RESEARCH TRENDS IN INDUSTRY 4.0 AND SUSTAINABLE SUPPLY CHAIN MANAGEMENT

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RESUMO

Indústria 4.0 é um tópico central nos debates sobre novos paradigmas de produção e a Gestão Sustentável da Cadeia de Suprimentos pode criar uma vantagem competitiva para as empresas. No entanto, a conexão entre Indústria 4.0 e Gestão Sustentável da Cadeia de Suprimentos ainda é pouco explorada na literatura. Este artigo investiga as tendências na pesquisa sobre Indústria 4.0 e Gestão Sustentável da Cadeia de Suprimentos. Baseado em registros bibliográficos recuperados do banco de dados da Web of Science, avalia o crescimento do número de publicações, os tipos de documentos, os principais países de origem, periódicos e áreas de conhecimento, o pioneiro e o mais citado artigo e as palavras-chave mais frequentes. Estes resultados não apenas fornecem um panorama das pesquisas sobre Indústria 4.0 e Gestão Sustentável da Cadeia de Suprimentos, mas também podem contribuir para direcionar futuras pesquisas neste campo.

PALAVRAS-CHAVE: Indústria 4.0, Gestão Sustentável da Cadeia de Suprimentos, Tendências de pesquisa.

ABSTRACT

Industry 4.0 is a hot topic in debates about new production paradigms and Sustainable Supply Chain Management can to create a competitive advantage for companies. However, the connection between Industry 4.0 and Sustainable Supply Chain Management is still under-explored in the literature. This paper investigates the research trends in Industry 4.0 and Sustainable Supply Chain Management. Based on bibliographic records retrieved from the Web of Science database, asses the growth in numbers of publications, documents types, major source countries, subject areas, journals, pioneer and most-cited article, and frequent keywords. These results not only provide a landscape on Industry 4.0 and Sustainable Supply Chain Management research, but also can contribute to direct for further research in this field.

KEY WORDS: Industry 4.0, Sustainable Supply Chain Management, Research trends.

INTRODUTION

Although there are hundreds of papers on Industry 4.0 (MUHURI, SHUKLA and ABRAHAM, 2019; KIPPER; 2019), it is not yet clear what the implications of this new production paradigm (BRIXNER et al., 2020; CULOT et al, 2020; BONILLA, 2018). In addition, most companies are not aware of the challenges that will be faced when they adopt the Industry 4.0 technologies (PEREIRA and ROMERO, 2017), that include cyber-physical systems, internet of things, internet services, robotics, big data, cloud manufacturing and augmented reality (JAYASHREE, MALARVIZHI and REZA, 2020; OZTEMEL and GURSEV, 2020).

Some studies investigated the consequences the Industry 4.0 on Supply Chain Management, including capabilities and enabler technologies (FATORACHIAN and KAZEMI, 2020), technology transfer (SILVA, KOVALESKI and PAGANI, 2019), disruption risk control analytics (IVANOV, DOLGUI and SOKOLOV, 2019), and maturity levels (FREDERICO et al., 2019). However, the connection between Industry 4.0 and Sustainable Supply Chain Management (SSCM) is still under-explored in the literature (LUTHRA et al, 2020), despite planning and decision-making in SSCM context incorporate economic, social, and environmental dimensions (Ahi and Searcy 2013), practice that can be generate new revenues and increase customer and employee satisfaction (NARIMISSA, KANGARANI□FARAHANI and MOLLA□ALIZADEH□ZAVARDEHI, 2020; SÁNCHEZ-FLORES, 2020).

PURPOSE

To investigate the research trends in Industry 4.0 and Sustainable Supply Chain Management.

