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Green Supply Chain Management Research Trends and Linkages to UN Sustainable Development Goals

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Abstract: Growing awareness about environmental responsibility among businesses and policymakers has increased interest in Green Supply Chain Management (GSCM). For the first time, using the SDG mapping algorithms, this article focused on 7009 publications from 2013 to 2022 mapped explicitly to 17 SDGs. This study uses bibliometric and science mapping techniques to create a detailed mapping between GSCM research and SDGs. This study created an SDG citation network to show how specific SDGs are related to GSCM practices. The most mapped SDGs in this study are SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 17 (Partnership for the Goals). Our results showed that GSCM research mainly focuses on three thematic areas: industry 4.0 and sustainable supply chains, GSCM practice coordination, and sustainable environmental policy management. This also includes integrating the circular economy into GSCM, sustainable sourcing, supply chain resilience, digital transformation in GSCM for better environmental performance, and the social impact of GSCM. A shift towards integrating sustainability into supply chain processes has been found. Environmental management, performance monitoring, and new technologies like Industry 4.0 and AI have been used to support the SDGs. International interest and collaboration in GSCM research can be seen from the bibliographic coupling study covering countries like Europe, Western Countries, the Middle East, Southeast Asia, and Eastern Europe. This study shows how GSCM can directly address global challenges identified by the United Nations by mapping GSCM research to specific SDGs.

Keywords: green supply chain management; sustainable development goal; sustainable environmental policy management; Industry 4.0; bibliometrics; economic growth

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1. Introduction

In recent years, there has been a growing recognition of sustainable development's essential role in safeguarding our planet's and future generations' well-being [1]. Various initiatives and frameworks have been developed to respond to global society's urgent environmental difficulties in order to direct businesses and organizations towards more sustainable practices [2]. The idea of GSCM, which focuses on incorporating environmental factors into supply chain operations, is one such framework [3].

GSCM refers to implementing environmentally friendly practices throughout the supply chain, from acquiring raw materials to the product's disposal after its useful life [4,5]. Recognizing the possible environmental effects of supply chain operations, GSCM works to reduce them by using sustainable practices [6]. It includes a variety of tactics and initiatives, including "waste minimization", "energy efficiency", "life cycle analysis of products", and the "use of renewable energy and materials". GSCM provides a mechanism for businesses

to lessen their environmental impact and support sustainable development by integrating environmental factors into supply chain decision-making processes [7].

It is impossible to overestimate the importance of GSCM in the context of sustainable development. In other words, GSCM is essential to the advancement of sustainable development. It is a fundamental component that is necessary to attain sustainability goals on a global basis. Businesses may substantially contribute to addressing urgent challenges such as resource depletion, climate change, ethical labor practices, and more by managing their supply chains with sustainability in mind. Thus, to shape a more sustainable and responsible future, it is imperative to acknowledge the critical role that GSCM plays in sustainable development. Due to globalization and rising consumer demand, the global supply chain network has grown tremendously in recent decades [8]. While this increase has produced positive economic effects, it has also put enormous strain on ecosystems and natural resources. The environmental impacts have frequently been overlooked for cost-effectiveness and productivity in traditional supply chain practices [9]. Unsustainable practices have, therefore, proliferated widely, including excessive resource consumption, pollution, and waste production. By advocating a more comprehensive and ecologically responsible approach to supply chain management, GSCM represents a paradigm change [10].

The SDGs, established by the United Nations in 2015 as a worldwide agenda to solve the most urgent social, economic, and environmental concerns confronting humanity [11], align with the concepts of GSCM. The 17 objectives and 169 targets of the SDGs span a wide range of topics, including "ending poverty", "promoting gender equality", "combating climate change", "promoting responsible consumption and production", and "fostering sustainable cities and communities" [12]. The SDGs offer a thorough framework that combines social, economic, and environmental components, highlighting how these factors are interconnected to achieve sustainable development [13]. Organizations can support the group effort to create a more sustainable future by integrating the SDGs into their daily operations.

Supply chains have a significant environmental impact on waste production, resource usage, and carbon emissions. Supply chains with unsustainable practices exacerbate climate change, habitat destruction, air and water pollution, and deforestation. Traditional supply chains frequently ignore these effects in their pursuit of cost savings, which raises moral questions about their sustainability and long-term viability. GSCM has gained significance as a solution to the ethical and environmental concerns that supply chains pose. A paradigm shift, GSCM seeks to balance social and environmental aims with corporate objectives. While preserving economic viability, it aims to decrease resource usage, lower carbon emissions, and encourage ethical sourcing and production. As a result, GSCM becomes apparent as a vital tactic for businesses dedicated to accomplishing the SDGs.

Even though the significance of GSCM and the SDGs is becoming more widely acknowledged, there still needs to be a thorough understanding of how these two disciplines are mapped. Through the use of bibliometric analysis and science mapping, this work aims to fill this research gap. A quantitative approach called bibliometrics uses statistical analysis to look for patterns and trends in scholarly publications [14]. By performing a bibliometric study, this study can find the major issues, future research areas, and knowledge gaps in the literature on mapping the GSCM research to SDGs. In addition, science mapping methods like co-citation and co-word analysis will help us see the connections and links between various research fields [15].

