OPERATIONS AND SUPPLY CHAIN MANAGEMENT
Vol. 15, No. 3, 2022, pp. 345 - 358
ISSN 1979-3561 | EISSN 2759-9363

Explore the Research Trends of Green Supply Chain in the Manufacturing Industry: A Bibliometric Analysis

Erna Masfiza Mohamed Ramli
Department of Business Administration,
International Islamic University Malaysia, Malaysia
Email: ernamasfiza79@gmail.com *(Corresponding Author)*

Dolhadi Bin Zainudin
Department of Business Administration,
International Islamic University Malaysia, Malaysia
Email: dolhadi@iium.edu.my

Rafikul Islam
Department of Business Administration,
International Islamic University Malaysia, Malaysia
Email: rislam@iium.edu.my

ABSTRACT

The green supply chain management practices for the manufacturing industry have been a recent phenomenon in the recent decade. Accordingly, it has received gigantic attention among academic researchers. A few bibliometric analyses have been published focusing on a general view of green supply chain management. This study provides a thorough bibliometric analysis on the relationship between green supply chain management and manufacturing not previously explored or grasped. Further, the bibliometric analysis was employed on academic journal articles published in two prominent online databases, the Scopus, and Web of Science, while prior studies have preferred only a single database. A machine learning tool, "R Studio", and a visualization tool, "VOSViewer", were used to analyze and visualize the analysis results. The results show a 22.63% annual growth in academic publications and a significant growth in recent periods. The findings from science mapping unveiled the popularity and generally focused on Chinese manufacturing firms. Besides, studies have focused on the barriers, drivers, and practices of green supply chain management and performance from economic and environmental perspectives. The findings deliver a vigorous roadmap for further studies in this constituent. Policymakers may improve legal procedures to encourage manufacturers to enhance green manufacturing to reduce carbon emissions.

Keywords: *green supply chain, sustainable green supply chain, green manufacturing, bibliometric analysis*

1. INTRODUCTION

Firms globally have uttered their awareness for the environmental effect of their operations as a significance of compression from regulations, consumers, and competitors for the last few decades (Govindan et al., 2014). As a result, firms have constantly been assimilating environmental practices into their operational strategy. Several environmental programs are considered those are part of their technological and organizational plans as possible substitutes to improve or uphold modest advantage (Hollos *et al*., 2012). Green supply chain management is greatly initiated in this consequence (Vanalle *et al*., 2017). It is a notion that is gradually being accredited in the industry and described as a firm's procuring plans and arrangements that take into the attention of environmental awareness as a chunk of the supply chain management (Bowen *et al*., 2006). These plans and arrangements target increasing the environmental performance of both consumers and suppliers (Vanalle *et al*., 2017), incorporating environmental awareness into the inter-firm supply chain management practices (Vachon, 2007; Zhu *et al*., 2013).

The rapid growth of attention in green supply chain and sustainable supply chain studies have influenced the exploration of the trends and research directions among academic researchers. Several prior studies applied bibliometric analyses to explore the research insights and progress in green supply chain management (Amirbagheri *et al*., 2019; Fahimnia *et al*., 2015; Gong *et al*., 2019; Maditati *et al*., 2018; Mishra *et al*., 2017). These studies reviewed the literature on green supply chain management from a general view. Each study provided insight into the constituent and adding a particular field can provide further vision and progress not fully grasped or explored previously. However, El Baz and Iddik (2021) employed a bibliometric analysis to explore the relationship between green supply chain management and organizational behaviour. Besides, previous bibliometric studies selected a single database, either the Web of science or the Scopus, to review the green supply chain management literature. Therefore, it motivates to identify the research gaps and scopes to conduct concurrent studies related to a specific field such as manufacturing and use both the web of science and the Scopus database.

Manufacturing firms have been observing this method as an achievable alternative to progress the operational performance of firms while concurrently lessening the environmental effect of their operations (Zhu *et al*., 2013). The manufacturing process particularly produces goods or services by combining supplies, ingredients or raw materials within a system or chain. Manufacturing firms' adoption of green supply chain management practices persuades greater economic and environmental performances, thus improving organisational and operational performances (Green *et al*., 2012). Academic researchers have been discussing diverse topics and including several aspects in the context of green supply chain management in the manufacturing industry (Green *et al*., 2012; Vanalle *et al*., 2017; Yu *et al*., 2020).

Subsequently, it is crucial to find the depth and focus of empirical and conceptual constituents, themes, and sub-themes of green supply chain studies related to the manufacturing industry. More so, an exploration of the green supply chain in the manufacturing industry will enable both manufacturers and policymakers to gauge the insights and progress of green manufacturing. Besides, the findings will enable scholars to identify the opportunities and ideas to apply in their future studies. Finally, an investigation of academic research articles related to the green supply chain in the manufacturing industry is crucial to benefit all stakeholders, including scholars, manufacturers, community members and policymakers. Therefore, this study aims to explore publications and in-depth exploration of related themes attached to green supply chain management.

2. METHODS

Bibliometric analysis has achieved enormous popularity in social sciences research in the current years (Bretas & Alon, 2021; Donthu *et al*., 2021; Nobanee, 2021). Due to the advancement, convenience, availability of different software such as Gephi, VOSViewer, biblioshiny, Bibliometric analysis has been gaining popularity (Donthu *et al*., 2021). Apart from it, online publication databases such as Scopus, web of science, and PubMed are equally contributing to the rapid growth of bibliometric techniques in scientific production from information science to social science. This technique is not only a trend but, ascetically, a picture of its expediency for creating high research impact through handling an excessive volume of scientific data (Donthu *et al*., 2021).

The bibliometric analysis is useful for updating the trends in the academic research articles categorising "blind spots" and "hot spots". Moreover, it enables to find a more comprehensive understanding of the published research articles (Gaur & Kumar, 2018). In detail, this analysis vests the recognition of the most advanced (hot spots) and the less recognised topics (blind spots) within the articles that, shared with other bibliometric procedures, commend future research avenues. It further reveals several attributions, such as unveiling evolving trends in articles and the performance of journals, research constituents, and teamwork patterns and determining the intellectual edifice of an exact domain in the existing literature (Verma & Gustafsson, 2020).

In this technique, the data slopes to be gigantic (hundreds, thousands) and dispassionate (publications and citations number, keywords occurrences and topics). However, its enlightenments frequently depend on both subjective (thematic analysis) and objective (performance analysis) valuations shaped through well-versed procedures and measures (Donthu *et al*., 2021).

2.1 Data Mining Procedures

Mainly two online databases, the Scopus, and Web of Science (WoS), are commonly used in the bibliometric analysis (Aria & Cuccurullo, 2017). Accordingly, this study collected data from these online databases (Scopus, 2021; WoS, 2021). These online databases are protuberant for the quality of carefully peer-reviewed research papers. This study has followed a two-stage data mining process, following Bretas and Alon (2021), and Islam *et al*. (2022). **Table 1** displays the detailed data mining process. In the beginning, the keyword search term was chosen from the earlier related papers, then executed in the Scopus and Web of Science online database on 6th September 2021. A grouping of keywords was considered; "Green Supply Chain*" to spike all differences of the term such as 'environmental supply chain management', 'sustainable supply chain management', 'supply chain sustainability', and "manufacturing" or 'manufacture' for both databases. Henceforth, the data were refined and selected only research articles from the categories; Environmental sciences, Operations Research Management sciences, Management, Engineering manufacturing, Business, Economics, Business finance (WoS, 2021); Business, Management and Accounting, Engineering, Social sciences, Economics, econometrics, and finance (Scopus, 2021) and documents written in English.

The extracted data from both databases were combined and checked for duplication using the machine learning tool "RStudio" in the second phase. A total of 265 duplicate articles was identified and removed by using "RStudio". Upon combination and removal of duplicate articles, a total of 962 data were used for bibliometric analysis. "Biblioshiny" package developed by (Aria & Cuccurullo, 2017), along with the VOSViewer visualisation tool were used for bibliometric analysis on selected journal articles. Hence, "Biblioshiny" initially used for filtering selected articles to remove book chapters, conference proceedings and the results provided a total of 918 journal articles for the analysis. The reason to remove book chapters and conference proceedings is to keep the analysis within a specific domain that considers only peer-reviewed and impactful articles.