METHODS

Data source and search strategy

The Web of Science (WoS) database was consulted on March 10, 2020 to retrieve bibliometric records of documents related to Industry 4.0 and Sustainable Supply Chain Management research. The search expression (("Industr* 4.0") OR ("the fourth industrial revolution") OR ("the 4th industrial revolution")) AND ((("Supply Chain Management") OR(SCM)) AND (("Sustainab*") OR ("Environmental") OR("Green") OR ("Ecofriendly"))) was applied to gather all the publications with those terms in their titles, abstracts, or keywords. These search terms were used in systematic literature reviews on Industry 4.0 (CULOT et al. 2020; DHAMIJA, BEDI and GUPTA, 2020; COBO et al., 2018) and Sustainable Supply Chain Management (FRAZZON et al., 2019; GONG et al., 2019; KOBERG and LONGONI, 2019). Were retrieved the documents published from 2011, the year that the notion of Industry 4.0 was presented (KAGERMANN, LUKAS and WAHLSTER, 2011), until 2019. No language or document type was restricted in this search.
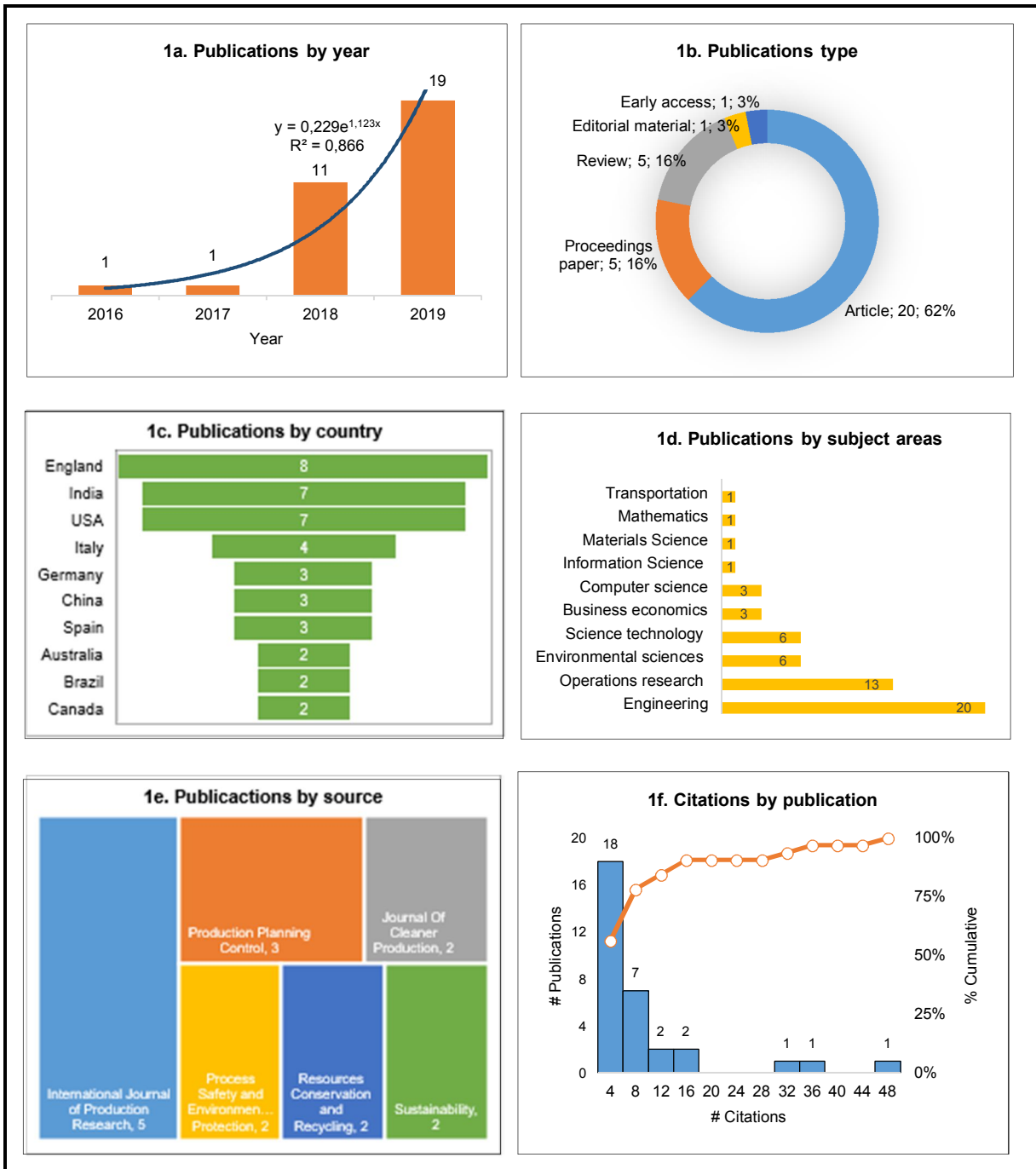
Data analysis

