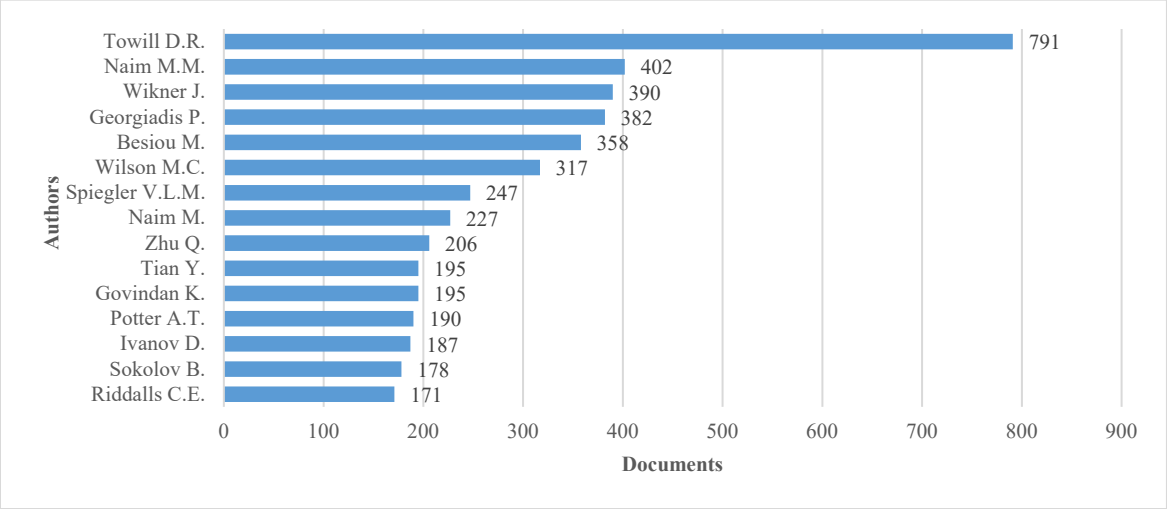

Figure 8. Most cited author in SD-SC

3.8 Most cited documents and journals

Table 3 illustrates the specific documents with the most citations in descending order. It can be seen that Wilson (2007), Angerhofer and Angelides (2000), and Wikner et al. (1991) have more than 200 citations, so it can be said that they have been documents that revolutionized the SD-SC binomial and are a reference for many other documents (remember that Wikner et al. (1991) was one of the pioneers). The citations to these documents are not surprising since they are among the first to be generated, but Tian et al. (2014) document is much more recent and referenced on 195 occasions.

Table3. Most cited documents

Document	Author	Citations
The impact of transportation disruptions on supply chain performance	Wilson (2007)	317
System Dynamics Modelling in supply chain management: Research review	Angerhofer and Angelides (2000)	231
Smoothing supply chain dynamics	Wikner et al. (1991)	227
A system dynamics model based on evolutionary game theory for green supply chain management diffusion among Chinese manufacturers	Tian et al. (2014)	195
Sustainability in electrical and electronic equipment closed-loop supply chains: A System Dynamics approach	Georgiadis and Besiou (2008)	172
Modelling the dynamics of supply chains	Riddalls, Bennett, and Tipi (2000)	164
A control engineering approach to the assessment of supply chain resilience	Spiegler, Naim, and Wikner (2012)	163
Supply chain simulation – a tool for education, enhancement and endeavour	Holweg and Bicheno (2002)	149
Supply chain dynamics	Towill (1991)	146
The impact of vendor managed inventory on transport operations	Disney, Potter, and Gardner (2003)	132
Environmental and economical sustainability of WEEE closed-loop supply chains with recycling: a system dynamics analysis	Georgiadis and Besiou (2010)	108
Big data and supply chain decisions: the impact of volume, variety and velocity properties on the bullwhip effect	Hofmann (2017)	106
Value chain analysis using hybrid simulation and AHP	Rabelo, Eskandari, Shaalan, and Helal (2007)	106
Disruption-driven supply chain (re)-planning and performance impact assessment with consideration of pro-active and recovery policies	Ivanov, Pavlov, Dolgui, Pavlov, and Sokolov (2016)	99
The Impact of Product Lifecycle on Capacity Planning of Closed-Loop Supply Chains with Remanufacturing	Georgiadis, Vlachos, and Tagaras (2006)	97

Finally, the Journals that have more than 100 citations to the papers they have published are the following: International Journal of Production Economics (1347), International Journal of Production Research (1090), Journal of Cleaner Production (849), Transportation Research Part E: Logistics and Transportation Review (653), Production and Operations Management (307), Journal of Manufacturing Technology Management (301), International Journal of Computer Integrated Manufacturing (282), Production Planning and Control (273), Winter Simulation Conference Proceedings (244), Computers and Industrial Engineering (223), International Journal of Systems Science (196), International Journal of Advanced Manufacturing Technology (177).