The extracted data from both databases were combined and checked for duplication using the machine learning tool "RStudio" in the second phase. A total of 265 duplicate articles was identified and removed by using "RStudio". Upon combination and removal of duplicate articles, a total of 962 data were used for bibliometric analysis. "Biblioshiny" package developed by (Aria & Cuccurullo, 2017), along with the VOSViewer visualisation tool were used for bibliometric analysis on selected journal articles. Hence, "Biblioshiny" initially used for filtering selected articles to remove book chapters, conference proceedings and the results provided a total of 918 journal

articles for the analysis. The reason to remove book chapters and conference proceedings is to keep the analysis within a specific domain that considers only peer-reviewed and impactful articles.

Table 1 Data collection procedures

Selection of the main topic (Green supply chain in manufacturing) Date: 6th September, 2021	
Online database (Web of Science) **Input keywords** ("Green Supply Chain" OR "Environmental Supply Chain Management" OR "Sustainable Supply Chain Management" OR "Supply Chain Sustainability") AND ("Manufacturing" or "Manufacture") **Results:** 1029 articles **Refine/Filter:** Document types: articles Subject categories: Environmental sciences, Operations Research Management sciences, Management, Engineering manufacturing, Business, Economics, Business finance **Language**: English **Refined results:** 358 articles **Extracted:** bibtex format	**Online database** (The Scopus) **Input keywords** ("Green Supply Chain" OR "Environmental Supply Chain Management" OR "Sustainable Supply Chain Management" OR "Supply Chain Sustainability") AND ("Manufacturing" or "Manufacture") **Results:** 1446 articles **Refine/Filter:** Document types: articles Subject categories: Business, Management and Accounting, Engineering, Social sciences, Economics, econometrics, and finance **Language**: English **Filtered results:** 869 articles **Extracted:** bibtex format
Removed duplicate articles: 265 Total documents: 962 Filtered documents in "Biblioshiny' package **Total data for analysis**: 918	

3. RESULTS

3.1 Performance

Performance analysis explores the aids of research constituents to a particular discipline (Cobo & Herrera, 2011) that is vivid in nature, is the trademark of bibliometric investigations (Donthu *et al*., 2020). This analysis is acknowledged in most reviews, even those that do not involve science mapping. It is typical practice in reviews to exhibit the performance of various research elements in the discipline (Donthu *et al.,* 2021). It is similar to the empirical study, although more analytically presents the profile or background of respondents. Based on **Table 2**, significant productivity in the green supply chain to manufacturing research area was evolved in 21 years with an average of 43.71 publications per year.

A total of 36,621 citations were received, with an average of 1,743.86 per year. Among these citations, 564 citations were reported in h-index, 720 in g-index and 89 in m-index. The results acknowledged 1,931 contributing authors consisting of 72 authors produced sole-authored while 846 authors multi-authored documents. In detail, an average of more than two authors published a single document with a collaboration coefficient of 0.52.

Figure 1 demonstrates the publications trend of green supply chain research in both Scopus and Web of Science journals. The first publication in this area was noticed in 2001, and three papers were published in the same year. However, no publication was observed between 2002-2003. Starting from 2004, the publications on the green supply chain have emerged steadily till the present. However, there was a decline in 2009-2010 which can be predicted due to the financial crisis. The most significant number of publications were observed in 2020 (165) and progressively reported to 118 publications to the current year. Besides, an annual growth of 22.63% was reported for the publications on the green supply chain in the manufacturing industry. Conclusively, the trend of publications is increasing in recent times, which indicate that scholars are focusing and giving attention to the green supply chain and its effect on the manufacturing industry.

3.2 Science Mapping

Science mapping has become a vital commotion for researchers of all scientific areas. Due to the expansion and fragmentation of publications, the task of accruing knowledge set off more complex (Aria & Cuccurullo, 2017). Hence, science mapping is a longitudinal illustration of how fields, disciplines, spheres and individual research articles or authors are connected to one another as revealed by their physical propinquity and relative settings, parallel to the way terrestrial maps display the associations of

physical or political structures on the earth (Small, 1999). The grit of intellectual structure and the research-front of scientific spheres are imperative for research, policymaking, and practice (Aria & Cuccurullo, 2017). Thus, this technique is precisely associated with predicting similar thoughts and expertise within a fringe research constituent (Alam *et al*., 2021). In other words, it synchronizes various authors deliver their justifications, explorative ideas, and techniques in the same research sphere in various sources (journals).

Table 2 Descriptive analysis of documents

Components	Description	Results
Publications (P)	Total number of documents	918
Periods (NAY)	Active years of publication by research area {2001-2021(6th September)}	21 years
Productivity (PAY)	Publications/periods (P/NAY)	43.71
Sources	Number of journal sources	256
Total citations (TC)	Total citations received by published documents	36,621
Average citations (AC)/year	The average number of citations per year of publications	1743.86
Authors (NCA)	Total number of contributing authors	1931
Single-authored publications (SA)	Number of solely authored documents	72
Multi-authored documents (MA)	Number of documents written by more than single author	846
Collaboration Index (CI)	The degree of collaboration (NCA/P)	2.2
Collaboration coefficient (CC)	Standardizes the degree of researcher collaboration between 0 and 1 {1 - (P/NCA)}	0.52
h-index	*h* number articles cited at least h times (a measure of influence)	564
g-index	*g* number articles cited at least g^2 times (a measure of influence)	720
m-index	Unbroken research activity since the first publication by an author	89

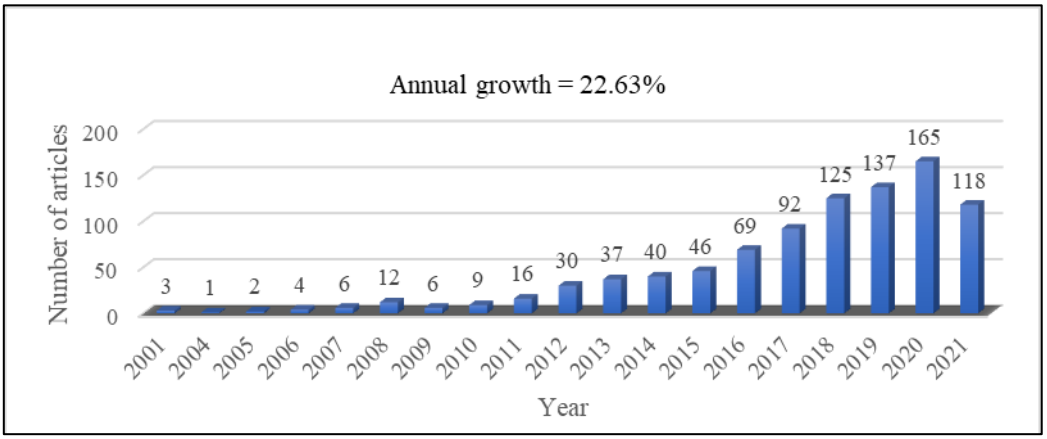

Figure 1 Annual publications trend

3.2.1 Citation & Co-citation

Citation and co-citation represent a crucial part of the scientific mapping within a research constituent that exhibits influential authors and their impactful research articles. It further presents the communicative shapes of millions of researchers, both dead and living (Small, 1999). These techniques represent the way scholars make important contributions through entrenching their work in the task of past authors both competitively and cooperatively (Small, 1999). Citation predominantly exposes the depth of knowledge introduced by prior researchers, which several generations have carried out over time.

A graphical citation network might provide a complex visualization of prominent and top-cited authors. Therefore, this study presents a clear image of top-cited authors and their documents receiving global and locations citations in **Table 3**. Global citations reflect the overall citations that cater to all kinds of literature and journals, while local citations represent the citations incurred within the 918 documents. The rationale for displaying top articles from both perspectives is to observe the impact and influence within the research constituent and pertinent other disciplines, selected databases, and other databases.

The paper was written by Zhu and Sarkis (2004), entitled "Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises" received the highest citations in both global (1238) and local citations (109) with an average of 68.78 global citations and 9% ratio of local and global citations.