To identify the research trends on Industry 4.0 and Sustainable Supply Chain Management were used the co-word analysis method, which is the only approach to construct a similarity measure using the actual content of documents (NÁJERA-SÁNCHEZ, 2020). Other methods (based on citations or co-authorships, for example) identify indirect relationships between documents (ZUPIC and ČATER, 2015). As Xu et al. (2020), Özdağoğlu et al. (2020) and Grzybowska e Awasthi (2020), were analysis of keywords used by the authors. Keywords are used to express the theme of the academic documents, and the clustering analysis of these co-occurrence keywords can reveal the knowledge structure and hotspots in this research field (SHI and MIAO, 2019).

Using VOSviewer software (www.vosviewer.com) were produced keywords map, in which strongly related terms are located close to each other and the weaker the relationship is between terms, the bigger the distance is between them. Thus, keywords maps provide overviews for identifying the structure of a topic (VAN ECK and WALTMAN, 2010). Each keyword was represented by a rectangle, where the size of its label indicates the number of publications, where the term appears in keywords. The keywords that often co-occur are strongly related to each other and are assigned automatically to the same cluster. On the contrary, keywords with a low co-occurrence or no-occurrences at all, are assigned to different clusters. Therefore, a cluster that is made up of keywords of the same colors represents a research theme in which one or more research topics can be identified.

RESULTS

Were identified 32 publications in Industry 4.0 and Sustainable Supply Chain Management research. The Figure 1a reveals an increasing exponential trend in the number of scientific publications in the last years. Articles (20) were the most commonly used document type which accounted for 62% of the total publications (Figure 1b). With 8 publications (25%), England was the country with the greatest number of scientific publications (Figure 1c), International Journal of Production Research (impact factor 2018 equal 1.585) was the most productive source with five articles (16%) (Figure 1d), and Engineering was the most common subject area (Figure 1e). Most publications (18; 56%) were cited up to four times (Figure 1f). Table 1 show the others highlights on Industry 4.0 and Sustainable Supply Chain Management research publications.

1a. Publications by year

$$y = 0{,}229e^{1{,}123x}$$
$$R^2 = 0{,}866$$

Year

1b. Publications type

- Early access; 1; 3%
- Editorial material; 1; 3%
- Review; 5; 16%
- Proceedings paper; 5; 16%
- Article; 20; 62%

1c. Publications by country

Country	Count
England	8
India	7
USA	7
Italy	4
Germany	3
China	3
Spain	3
Australia	2
Brazil	2
Canada	2

1d. Publications by subject areas

Subject area	Count
Transportation	1
Mathematics	1
Materials Science	1
Information Science	1
Computer science	3
Business economics	3
Science technology	6
Environmental sciences	6
Operations research	13
Engineering	20

1e. Publicactions by source

- Production Planning Control, 3
- Journal Of Cleaner Production, 2
- International Journal of Production Research, 5
- Process Safety and Environmen... Protection, 2
- Resources Conservation and Recycling, 2
- Sustainability, 2