Conclusions

A total of 519 documents related to the SD-SC were analyzed, and it has been observed that there is an increasing trend in the number of publications dealing with this topic, which is relatively new and began in 1991 with one document, but by the end of 2021, there are a total of 44. When reviewing the countries that finance this type of research the most, it was found that China, through various agencies, is the one that provides the most economic funds, although Mexico is in second place. The countries that most research the SD-SC binomial are China, the United States of America, the United Kingdom, India, and Germany, where the educational institutions that publish the most are located, led by Cardiff University and the University of Central Florida.

It was found that there are several authors focused on these topics, which Towill, D.R., Naim, M.M. and Rabelo, L. are leading. These authors publish in journals closely associated with production systems, such as the International Journal of Production Research, the International Journal of Production Economics and the Journal of Cleaner Production. Logically, the main keywords used are system dynamics, supply chain, simulation, supply chain management and the whip effect.

Regarding the most cited countries, it was found that the United Kingdom leads them, United States of America, China, Germany, Greece and India, and the main institutions most cited are the Aristotle University of Thessaloniki, University of Wales and California State University. Finally, the most-cited authors are led by Towill, D.R., Naim, M.M. and Wikner, J.

References

Abdullah, M. A., Hishamuddin, H., & Bazin, N. (2019). *A System Dynamics Approach to Investigate the Effects of Disruption on the Supply Chain with A Mitigation Strategy.* Paper presented at the 4th International Conference on Ergonomics and 2nd International Conference on Industrial Engineering, ICE and ICIE 2019.

Agarwal, A., Shankar, R., & Tiwari, M. K. Modeling agility of supply chain. *Industrial Marketing Management,*vol. 36, no. 4, pp. 443-457, 2007.

Angerhofer, B. J., & Angelides, M. C. (2000). *System Dynamics Modelling in supply chain management: Research review.* Paper presented at the 2000 Winter Simulation Conference Proceedings, Orlando, FL,USA.

Bajomo, M., Ogbeyemi, A., & Zhang, W. A systems dynamics approach to the management of material procurement for Engineering, Procurement and Construction industry. *International Journal of Production Economics,*vol. 244, no., pp., 2022.

Brailsford, S. C., Eldabi, T., Kunc, M., Mustafee, N., & Osorio, A. F. Hybrid simulation modelling in operational research: A state-of-the-art review. *European Journal of Operational Research,*vol. 278, no. 3, pp. 721-737, 2019.

de Paula Ferreira, W., Armellini, F., & De Santa-Eulalia, L. A. Simulation in industry 4.0: A state-of-the-art review. *Computers and Industrial Engineering,*vol. 149, no., pp., 2020.

Disney, S. M., Potter, A. T., & Gardner, B. M. The impact of vendor managed inventory on transport operations. *Transportation Research Part E: Logistics and Transportation Review,*vol. 39, no. 5, pp. 363-380, 2003.

Gamage, S. H. P. W., Ayres, J. R., & Behrend, M. B. A systematic review on trends in using Moodle for teaching and learning. *International Journal of STEM Education,*vol. 9, no. 1, pp., 2022.

Georgiadis, P., & Besiou, M. Sustainability in electrical and electronic equipment closed-loop supply chains: A System Dynamics approach. *Journal of Cleaner Production,*vol. 16, no. 15, pp. 1665-1678, 2008.

Georgiadis, P., & Besiou, M. Environmental and economical sustainability of WEEE closed-loop supply chains with recycling: A system dynamics analysis. *International Journal of Advanced Manufacturing Technology,*vol. 47, no. 5-8, pp. 475-493, 2010.

Georgiadis, P., Vlachos, D., & Tagaras, G. The impact of product lifecycle on capacity planning of closed-loop supply chains with remanufacturing. *Production and Operations Management,*vol. 15, no. 4, pp. 514-527, 2006.

Goli, F., & Haghighinasab, M. Dynmic Pricing: A Bibliometric Approach. *Iranian journal of Management Studies,*vol. 15, no. 1, pp. 111-132, 2022.

Hofmann, E. Big data and supply chain decisions: the impact of volume, variety and velocity properties on the bullwhip effect. *International Journal of Production Research,*vol. 55, no. 17, pp. 5108-5126, 2017.

Holweg, M., & Bicheno, J. Supply chain simulation - A tool for education, enhancement and endeavour. *International Journal of Production Economics,*vol. 78, no. 2, pp. 163-175, 2002.

Ivanov, D., Pavlov, A., Dolgui, A., Pavlov, D., & Sokolov, B. Disruption-driven supply chain (re)-planning and performance impact assessment with consideration of pro-active and recovery policies. *Transportation Research Part E: Logistics and Transportation Review,*vol. 90, no., pp. 7-24, 2016.