This article investigated the linkage between green supply chain management and both environmental and economic performance using a moderated hierarchical regression analysis in 186 Chinese manufacturing enterprises. Another top-cited document {third in global cited (661) and second in local cited (65)} was also written by Zhu *et al*. (2005). This article assessed and defined the practices, drivers and performance applying exploratory factor analysis on survey data of Chinese manufacturing firms. Their findings demonstrated an increase in environmental awareness caused by regulatory, competitive, marketing drivers and pressures. Hence, most of the influential and top-cited articles were published earlier than 2015. Thus, a recent paper published in 2018 was written by Kalmykova *et al*., who provided a theoretical overview on circular economy that includes value chain, green supply chain, industrial ecology received a total of 338 global citations with an average of 85.50 per year. On the other hand, three papers published in 2017, written by Geng et al., Vanalle *et al*., and Qin *et al*., ranked 9th (local cited), 11th (local cited) and 18th (global cited), respectively. These papers focused on green supply chain management and its pressures, practices, and performances.

Table 3 Top 20 articles based on global and local citations

Rk.	Article	TGC	TGC/Y	Article	TLC	TGC	Ratio %
1	Zhu Qh, 2004, J Oper Manag	1238	68.78	Zhu Qh, 2004, J Oper Manag	109	1238	8.80
2	Zhu Q, 2008, Int J Prod Econ	791	56.50	Zhu Qh, 2005, Int J Oper Prod Man	65	661	9.83
3	Zhu Qh, 2005, Int J Oper Prod Man	661	38.88	Green Kw, 2012, Supply Chain Manag	55	518	10.62
4	Diabat A, 2011, Resour Conserv Recycl	598	54.36	Zhu Qh, 2013, J Purch Supply Manag	39	398	9.80
5	Zhu Q, 2006, J Clean Prod	590	36.88	Zhu Q, 2007, Int J Prod Res	35	519	6.74
6	Zhu Q, 2007, Int J Prod Res	519	34.60	Zhu Qh, 2012, Int J Prod Res	34	247	13.77
7	Green Kw, 2012, Supply Chain Manag	518	51.80	Mitra S, 2014, Int J Prod Res	30	168	17.86
8	Buyukozkan G, 2012, Expert Syst Appl	502	50.20	Zhu Qh, 2008, Omega-Int J Manage S	29	308	9.42
9	Kannan D, 2013, J Clean Prod	437	48.56	Geng Rq, 2017, Int J Prod Econ	28	157	17.83
10	Zhu Q, 2008, Transp Res Part E Logist Transp Rev	420	30.00	Zailani S, 2012, Int J Prod Econ	23	250	9.20
11	Eltayeb Tk, 2011, Resour Conserv Recycl	413	37.55	Vanalle Rm, 2017, J Clean Prod	22	131	16.79
12	Mathiyazhagan K, 2013, J Clean Prod	412	45.78	Vachon S, 2007, Int J Prod Res	21	263	7.98
13	Srivastava Sk, 2008, Omega	400	28.57	Wu Gc, 2012, Int J Prod Econ	21	224	9.38
14	Zhu Qh, 2013, J Purch Supply Manag	398	44.22	Govindan K, 2014, Int J Prod Econ	19	343	5.54
15	Hsu Cw, 2013, J Clean Prod	350	38.89	Swami S, 2013, J Oper Res Soc	18	230	7.83
16	Govindan K, 2014, Int J Prod Econ	343	42.88	Ghosh D, 2015, Int J Prod Econ	17	306	5.56
17	Kalmykova Y, 2018, Resour Conserv Recycl	338	84.50	Testa F, 2010, J Clean Prod	16	282	5.67
18	Qin Jd, 2017, Eur J Oper Res	310	62.00	Kannan D, 2013, J Clean Prod	15	437	3.43
19	Luthra S, 2011, J Ind Eng Manage	310	28.18	Zhu Qh, 2011, Transport Res E-Log	14	122	11.48
20	Zhu Qh, 2008, Omega-Int J Manage S	308	22.00	Tseng Ml, 2013, J Clean Prod	14	239	5.86

Note (s): Rk. = rank, TGC= total global citations, TGC/Y= total global citations/publication periods, TLC= total local citations, Ratio= (TLC/TGC) *100; global citations= number of citations received in the Scopus database, local citations= number of citations received within 918 articles (dataset used in this study). Source: Biblioshiny

Co-citation refers to the occurrence of citation in a third article; thus, a counterpart of bibliographic coupling (Aria & Cuccurullo, 2017). This technique predicts how research articles on the green supply chain are cited and co-cited simultaneously over the period. These articles chart out research constituents and explore the basis and path of future study (Small, 1999). Consequently, co-citation networks within the 918 articles were identified to figure out meaningful and parsimonious results. **Figure 2** presents the co-citation networks where it categorised three clusters. Each cluster depicts similar and meaningful research orientations. The largest cluster (red-coloured) is indirectly led by the top-cited and prominent author Zhu Qh, associated by Sarkis, Lee, Wu, and many more in the green supply chain research constituent. This cluster mainly explores the importance of green supply management linked to business gains and environmental benefits in different aspects such as green logistics and cause marketing.

Meanwhile, the blue-coloured cluster that was influenced by Chen was associated with Li, Zhang, and Wang. This cluster generally studies supply chain management, greening products, sustainable operations, reverse logistics etc. the last cluster (green) represents a few top-cited authors such as Green Kw and Govindan K. They basically focus on total quality management, green management, green manufacturing, environmental collaboration, barriers, and drivers of green supply management. It can be elucidated that the red-coloured cluster represents the theoretical representation and business opportunities for green supply management for the manufacturing industry. The blue-coloured cluster shows the process of green manufacturing and is linked to environmentally friendly green products, while the green-coloured cluster discusses the quality, opportunities, and challenges of green supply management.

3.2.2 Co-word Analysis

It is mainly used to induce the conceptual structure of a framework by means of word co-occurrence (Aria & Cuccurullo, 2017). Co-word analysis uses text-mining methods to the titles, keywords, and abstracts of research articles (van Eck & Waltman, 2010). Co-word mapping detects the occurrence of multiple keywords together in the same document (Verma & Gustafsson, 2020). The link between keywords is determined by keywords' occurrence together in the number of documents (van Eck & Waltman, 2010). This co-word mapping allows understanding the

research attention and links among keywords, thus identifying the prominent research themes (Verma & Gustafsson, 2020). Accordingly, it indicates the gaps and directions for future studies. This study analyses the co-word analysis using the VOSviewer tool, which collects the keywords from the dataset and establishes a co-occurrence mapping. **Figure 3** displays the co-occurrence of keywords mapping comprising four main themes within 918 published documents linked to the green supply chain. In order to present relevant keywords linked to the focused keywords, the "supply chain management (occurred 370 times)", "manufacture (154 times)", "supply chains (171 times)", "sustainable development (158 times)" "green supply chain management (183 times)" and "green supply chain (165)" were removed from the network. The co-occurrence of keywords demonstrated four main key themes within 918 documents.

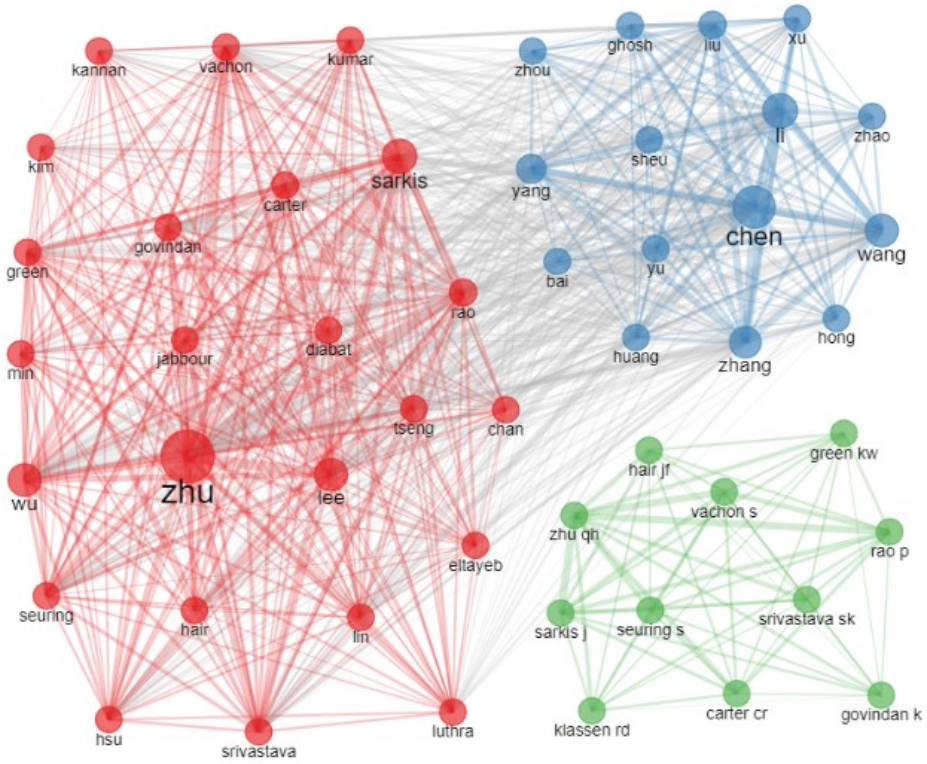

Figure 2 Co-citation network, Source: Biblioshiny
Note: the nodes' size refers to the absolute proportional contribution, lines present the relational ties and thickness of lines show the number of occurrences.