1f. Citations by publication

Publications

% Cumulative

Citations

Figure 1: Dashboard in Industry 4.0 and Sustainable Supply Chain Management research publications
Note: Only countries and sources that published at least two documents were plotted

Table 1: Highlights on Industry 4.0 and Sustainable Supply Chain Management research publications

	Reference	Citations	Title	Contribution
Pioneers	Lin, Ieromonachou and Sun (2016)	-	Smart Manufacturing and Supply Chain Management	Develops supply chain related propositions to pursue the success of the smart manufacturing.
Most cited	Kamble, Gunasekaran and Gawankar (2018)	48 / 230	Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives	Proposes a sustainable Industry 4.0 framework based on technologies, process integration and sustainable outcomes.
Most Recent	Liu and Giovanni (2019)	-	Green process innovation through Industry 4.0 technologies and supply chain coordination	Presents a model to evaluate the trade-offs between environmental and economic performance entailed by green process innovation linked to Industry 4.0.

Of the 32 publications, 143 keywords were extracted. Prior to doing the analysis, the keywords were standardized in line with Choi et al. (2011). Were used a unique keyword, e.g., industries and industry. Abbreviations were avoided. When both the original word and the abbreviated form(s) appeared in the keyword list, they were consolidated into the original word, e.g., internet of things, iot. Synonyms were unified. When there were two or more synonyms in the list, they were exchanged for the most general keyword, e.g., the 4th industrial revolution and Industry 4.0. After the refinement produced a database with 125 different terms. Figure 2 represent the co-word networks of 10 keywords, which appear at least two documents.
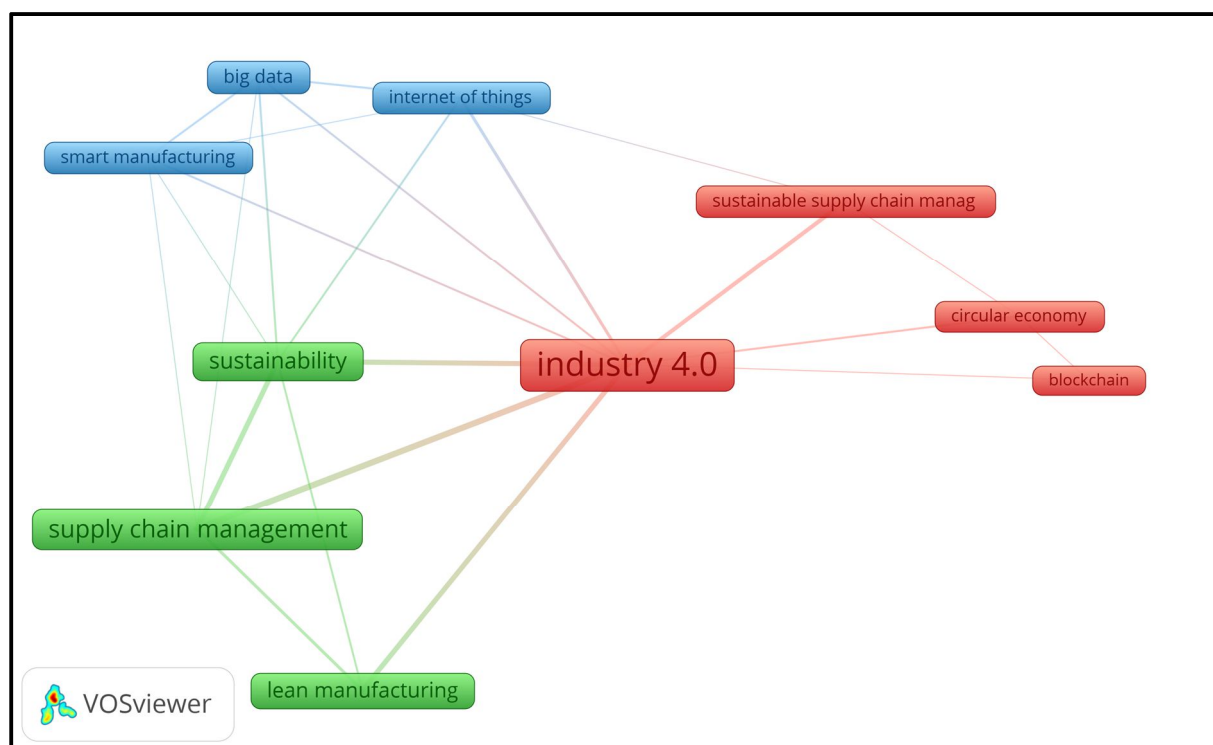
Figure 2: Co-occurrence network of keywords in publications on Industry 4.0 and Sustainable Supply Chain Management