Lin, J., Zhou, L., Spiegler, V. L. M., Naim, M. M., & Syntetos, A. Push or Pull? The impact of ordering policy choice on the dynamics of a hybrid closed-loop supply chain. *European Journal of Operational Research,*vol. 300, no. 1, pp. 282-295, 2022.

Mula, J., Campuzano-Bolarin, F., Díaz-Madroñero, M., & Carpio, K. M. A system dynamics model for the supply chain procurement transport problem: Comparing spreadsheets, fuzzy programming and simulation approaches. *International Journal of Production Research,*vol. 51, no. 13, pp. 4087-4104, 2013.

Oláh, J., Krisán, E., Kiss, A., Lakner, Z., & Popp, J. PRISMA statement for reporting literature searches in systematic reviews of the bioethanol sector. *Energies,*vol. 13, no. 9, pp., 2020.

Rabelo, L., Eskandari, H., Shaalan, T., & Helal, M. Value chain analysis using hybrid simulation and AHP. *International Journal of Production Economics,*vol. 105, no. 2, pp. 536-547, 2007.

Rebs, T., Brandenburg, M., & Seuring, S. System dynamics modeling for sustainable supply chain management: A literature review and systems thinking approach. *Journal of Cleaner Production,*vol. 208, no., pp. 1265-1280, 2019.

Riddalls, C. E., Bennett, S., & Tipi, N. S. Modelling the dynamics of supply chains. *International Journal of Systems Science,*vol. 31, no. 8, pp. 969-976, 2000.

Roci, M., Salehi, N., Amir, S., Shoaib-ul-Hasan, S., Asif, F. M. A., Mihelič, A., & Rashid, A. Towards circular manufacturing systems implementation: A complex adaptive systems perspective using modelling and simulation as a quantitative analysis tool. *Sustainable Production and Consumption,*vol. 31, no., pp. 97-112, 2022.

Saavedra M, M. R., de O. Fontes, C. H., & M. Freires, F. G. Sustainable and renewable energy supply chain: A system dynamics overview. *Renewable and Sustainable Energy Reviews,*vol. 82, no., pp. 247-259, 2018.

Sánchez-ramírez, C., Ramos-hernández, R., Fong, J. R. M., Alor-Hernández, G., & García-alcaraz, J. L. A system dynamics model to evaluate the impact of production process disruption on order shipping. *Applied Sciences (Switzerland),*vol. 10, no. 1, pp., 2020.

Song, M., Cui, X., & Wang, S. Simulation of land green supply chain based on system dynamics and policy optimization. *International Journal of Production Economics,*vol. 217, no., pp. 317-327, 2019.

Spiegler, V. L. M., Naim, M. M., & Wikner, J. A control engineering approach to the assessment of supply chain resilience. *International Journal of Production Research,*vol. 50, no. 21, pp. 6162-6187, 2012.

Tian, Y., Govindan, K., & Zhu, Q. A system dynamics model based on evolutionary game theory for green supply chain management diffusion among Chinese manufacturers. *Journal of Cleaner Production,*vol. 80, no., pp. 96-105, 2014.

Tombido, L., Louw, L., van Eeden, J., & Zailani, S. A system dynamics model for the impact of capacity limits on the Bullwhip effect (BWE) in a closed-loop system with remanufacturing. *Journal of Remanufacturing,*vol. 12, no. 1, pp., 2022.

Towill, D. R. Supply chain dynamics. *International Journal of Computer Integrated Manufacturing,*vol. 4, no. 4, pp. 197-208, 1991.

Towill, D. R. System dynamics— background, methodology, and applications: Part 1: Background and methodology. *Computing and Control Engineering Journal,*vol. 4, no. 5, pp. 201-208, 1993a.

Towill, D. R. System dynamics— background, methodology, and applications: Part 2: Applications. *Computing and Control Engineering Journal,*vol. 4, no. 6, pp. 261-268, 1993b.

van Oorschot, K. E., Akkermans, H. A., Van Wassenhove, L. N., & Wang, Y. Organizing for permanent beta: performance measurement before vs performance monitoring after release of digital services. *International Journal of Operations and Production Management,*vol. no., pp., 2022.

Wikner, J., Towill, D. R., & Naim, M. Smoothing supply chain dynamics. *International Journal of Production Economics,*vol. 22, no. 3, pp. 231-248, 1991.

Wilson, M. C. The impact of transportation disruptions on supply chain performance. *Transportation Research Part E: Logistics and Transportation Review,*vol. 43, no. 4, pp. 295-320, 2007.

Zanker, M., Bureš, V., & Tučník, P. Environment, business, and health care prevail: A comprehensive, systematic review of system dynamics application domains. *Systems,*vol. 9, no. 2, pp., 2021.

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