Begin with the red-coloured cluster (23 keywords) that demonstrated the greatest theme of environmental management (occurred 116 times) focused on environmental performance in manufacturing industries. This cluster denoted the variables such as competitive advantage, environmental regulations, eco-design, environmental sustainability, sustainable operations, roles of managers to evaluate performance, including operational performance applying structural equation modelling on survey data. The green-coloured cluster (20 keywords) maps out another significant theme with decision making in designing products. This theme adopts sustainable supply chains as a crucial variable along with closed-loop supply chain, recycling, remanufacturing that link to the emission of carbon, greenhouse gases and cost-benefit analysis to measure economic and social effects for sustainable manufacturing.

The blue-coloured cluster (13 keywords) represents the theme of sustainability of manufacturing. The theme that emerged from the performance assessment comprises environmental and economic performance under a green economy using uncertainty and optimization analysis. This theme has also included the marketing approach and sustainable supply chain management that greatly focused on the Chinese market. Finally, sales (12 keywords) of green manufacturing products have emerged in the green supply chain research, particularly applying game theory. It can be further elaborated with game theory application to the commercial process of green products to evaluate profitability. Further, this theme comprises several variables: costs, environmental protection, investments, supplier selection, and cost-effectiveness.

3.3 Collaboration

This analysis is one of the prominent forms of scientific collaboration (Glänzel, 2001). Typically, collaboration demonstrates the cooperation between authors (co-authorship), affiliated institutions and countries, representing how scholars collaborate.

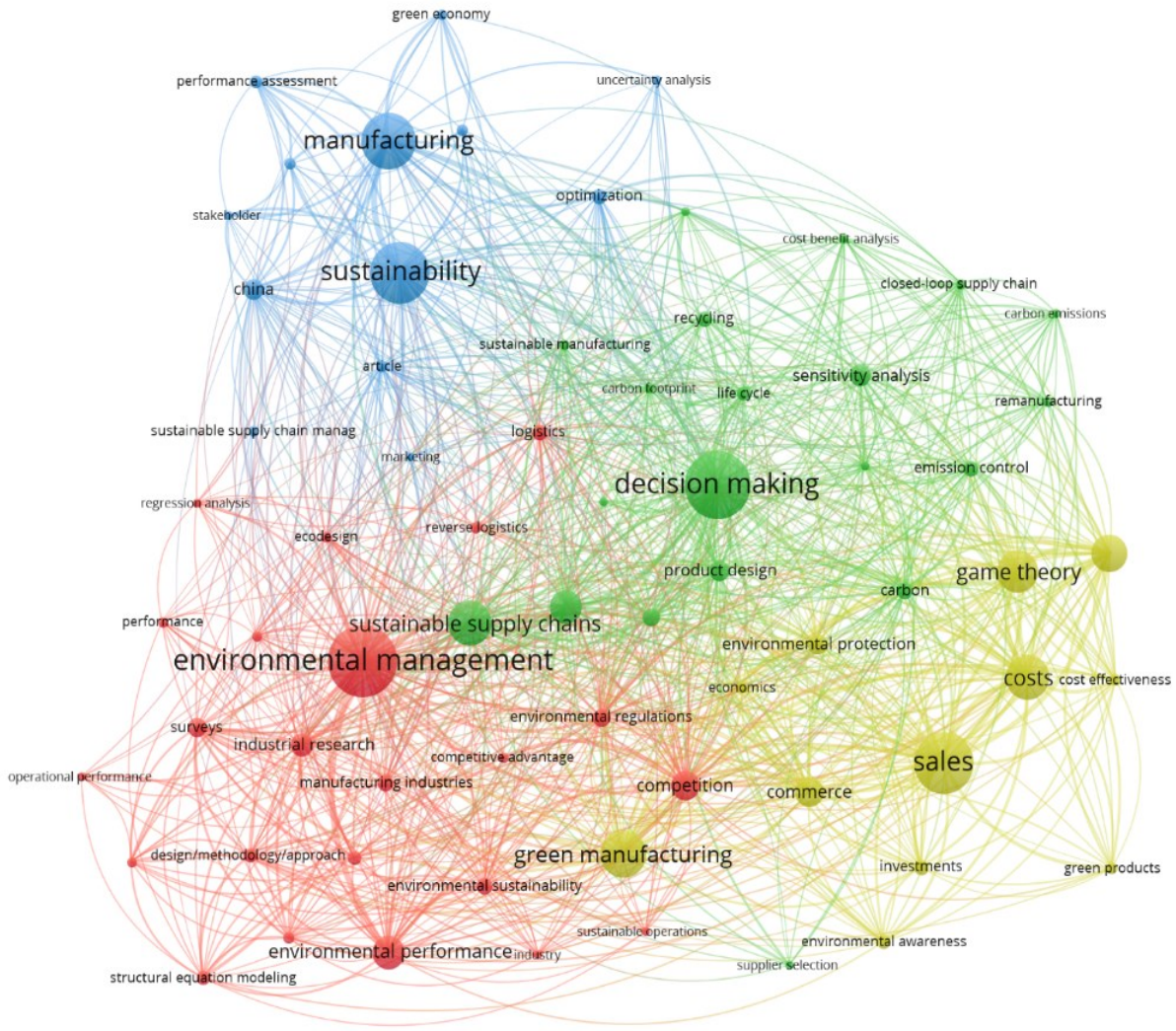

Figure 3 Co-occurrence of keywords; each keyword is used at least fifteen times in selected data files
Source: VOSviewer
Note: the nodes' size refers to the absolute proportional contribution, lines present the relational ties and thickness of lines show the number of occurrences.

3.3.1 Co-autorship

Co-authorship is undertaken as an effort (Cisneros et al., 2018), from a methodological view, to form a more multidisciplinary tactic, empirically focused and statistically laborious research (Benavides-Velasco et al. 2013). The findings validate this effort; a large number of documents (92.16%) were the output of the collaboration between authors. Meanwhile, only 72 out of 98 papers were written by one scholar. **Figure 4** exhibits the cooperation of authors (co-authorship) in publishing documents in the field of the green supply chain. Among 1931 authors, only a few are represented in the graph because others have very few clusters or have not collaborated multiple publications or impartial nodes and depict less importance for gauging co-authorship (Cisneros et al., 2018).

The largest node (red-coloured) that represents the highest proportion of contribution and bigger cluster in collaboration of authors; represented by the leading author Zhu Qh (top-cited & 19 publications) and Sarkis J (22 publications) along with Bai C (5 publications), Lai K (9 publications), Geng Y (7 publications), and Kusi-Sarpong S (6 publications). Another cluster (pink-coloured) represented by five authors comprising Kumar S (4 publications), Kumar P (5 publications), Barua M (6 publications), Mangla S (12 publications) and Luthra S (8 publications). Another influential collaborated cluster (green-coloured) represents influential authors who exhibited in top-cited authors such as Kannan D (1,166 total citations), Govindan K (2,175 total citations), Mathiyazhagan K (792 total citations) and Haq A (647 total citations).