Analysis of the relations among the most frequent keywords reveals three well-defined groups. In the upper, the blue cluster includes applications from Industry 4.0 technologies on Sustainable Supply Chain Management. For example, the Big Data can to help identify potential risks in supply chain based on the supplier's geographic location, how large they are, and whether they have a higher or lower propensity for forced labor (RAUT et al., 2019), and the IoT can monitors the condition of perishable products during transit, minimized the wasted (MANAVALAN and JAYAKRISHNA, 2019).

To the left, green cluster, explores linkages between Lean Manufacturing, Sustainable Supply Chain and the Industry 4.0. It is not conclusive that Lean Manufacturing is correlated with any of the sustainability pillars (economic, environmental, and social); and Industry 4.0 shows a strong correlation with the three sustainability pillars (VARELA et al., 2019).

To the right, red cluster, includes emerging themes on Industry 4.0 and Sustainable Supply Chain Management research: Circular Economy (RAJPUT and SINGH, 2019) and Blockchain (PRAUSE, 2019). The Circular Economy is concerned with the creation of self-sustaining production systems in which materials are used repeatedly (GOVINDAN and HASANAGIC, 2018). The Sustainable Supply Chain Management contributes towards implementing the linkage between Circular Economy and Industry 4.0 (RAJPUT and SINGH, 2019). Blockchains support information sharing in supply chains, linkstand-alone systems, and provide real-time data to all stakeholders (KOUHIZADEH, ZHU and SARKIS, 2019). High levels of transparency, verifiability, immutability, and reliability of data provided by blockchain can benefit supply chain sustainability (PRAUSE, 2019).

CONCLUSIONS

Up to the authors' best knowledge, this is the first ever study to report the research trends in Industry 4.0 and Sustainable Supply Chain Management. There is an increasing trend of Industry 4.0 and Sustainable Supply Chain Management research in two last years. The England had the leading position in global research in this field and the number largest studies could be found in International Journal of Production Research. Although applications from Industry 4.0 technologies and Lean Manufacturing are among the popular topics, Circular Economy and Blockchain are the latest hot spots, and can to direct the research in the next few years. This study not only presents a landscape in Industry 4.0 and Sustainable Supply Chain Management research, but also can contribute for direct further research in this field.