This analysis will highlight the current state of research, along with areas that call for more study. Research on GSCM shows a significant change in sustainability, creativity, and ethical behavior. The present analysis highlights the crucial correlation between supply chain management (SCM) practices and the SDGs of the United Nations. It also emphasizes the noteworthy contribution of SCM to resolving global sustainability issues. To advance sustainability and responsible production and consumption, it is critical to investigate new areas, improve methods, and foster international cooperation as this field of study continues to develop. This analysis provides a solid starting point for scholars, practitioners,

and legislators looking to promote GSCM and its benefits to sustainable development. This study uses scientific mapping methodologies to map the field's intellectual structure. The relationships between various study fields, the historical development of research themes, and prospective future research directions will all be revealed by this mapping exercise. The findings of this study will benefit practitioners and policymakers who seek to advance the mapping of GSCM to SDGs in addition to adding to the scholarly literature. This paper investigates how bibliometric research and a science mapping technique map the GSCM research to SDGs.

In this study, the following research queries are addressed:

RQ1: What are the main thematic clusters based on keyword co-occurrence, and how do they map to SDGs?

RQ2: How has the research focus in GSCM shifted in response to adopting the SDGs in 2015, and what are the emerging trends and topics in the field from 2017 to 2021?

RQ3: How has international cooperation and interest in GSCM research evolved, and which countries have contributed significantly to the field through bibliographic coupling analysis?

RQ4: How are GSCM practices interconnected with specific SDGs, and how do these connections impact businesses' sustainable practices and supply chain management strategies?

The present study aims to deconstruct the research paper's conclusions, elucidating the interaction between GSCM and the SDGs and pinpointing areas that warrant additional investigation. The aim is to understand how businesses may use GSCM to contribute to a more responsible and sustainable future for the world.

The paper is divided into the following sections, each of which focuses on a different component of the research:

Our paper is organized as follows. Section 2 provides an extensive literature review on GSCM, identifying crucial themes and trends and forming a basis for our bibliometric analysis. Section 3 explains the methodology, outlining the scientific mapping approach to analyze influential publications. Section 4 details the results, analyzing thematic clusters, keywords co-occurrence, and the relationship between GSCM and specific Sustainable Development Goals (SDGs). This study explores international collaboration shifts in keywords trends from 2017–2021. Section 5 suggests future research directions, and finally, in Section 6, the study concludes by summarizing key findings, implications, and study limitations.

2. Literature Review

Previously, it appeared that integrating Supply Chain Management (SCM) into corporate operations may help businesses gain a competitive edge [16]. Utilizing GSCM, organizations may more effectively manage environmental challenges and expand their economic potential [17]. Even with the addition of the "green" component, GSCM maintains a comparable approach to its core concept in conventional SCM [18]. From a supply chain viewpoint, the environmental management principles gave rise to GSCM [19,20]. Although GSCM and SCM share a similar focus, GSCM still depends on research goals to determine whether it should only address the procurement stage or the entire logistical channel [21]. GSCM requires a thorough and clear definition because the combination of corporate environmental management and SCM is still a relatively new field of research and practical application [21]. Green et al. [22] created the idea of green GSCM. They coined the phrase "green supply chain" to describe the novel SCM and industrialized purchasing technique considering the environmental context.

Within the green and sustainable Supply Chain Management (SCM) literature, a prior study has concentrated on various topics relating to organizational research and real-world applications. Multiple previously published works recently examined the problems with green SCM using various techniques and strategies. For instance, Fahimnia et al. [23] undertook a detailed bibliometric and network study, shedding light on different GSCM areas that need to be understood and assessed by more reviews. The findings show that a small number of scholars create essential works. The majority of works are conducted in

Europe, followed by North America. The impact of Asia is growing. The most compelling research is conceptual and empirical.

In [24], the authors address a lacuna in scholarship by exploring the nexus between Sustainable Supply Chain Management (SSCM) and the United Nations' Sustainable Development Goals (SDGs). Utilizing a methodical review of 97 publications in conjunction with an examination of sustainability reports from leading Forbes companies, the study identifies areas requiring further inquiry. Specifically, it reveals a tendency among both corporations and existing literature to focus on select SDGs. The current study differentiates itself by employing Elsevier's machine learning algorithms to map a robust dataset of 7009 publications to each of the 17 SDGs, thereby overcoming the limitations of keyword-based searches. The expanded dataset, spanning a decade, enhances the study's reliability and generalizability. Additionally, the use of the Scopus database provides a broader range of journals and conferences for analysis when compared to Web of Sciences, thereby enriching the scholarly context.