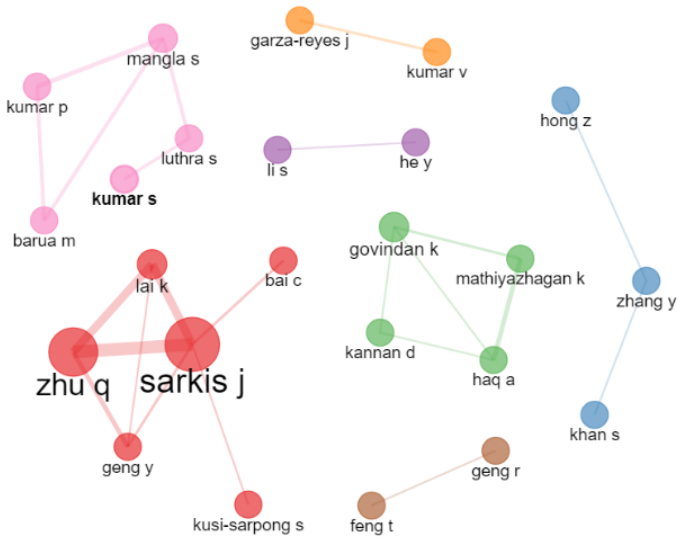

Figure 4 Co-authorship network
Source: Biblioshiny
Note: the nodes' size refers to the absolute proportional contribution, lines present the relational ties and thickness of lines show the number of occurrences

3.3.2 Collaborated Institutions

Collaboration of affiliated institutions depicts the cooperation or partnership within affiliated institutions of authors. **Figure 5** displays the highly cooperated institutions in regards to publications within the green supply chain research constituent. Hong Kong Polytechnic University extensively collaborated with Dalian University technology and Clark University. These universities are affiliated with leading authors Lai K, Zhu Qh, and Sarkis J, respectively. In a separate network, these institutions have also collaborated with Tianjin University. Meanwhile, University Southern Denmark has published articles by collaborating with the University Tehran and Natl Institution of technology. Therefore, it can be elucidated that several institutions located in different areas collaborated to publish papers related to green supply chain research constituents. Collaborating with various institutions allow authors to share their resources and expertise in publications.

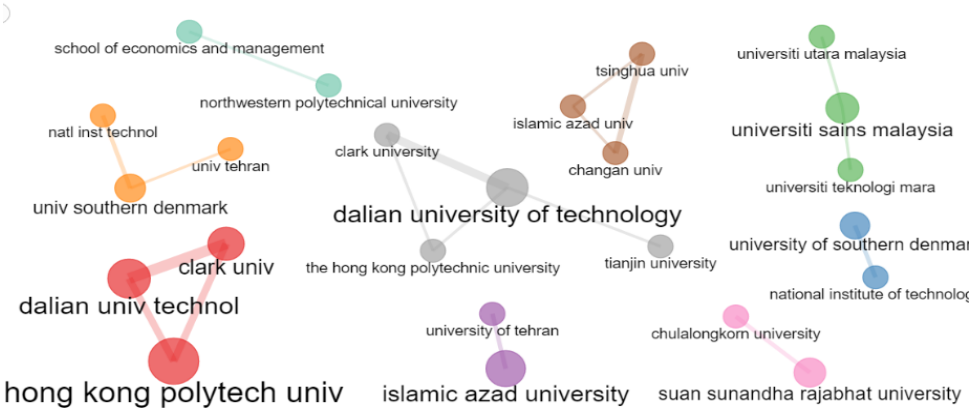

Figure 5 Collaborated institutions
Source: Biblioshiny
Note*: the nodes' size refers to the absolute proportional contribution, lines present the relational ties and thickness of lines show the number of occurrences.*

3.3.3 Collaborated Countries

Similar to the collaborated institutions, authors affiliated countries' collaboration demonstrates the cooperation or partnership of nations in research constituents. This collaboration network aims to identify the focused geographical locations in particular disciplines. This network mapping can elucidate which geographical areas or countries focus on green supply chain studies that represent the awareness and interest. **Figure 6** exhibits the collaborated affiliated countries. China has established the most significant attention in green supply management, its barriers, practices and opportunities, and industrial performance. Therefore, China has published the largest number of articles (228 documents) and collaborated beyond borders comprising Asian, European, USA and African countries. The second cluster of affiliated countries

is led by India (95 documents) that cooperated with countries like Malaysia, Korea, Canada, Iran, and Denmark. Another crucial collaborated cluster is represented by Singapore, Australia, Thailand, and the United Arab Emirates. These clusters confirmed the diverse geographical collaboration within the published documents linked to green supply chain management. This trend predicts the importance of green supply management as well as its borderless effects in the world.

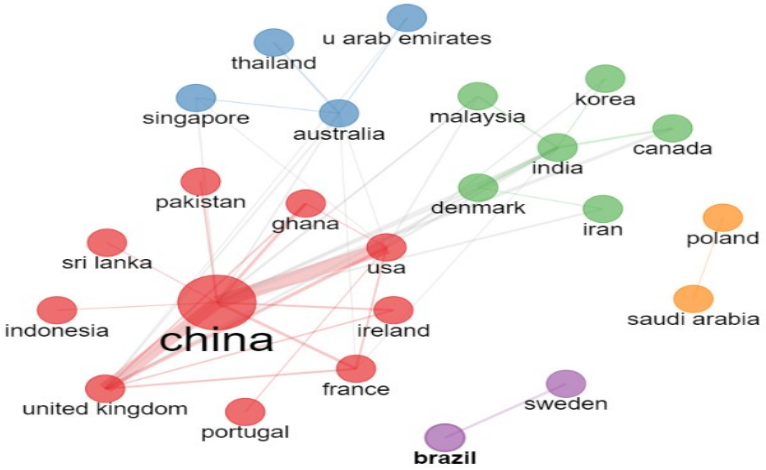

Figure 6 Network of collaborated countries
Source: Biblioshiny
Note*: the nodes' size refers to the absolute proportional contribution, lines present the relational ties, and the thickness of lines shows the number of occurrences.*

4. DISCUSSION

In order to enhance the robustness of the findings, this study has crucially reviewed the most cited documents and most recent documents with citations. Findings from these articles were discussed together with the findings from bibliometric analysis and the growth of keywords (**Figures 7 & 8**). Green supply chain management has mainly gotten attention in the recent period, though it started to explore at the beginning of the 21st century. Earlier in the century, scholars have mainly focused on knowledge sharing and integrating green supply chain management in the manufacturing industry. Further, the evolution of the study mainly started and yet focused on china greatly. Particularly, the academic authors prioritised the performance, both economic and environmental (Zhu & Sarkis, 2004), drivers, practices, and performances (Vachon, 2007; Zhu *et al*., 2005), and framework for remanufacturing, repair, and refurbishing (Srivastava, 2008) of manufacturing products by adopting green supply chain management. Ben-Daya *et al*. (2022) proposed a framework for understanding the effect of IoT (Internet of Things) on supply chain management. Simultaneous growth in green supply management studies carried out in recent decades with ample research publications.

Meanwhile, a sustainable supply chain has caught the crucial attention of scholars, which demonstrated the progressive and innovative mechanisms in the manufacturing sector. A cohesive economic and social sustainability performance dimension in supply chains is an evolving route in sustainable supply chain management (Sudusinghe & Seuring, 2020). Accordingly, several studies demonstrated an effective contribution of a sustainable supply chain to economic compliance and influenced the social sustainability in the manufacturing sector. For instance, Sudusinghe and Seuring (2020) observed that the significant contribution of practising social sustainability within apparel manufacturing positively affects economic performance. Malsinghe *et al*. (2022) presented an examination of operational excellence models of the sustainable supply chain in manufacturing firms in Sri Lanka. Subsequently, green innovation criteria in the form of economic criteria have been a vital component for sustainable supply chain management in textile manufacturing (Yang & Wang, 2020). Henceforth, Hsu *et al*. (2021) proposed a decision-making framework with integration of multi-criteria decision-making and quality function deployment approach to recognise the foremost sustainable risks and the imperative resilience to alleviate these risks. In a similar context, Sirilertsuwan *et al*. (2020) proposed a decision-making approach to objectively choosing multi-tier supply locations on the basis of cost and CO2 equivalents from logistics, manufacturing, and sustainability-assurance activities. This approach was designed to help evaluate whether the prices of the supplier are very low to create social and environmental compliance. In light of this evidence, it is perpetual to exclaimed that a sustainable supply chain has been studied to measure and encourage the manufacturing sector to highlight the importance of a sustainable supply chain.

Current and past studies contributed diverse and extensive themes to the research account, such as performance analysis of green supply chain adoption in the manufacturing industry (Agyabeng-Mensah et al., 2021; Geng *et al*., 2017; Green *et al*., 2012; Rehman Khan & Yu, 2021; Robb *et al*., 2022). Meanwhile, studies have also focused on institutional pressures in adopting green supply chain management (Vanalle *et al*., 2017; Zhu *et al*., 2013).