REFERENCES

1. AHI, Payman; SEARCY, Cory. **A comparative literature analysis of definitions for green and sustainable supply chain management.** Journal of cleaner production, v. 52, p. 329-341, 2013.
2. BONILLA, Silvia H. et al. **Industry 4.0 and sustainability implications: A scenario-based analysis of the impacts and challenges.** Sustainability, v. 10, n. 10, p. 3740, 2018.
3. BRIXNER, Cristian et al. Back to the future. **Is industry 4.0 a new tecno-organizational paradigm? Implications for Latin American countries.** Economics of Innovation and New Technology, p. 1-15, 2020.
4. CHOI, Jinho; YI, Sangyoon; LEE, Kun Chang. **Analysis of keyword networks in MIS research and implications for predicting knowledge evolution.** Information & Management, v. 48, n. 8, p. 371-381, 2011.
5. COBO, M. J. et al. **Industry 4.0: a perspective based on bibliometric analysis.** Procedia computer science, v. 139, p. 364-371, 2018.
6. CULOT, Giovanna et al. **Behind the definition of industry 4.0: Analysis and open questions.** International Journal of Production Economics, p. 107617, 2020.
7. DHAMIJA, Pavitra; BEDI, Monica; GUPTA, M. L. **Industry 4.0 and Supply Chain Management: A Methodological Review.** International Journal of Business Analytics (IJBAN), v. 7, n. 1, p. 1-23, 2020.
8. FATORACHIAN, Hajar; KAZEMI, Hadi. **Impact of Industry 4 .0 on supply chain performance.** Production Planning & Control, p. 1-19, 2020.
9. FRAZZON, Enzo Morosini et al. **Towards Supply Chain Management 4.0.** Brazilian Journal of Operations & Production Management, v. 16, n. 2, p. 180-191, 2019.
10. FREDERICO, Guilherme F. et al. **Supply Chain 4.0: concepts, maturity and research agenda.** Supply Chain Management: an International Journal, 2019.
11. GONG, Ruifeng et al. **A Bibliometric Analysis of Green Supply Chain Management Based on the Web of Science (WOS) Platform.** Sustainability, v. 11, n. 12, p. 3459, 2019.
12. GOVINDAN, Kannan; HASANAGIC, Mia. **A systematic review on drivers, barriers, and practices towards circular economy: a supply chain perspective.** International Journal of Production Research, v. 56, n. 1-2, p. 278-311, 2018.
13. GRZYBOWSKA, Katarzyna; AWASTHI, Anjali. **Literature Review on Sustainable Logistics and Sustainable Production for Industry 4.0.** In: Sustainable Logistics and Production in Industry 4.0. Springer, Cham, 2020. p. 1-18.
14. IVANOV, Dmitry; DOLGUI, Alexandre; SOKOLOV, Boris. **The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics.** International Journal of Production Research, v. 57, n. 3, p. 829-846, 2019.

15. JAYASHREE, Sreenivasan; MALARVIZHI, C. A.; REZA, Mohammad Nurul Hassan. **The Challenges and Opportunities of Industry 4.0- A Review.** Asia Proceedings of Social Sciences, v. 5, n. 2, p. 173-178, 2020.

16. KAGERMANN, Henning; LUKAS, Wolf-Dieter; WAHLSTER, Wolfgang. I**ndustrie 4.0: Mit dem Internet der Dinge auf dem Weg zur 4. industriellen Revolution.** VDI nachrichten, v. 13, n. 11, p. 2, 2011.

17. KAMBLE, Sachin S.; GUNASEKARAN, Angappa; GAWANKAR, Shradha **A. Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives**. Process Safety and Environmental Protection, v. 117, p. 408-425, 2018.

18. KIPPER, Liane Mahlmann et al. S**copus scientific mapping production in industry 4.0 (2011–2018): a bibliometric analysis.** International Journal of Production Research, p. 1-23, 2019.

19. KOBERG, Esteban; LONGONI, Annachiara. **A systematic review of sustainable supply chain management in global supply chains**. Journal of cleaner production, v. 207, p. 1084-1098, 2019.

20. KOUHIZADEH, Mahtab; ZHU, Qingyun; SARKIS, Joseph. **Blockchain and the circular economy: potential tensions and critical reflections from practice.** Production Planning & Control, p. 1-17, 2019.

21. LIN, Yong; IEROMONACHOU, Petros; SUN, Wenxian. **Smart manufacturing and supply chain management**. In: 2016 International Conference on Logistics, Informatics and Service Sciences (LISS). IEEE, 2016. p. 1-5.

22. LIU, Baolong; GIOVANNI, Pietro. **Green process innovation through Industry 4.0 technologies and supply chain coordination.** Annals of Operations Research, p. 1-36, 2019.