Nevertheless, the literature further investigated the ignorance of the green supply chain and awareness of environmental sustainability (Mitra & Datta, 2014). An extensive literature explored the barriers (technology, outsourcing, financial concerns, and knowledge barriers) and drivers (Govindan *et al*., 2014) in the adoption of green supply chain management. Several scholars proposed strategies, such as price strategies (Li *et al*., 2021), models to evaluate efficiency (Liu *et al*., 2018) and solutions to overcome challenges (Yadav *et al*., 2020), and the value of green human resource management (Yu *et al*., 2020). Meanwhile, recent studies suggested several frameworks based on big data analytics, blockchain technologies, and the internet of things to improve green supply chain management practices (Esmaeilian *et al*., 2020; Venkatesh *et al*., 2020; Yadav *et al*., 2020).

Overall findings demonstrated a rising green supply chain management trend to the manufacturing industry, including the automotive industry. The game theory has been extensively applied along with Stackelberg theory, ability-motivation-opportunity, contingency theory etc. Furthermore, studies have adopted regression analysis, primarily structural equation modelling and recently the PLS-SEM approach. Additionally, several moderating and mediating variables, including green supply chain management, firm size was used. Besides, sustainable supply chain management has gained the attention of recent scholars (Esmaeilian *et al*. 2020; Venkatesh *et al*. 2020) that concurrently investigate it. Based on the overall analysis, several topics are more improved and moving forward to a normative approach, for instance, efficiency, reverse logistics, circular economy, life cycle management, big data analytics, Internet of Things, systems integration frameworks, while few provided opportunities to be explored further, for example, green human supply cycle, sustainable production and supply chain, green manufacturing and products, carbon emissions, energy consumption and impacts of industry 4.0.

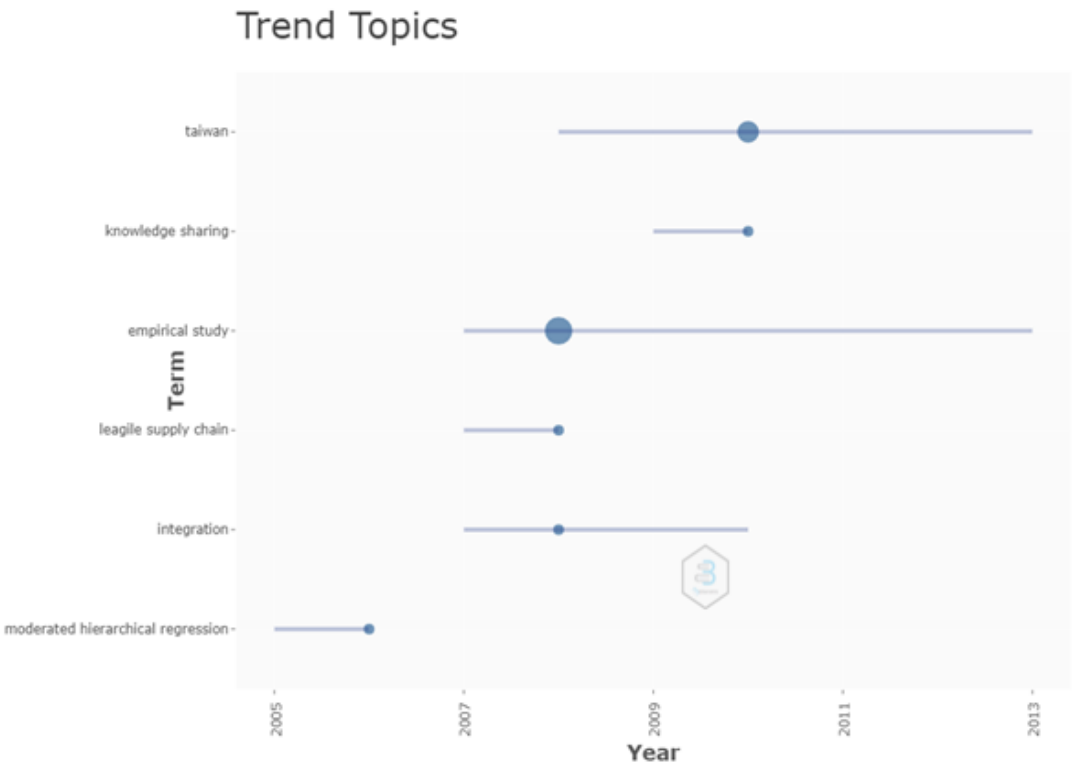

Figure 7 Trend topics between 2011-2010, each keyword appeared at least two times per year

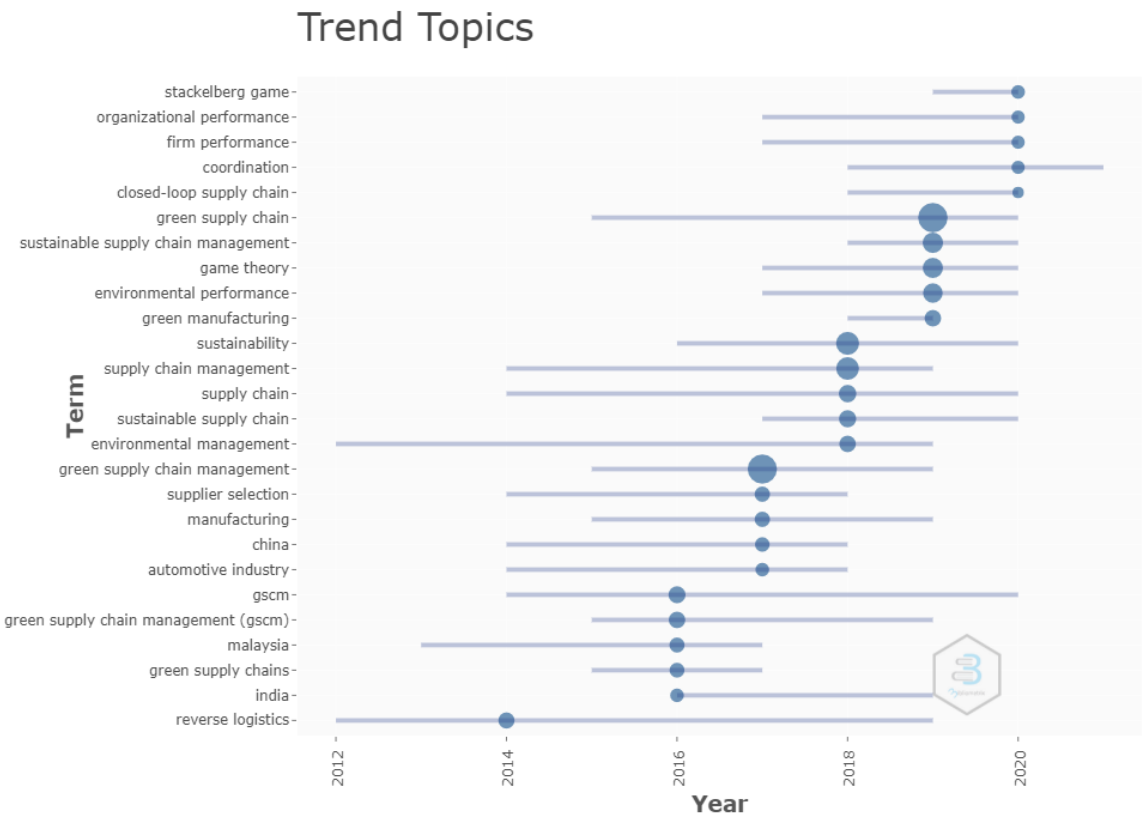

Figure 8 Trend topics between 2011 to the present, each keyword appeared at least five times per year

4.1 Suggestion for Future Research

By analysing and exploring the current and past research contributions, this study has identified several research questions that can be the basis for future studies. Concurrently, these research questions hint at the current research gaps and future research agenda that can be void by contribution with future studies. Firstly, what are the extents of performance analysis for various manufacturing industry types? In other words, green supply chain management practices might affect the overall performances for different types of industry, for example, automotive, food etc. Therefore, future studies can perform performance analysis based on types of industry. Secondly, how can the machine learning approach be integrated to improve the efficiency and prediction of future growth of green supply chain management practices? Therefore. Future studies can evaluate the accuracy and implementation of machine learning in improving the manufacturing industry's green supply chain management practices as well as the evaluation of sustainable supply chain management. Thirdly, prior studies vastly focused on high industrial economies, mainly China, India. Future studies can be integrated into other emerging economies such as Malaysia, Indonesia.