23. LUTHRA, Sunil et al. **Industry 4.0 as an enabler of sustainability diffusion in supply chain: an analysis of influential strength of drivers in an emerging economy.** International Journal of Production Research, v. 58, n. 5, p. 1505-1521, 2020.

24. MANAVALAN, E.; JAYAKRISHNA, K. **A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements.** Computers & Industrial Engineering, v. 127, p. 925-953, 2019.

25. MUHURI, Pranab K.; SHUKLA, Amit K.; ABRAHAM, Ajith. **Industry 4.0: A bibliometric analysis and detailed overview.** Engineering applications of artificial intelligence, v. 78, p. 218-235, 2019.

26. NÁJERA-SÁNCHEZ, Juan J. **A Systematic Review of Sustainable Banking through a Co-Word Analysis.** Sustainability, v. 12, n. 1, p. 278, 2020.

27. NARIMISSA, Omid; KANGARANI☐FARAHANI, Ali; MOLLA☐ALIZADEH☐ZAVARDEHI, Saber. **Evaluation of sustainable supply chain management performance: Indicators.** Sustainable Development, v. 28, n. 1, p. 118-131, 2020.

28. ÖZDAĞOĞLU, Aşkın et al. **A predictive filtering approach for clarifying bibliometric datasets: an example on the research articles related to industry 4.0.** Technology Analysis & Strategic Management, v. 32, n. 2, p. 158-174, 2020.

29. OZTEMEL, Ercan; GURSEV, Samet. **Literature review of Industry 4.0 and related technologies.** Journal of Intelligent Manufacturing, v. 31, n. 1, p. 127-182, 2020.

30. PEREIRA, A. C.; ROMERO, Fernando. **A review of the meanings and the implications of the Industry 4.0 concept.** Procedia Manufacturing, v. 13, p. 1206-1214, 2017.

31. PRAUSE, Gunnar. **Smart Contracts for Smart Supply Chains.** IFAC-PapersOnLine, v. 52, n. 13, p. 2501-2506, 2019.

32. RAJPUT, Shubhangini; SINGH, Surya Prakash. **Connecting circular economy and industry 4.0.** International Journal of Information Management, v. 49, p. 98-113, 2019.

33. RAUT, Rakesh D. et al. **Linking big data analytics and operational sustainability practices for sustainable business management.** Journal of cleaner production, v. 224, p. 10-24, 2019.

34. SÁNCHEZ-FLORES, Rebeca B. et al. **Supply Chain Performance Improvement: A Sustainable Perspective.** In: Techniques, Tools and Methodologies Applied to Global Supply Chain Ecosystems. Springer, Cham, 2020. p. 333-358.

35. SHI, Jian-gang; MIAO, Wei; SI, Hongyun. **Visualization and analysis of mapping knowledge domain of urban vitality research.** Sustainability, v. 11, n. 4, p. 988, 2019.

36. SILVA, Vander Luiz; KOVALESKI, João Luiz; PAGANI, Regina Negri. **Technology transfer in the supply chain oriented to industry 4.0: a literature review.** Technology Analysis & Strategic Management, v. 31, n. 5, p. 546-562, 2019.

37. VAN ECK, Nees; WALTMAN, Ludo. **Software survey: VOSviewer, a computer program for bibliometric mapping.** Scientometrics, v. 84, n. 2, p. 523-538, 2010.

38. VARELA, Leonilde et al. **Evaluation of the relation between lean manufacturing, Industry 4.0, and sustainability.** Sustainability, v. 11, n. 5, p. 1439, 2019.

39. XU, Song et al. **Disruption risks in supply chain management: a literature review based on bibliometric analysis.** International Journal of Production Research, p. 1-19, 2020.

40. ZUPIC, Ivan; ČATER, Tomaz. **Bibliometric methods in management and organization.** Organizational Research Methods, v. 18, n. 3, p. 429-472, 2015