Fourthly, how can the collaboration of humans and machines improve employees' health and safety? Will it positively affect the economic, environmental, and social performance of green manufacturing? Future studies may employ these two attributions to focus on internal employees' health and safety to smoothen green production. Besides, studies may also consider human and social capital, social norms, trust, behavioural factors and organisational climate. Similarly, the effect of advanced technologies can be included to provide efficient production. Fifthly, what are the internal factors that demonstrate the sustainability of the green manufacturing industry? Besides, what are the most relevant standards for illustrating sustainable green manufacturing and supply chain protocols? These circumstances offer ample scope for researchers to employ studies linked to the sustainability of the green manufacturing industry and sustainable green supply chain management practices. Sixthly, prior studies have vastly focused on the evaluation of economic and environmental performance while a little assessment carried out on social performance. Future studies incorporate economic, environmental, and social performance to accomplish the comprehensive effect of green supply chain management practices.

Seventhly, how do the green supply chain and manufacturing industry affect job creation and employment and to what extent does the green supply chain interact or mediate the manufacturing and production system drive the industry's sustainability? In these regards, future studies may adopt several variables as interacting or mediating to evaluate the relationship between production or operation process and sustainability of the industry. Finally, prior studies mostly applied multivariate regression analysis to measure the performance, namely, structural equation modelling and partial least square. The findings have also observed that studies mostly used qualitative or survey data for investigation while rarely used secondary data. Therefore, future studies may apply other techniques using secondary data, such as GMM, parametric and non-

parametric analysis for efficiency and productivity of green manufacturing firms.

5. CONCLUSION

The main purpose of this study is to investigate the research trends and directions of the green supply chain in the manufacturing industry. In order to achieve this objective, this study used academic published articles from online databases, namely, the Scopus and Web of Science and analysed by the bibliometric method using 'R' and 'Gephi'. Further, most cited and selected recent articles were reviewed to enhance the robustness of the discussion as well as to provide future research direction. According to the findings, recently, green manufacturing, green supply chain and sustainable manufacturing are getting significant attention from academic researchers. Extensive research has been taken to identify the drivers, challenges, practices of green supply chain management and evaluation of manufacturing firms' economic and environmental performance. Chinese manufacturing firms were widely chosen for such studies, while Indian firms are getting into the data for studies, whereas other manufacturing countries were not receiving attention from researchers.

Studies permit to accomplish that the area is well-founded but not widely consolidated. However, the area is growing based on the expansion of green business models, green supply chain management practices and legal pressures. The findings allowed us to identify several research gaps and demonstrated the scopes for future studies. This study also contributes to the knowledge as a reference for further studies. Meanwhile, practitioners may find these findings for their adequate and effective strategies to enhance their efficiency and performance. Finally, policymakers may gauge the trend and progressive implementation and performance of green manufacturing firms. Therefore, they can formulate and improve the legal process and offer subsidies and benefits to encourage businesses to adopt green supply chain management practices to reduce energy consumption and thus lessen carbon emissions.

This study has only covered documents published in the Scopus and Web of Science that review and maintain high quality. However, the inclusion of other databases such as google scholar, PubMed and EBSCO may have inclined the data illustration. Further, this study only combined journal articles by removing book chapters, conference proceedings. Future studies may include these databases and articles to provide comprehensive analysis results and evade biases.

REFERENCES

Agyabeng-Mensah, Y., Afum, E., Agnikpe, C., Cai, J., Ahenkorah, E., & Dacosta, E. (2021). Exploring the mediating influences of total quality management and just in time between green supply chain practices and performance. Journal of Manufacturing Technology Management, 32(1), 156–175. https://doi.org/10.1108/JMTM-03-2020-0086

Alam, S. M. S., Chowdhury, M. A. M., & Razak, D. B. A. (2021). Research evolution in banking performance: a bibliometric analysis. Futur Bus J, 7(66), 1–19. https://doi.org/10.1186/s43093-021-00111-7

Amirbagheri, K., Núñez-Carballosa, A., Guitart-Tarrés, L., & Merigó, J. M. (2019). Research on green supply chain: a bibliometric analysis. Clean Technologies and Environmental Policy, 21(1), 3–22. https://doi.org/10.1007/s10098-018-1624-1

Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2022). A Conceptual Framework for Understanding the Impact of Internet of Things on Supply Chain Management. Operations and Supply Chain Management: An International Journal, 15(2), 251–268. https://doi.org/10.31387/oscm0490345

Bowen, F., Cousins, P., Lamming, R., & Faruk, A. (2006). Horses for Courses: Explaining the Gap Between the Theory and Practice of Green Supply. In S. J. (Ed.), Greening the Supply Chain (pp. 151–172). Springer London. https://doi.org/10.1007/1-84628-299-3_9

Bretas, V. P. G., & Alon, I. (2021). Franchising research on emerging markets: Bibliometric and content analyses. Journal of Business Research, 133(May), 51–65. https://doi.org/10.1016/j.jbusres.2021.04.067

Cisneros, L., Ibanescu, M., Keen, C., Lobato-Calleros, O., & Niebla-Zatarain, J. (2018). Bibliometric study of family business succession between 1939 and 2017: mapping and analyzing authors' networks. Scientometrics, 117(2), 919–951. https://doi.org/10.1007/s11192-018-2889-1

Cobo, M. J., & Herrera, F. (2011). An approach for detecting, quantifying, and visualizing the evolution of a research field: A practical application to the Fuzzy Sets Theory field. Journal of Informetrics, 5(1), 146–166. https://doi.org/10.1016/j.joi.2010.10.002

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. Journal of Business Research, 133(May), 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Donthu, N., Kumar, S., & Pattnaik, D. (2020). Forty-five years of Journal of Business Research: A bibliometric analysis. Journal of Business Research, 109(October 2019), 1–14. https://doi.org/10.1016/j.jbusres.2019.10.039

El Baz, J., & Iddik, S. (2021). Green supply chain management and organizational culture: a bibliometric analysis based on Scopus data (2001-2020). International Journal of Organizational Analysis, 30(1), 156–179. https://doi.org/10.1108/IJOA-07-2020-2307

Esmaeilian, B., Sarkis, J., Lewis, K., & Behdad, S. (2020). Blockchain for the future of sustainable supply chain management in Industry 4.0. Resources, Conservation and Recycling, 163(August), 1–15. https://doi.org/10.1016/j.resconrec.2020.105064

Fahimnia, B., Sarkis, J., & Davarzani, H. (2015). Green supply chain management: A review and bibliometric analysis. International Journal of Production Economics, 162, 101–114. https://doi.org/10.1016/j.ijpe.2015.01.003

Gaur, A., & Kumar, M. (2018). A systematic approach to conducting review studies: An assessment of content analysis in 25 years of IB research. Journal of World Business, 53(2), 280–289. https://doi.org/10.1016/j.jwb.2017.11.003

Geng, R., Mansouri, S. A., & Aktas, E. (2017). The relationship between green supply chain management and performance: A meta-analysis of empirical evidence in Asian emerging economies. International Journal of Production Economics, 183(October 2016), 245–258. https://doi.org/10.1016/j.ijpe.2016.10.008

Glänzel, W. (2001). Coauthorship patterns and trends in the sciences (1980-1998): A bibliometric study with implications for database indexing and search strategies. Library Trends, 50(3), 461–473.

Gong, R., Xue, J., Zhao, L., Zolotova, O., Ji, X., & Xu, Y. (2019). A Bibliometric Analysis of Green Supply Chain Management Based on the Web of Science (WOS) Platform. Sustainability, 11(12), 34–59. https://doi.org/10.3390/su11123459

Govindan, K., Kaliyan, M., Kannan, D., & Haq, A. N. (2014). Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. International Journal of Production Economics, 147(PART B), 555–568. https://doi.org/10.1016/j.ijpe.2013.08.018

Green, K. W., Zelbst, P. J., Meacham, J., & Bhadauria, V. S. (2012). Green supply chain management practices: impact on performance. Supply Chain Management: An International Journal, 17(3), 290–305. https://doi.org/10.1108/13598541211227126

Hollos, D., Blome, C., & Foerstl, K. (2012). Does sustainable supplier co-operation affect performance? Examining implications for the triple bottom line. International Journal of Production Research, 50(11), 2968–2986. https://doi.org/10.1080/00207543.2011.582184

Hsu, C.-H., Yu, R.-Y., Chang, A.-Y., Chung, W.-H., & Liu, W.-L. (2021). Resilience-Enhancing Solution to Mitigate Risk for Sustainable Supply Chain—An Empirical Study of Elevator Manufacturing. Processes, 9(4), 1–41. https://doi.org/10.3390/pr9040596

Islam, M. M., Chowdhury, M. A. M., Begum, R. A., & Amir, A. A. (2022). A bibliometric analysis on the research trends of climate change effects on economic vulnerability. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-022-20028-0

Kalmykova, Y., Sadagopan, M., & Rosado, L. (2018). Circular economy - From review of theories and practices to development of implementation tools. Resources, Conservation and Recycling, 135(October 2017), 190–201. https://doi.org/10.1016/j.resconrec.2017.10.034

Li, P., Rao, C., Goh, M., & Yang, Z. (2021). Pricing strategies and profit coordination under a double echelon green supply chain. Journal of Cleaner Production, 278(January), 1–17. https://doi.org/10.1016/j.jclepro.2020.123694

Liu, B., Chen, D., Zhou, W., Nasr, N., Wang, T., Hu, S., & Zhu, B. (2018). The effect of remanufacturing and direct reuse on resource productivity of China's automotive production. Journal of Cleaner Production, 194, 309–317. https://doi.org/10.1016/j.jclepro.2018.05.119

Maditati, D. R., Munim, Z. H., Schramm, H. J., & Kummer, S. (2018). A review of green supply chain management: From bibliometric analysis to a conceptual framework and future research directions. Resources, Conservation and Recycling, 139(December 2017), 150–162. https://doi.org/10.1016/j.resconrec.2018.08.004

Malsinghe, M. T. D., Gunathilaka, M. H. A., Dinesh Bandara, I. P. C., Wijerathne, A. I., Nagendrakumar, N., & Madhavika, W. D. N. (2022). Sustainable Supply Chains of Sri Lankan Manufacturing Organizations: A Study on Operational Excellence Models During the COVID-19 Pandemic. Operations and Supply Chain Management: An International Journal, 15(2), 228–239. https://doi.org/10.31387/oscm0490343

Mishra, D., Gunasekaran, A., Papadopoulos, T., & Hazen, B. (2017). Green supply chain performance measures: A review and bibliometric analysis. Sustainable Production and Consumption, 10(February), 85–99. https://doi.org/10.1016/j.spc.2017.01.003

Mitra, S., & Datta, P. P. (2014). Adoption of green supply chain management practices and their impact on performance: an exploratory study of Indian manufacturing firms. International Journal of Production Research, 52(7), 2085–2107. https://doi.org/10.1080/00207543.2013.849014

Nobanee, H. (2021). A Bibliometric Review of Big Data in Finance. Big Data, 9(2), 73–78. https://doi.org/10.1089/big.2021.29044.edi

Qin, J., Liu, X., & Pedrycz, W. (2017). An extended TODIM multi-criteria group decision making method for green supplier selection in interval type-2 fuzzy environment. European Journal of Operational Research, 258(2), 626–638. https://doi.org/10.1016/j.ejor.2016.09.059

Rehman Khan, S. A., & Yu, Z. (2021). Assessing the eco-environmental performance: an PLS-SEM approach with practice-based view. International Journal of Logistics Research and Applications, 24(3), 303–321. https://doi.org/10.1080/13675567.2020.1754773

Robb, C., Kang, M., & Stephens, A. (2022). The effects of dynamism, relational capital, and ambidextrous innovation on the supply chain resilience of U.S. firms amid COVID-19. Operations and Supply Chain Management: An International Journal, 15(1), 1–16. https://doi.org/10.31387/oscm0480326

Scopus. (2021). Scopus searches. The Scopus. https://www.scopus.com/results/results.uri?sort=plf

Sirilertsuwan, P., Thomassey, S., & Zeng, X. (2020). A Strategic Location Decision-Making Approach for Multi-Tier Supply Chain Sustainability. Sustainability, 12(20), 8340. https://doi.org/10.3390/su12208340

Small, H. (1999). Visualizing science by citation mapping. Journal of the American Society for Information Science, 50(9), 799–813. https://doi.org/10.1002/(SICI)1097-4571(1999)50:9<799::AID-ASI9>3.0.CO;2-G

Srivastava, S. K. (2008). Network design for reverse logistics. Omega, 36(4), 535–548. https://doi.org/10.1016/j.omega.2006.11.012

Sudusinghe, J. I., & Seuring, S. (2020). Social Sustainability Empowering the Economic Sustainability in the Global Apparel Supply Chain. Sustainability, 12(7), 2595. https://doi.org/10.3390/su12072595

Vachon, S. (2007). Green supply chain practices and the selection of environmental technologies. International Journal of Production Research, 45(18–19), 4357–4379. https://doi.org/10.1080/00207540701440303

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Vanalle, R. M., Ganga, G. M. D., Godinho Filho, M., & Lucato, W. C. (2017). Green supply chain managementAn investigation of pressures, practices, and performance within the Brazilian automotive supply chain. Journal of Cleaner Production, 151, 250–259. https://doi.org/10.1016/j.jclepro.2017.03.066

Venkatesh, V. G., Kang, K., Wang, B., Zhong, R. Y., & Zhang, A. (2020). System architecture for blockchain based transparency of supply chain social sustainability. Robotics and Computer-Integrated Manufacturing, 63(November). https://doi.org/10.1016/j.rcim.2019.101896

Verma, S., & Gustafsson, A. (2020). Investigating the emerging COVID-19 research trends in the field of business and management: A bibliometric analysis approach. Journal of Business Research, 118(January), 253–261. https://doi.org/10.1016/j.jbusres.2020.06.057

WoS. (2021). Web of Science core collection. Web of Science. shorturl.at/fyDZ6

Yadav, G., Luthra, S., Jakhar, S. K., Mangla, S. K., & Rai, D. P. (2020). A framework to overcome sustainable supply chain challenges through solution measures of industry 4.0 and circular economy: An automotive case. Journal of Cleaner Production, 254, 120112. https://doi.org/10.1016/j.jclepro.2020.120112

Yang, Y., & Wang, Y. (2020). Supplier Selection for the Adoption of Green Innovation in Sustainable Supply Chain Management Practices: A Case of the Chinese Textile Manufacturing Industry. Processes, 8(6), 717. https://doi.org/10.3390/pr8060717

Yu, W., Chavez, R., Feng, M., Wong, C. Y., & Fynes, B. (2020). Green human resource management and environmental cooperation: An ability-motivation-opportunity and contingency perspective. International Journal of Production Economics, 219(June 2019), 224–235. https://doi.org/10.1016/j.ijpe.2019.06.013

Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. Journal of Operations Management, 22(3), 265–289. https://doi.org/10.1016/j.jom.2004.01.005

Zhu, Q., Sarkis, J., & Geng, Y. (2005). Green supply chain management in China: Pressures, practices, and performance. International Journal of Operations and Production Management, 25(5), 449–468. https://doi.org/10.1108/01443570510593148

Zhu, Q., Sarkis, J., & Lai, K. hung. (2013). Institutional-based antecedents and performance outcomes of internal and external green supply chain management practices. Journal of Purchasing and Supply Management, 19(2), 106–117. https://doi.org/10.1016/j.pursup.2012.12.001

Erna Masfiza Mohamed Ramli is a Ph.D. candidate at the Department of Business Administration, International Islamic University Malaysia (Malaysia). Her research interests are Supply Chain Management, Organizational Learning, Organizational behaviour. She is also a faculty member at the Faculty of Management and Business Technology, Kuala Lumpur Metropolitan University College (Malaysia).

Dolhadi Bin Zainudin is an Assistant Professor at the Department of Business Administration, International Islamic University Malaysia (Malaysia). His research interests are Economics, Business and Management, Economics, Business and Management, Management, Organizational Studies.

Rafikul Islam is a Professor at the Department of Business Administration, International Islamic University Malaysia (Malaysia). His research interests are Natural Science, Mathematical Sciences, Applied Statistics, Decision Theory, Economics, Business and Management, Operations Management.