Similarly, de Oliveira et al. [25] conducted a thorough literature study and bibliometric analysis of publications published between 2006 and 2016, providing a comprehensive view of GSCM practices. They analyzed the subject's behavior across the previous ten years. The findings indicate that 40% of research concentrated on GSCM advantages and 10% on hurdles. Future studies may explore ways to remove obstacles. Questionnaire-based empirical research was common. Fuzzy logic was applied in mathematical models (36%). Maditati et al. [26] thoroughly analyzed the structural links between the drivers, practice indicators, and performance metrics of the GSCM literature. GSCM research's important journals, organizations, and papers on the rise were determined by bibliometric analysis. Leading journals include "The International Journal of Production Economics", "The International Journal of Production Research", and "The Journal of Cleaner Production". Following citation mapping and content analysis, six research streams were identified: "(1) conceptualization and sensemaking; (2) performance impact of GSCM; (3) incorporation of green and sustainable operations in the supply chain; (4) development of green suppliers; (5) GSCM implementation drivers; and (6) review and future research directions". An extensive conceptual framework was provided based on a content analysis of the 39 publications that received the most significant citations. Gong et al. [27] investigated the research state and evolving GSCM frontiers in a separate study. The totality of existing research on the requirements, methods, and efficiency of GSCM is critically analyzed by Balon [28]. The extensive merger has been reduced to GSCM pressures, which include CSR, investment recovery, government laws and regulations, and the green market. Environmental, operational, and financial factors are all evaluated by GSCM's success. Fahim and Mahadi [29] performed a bibliometric analysis of the data from the previous 20 years in a separate study, revealing new areas in the GSCM sector. Environmental concerns have fueled the rapid development and rising acceptance of GSCM among scholars. Choudhary and Sangwan [30] critically evaluated the literature on GSCM pressure, practice, and performance for manufacturing organizations. Their evaluation is based on bibliometric, network, and frequency analysis findings. According to the study, researchers evaluated GSCM constructs and measures as their focus areas changed. This study also notes the need for case studies with more quantitative data and advises using life cycle analysis to quantify environmental performance. Zhang and Zhao [31] performed a bibliometric analysis of the GSCM in the platform economy literature. Through co-keyword analysis, they identified several popular topics related to GSCM-PE. First, there is much interest in researching how supply chain management might be applied in the context of Internet platforms, along with pertinent management techniques. Second, scientists are interested in examining how supply chain sustainability might be attained by utilizing principles of the "circular economy", "blockchain technology", "Internet of Things (IoT) technology", and other "cutting-edge methods". Third, the platform economy emphasizes technical innovation, information exchange, and related challenges. Bottani and Murino [32] provided a meta-analysis of review papers focusing on GSCM in a distinct study. This work has

focused on different analyses from various papers utilizing bibliographic and bibliometric tools. The synthesis of the review papers on GSCM is shown in Table 1.

Table 1. Synthesis of the review papers on GSCM.

Author	Duration	Tools Used	Journal	SJR	Citations
[23]	1996–2013	BibExcel	International Journal of Production Economics	Q1	1100
[24]	All years-September 2022	Self	Total Quality Management	Q1	38
[25]	2006–2016	CiteSpace	Journal of Cleaner Production	Q1	216
[26]	1997–2016	Graph Maker Tool of the HistCite software (http://www.histcite.com/)	Resources Conservation and Recycling	Q1	158
[27]	1997–2018	CiteSpace	Sustainability	Q1	62
[28]	1999–2019	Excel	Business Strategy and Development	Q1	26
[29]	2001–2021	VOSviewer	Environmental Science and Pollution Research	Q1	14
[30]	2004–2018	VOSviewer	Benchmarking: An International Journal	Q1	13
[31]	2003–2020	R and VOSviewer	International Journal of Logistics Research and Applications	Q1	12
[32]	2006–2021	Microsoft Excel	IFIP Advances in Information and Communication Technology	Q3	2

There appears to be little in-depth research focusing specifically on mapping within the context of the SDGs, despite previous review papers exploring the concept of GSCM and its relationship with various aspects of sustainable development. No study in the review has primarily looked at the mapping of GSCM to SDGs using advanced bibliometric and scientific mapping methodologies, despite some studies delving into bibliometric analysis and science mapping of GSCM research.

A complete methodology, including bibliometric analysis and science mapping of the GSCM literature, becomes necessary in order to assess the existing research environment regarding mapping GSCM to SDGs. This knowledge gap must be filled to effectively map GSCM initiatives with the SDGs' global sustainability agenda. By doing so, academics and policymakers will better understand the body of knowledge now available and will be able to suggest viable directions for future study.

3. Methodology

This study uses a bibliometric and science mapping approach to evaluate how the literature on GSCM and SDGs is integrated. The analysis covers 8305 articles from various sources and focuses on documents released between 2013 and 2022. The SciVal database, which offers access to a sizable collection of scholarly literature, including articles, conference papers, and other Scopus academic publications, serves as this study's primary data source. Using precise search terms linked to GSCM and sustainable development objectives, pertinent documents could be located in the SciVal database. By incorporating the Elsevier 2021 SDG mappings into SciVal, researchers and institutions may use pre-established Research Areas to track and highlight progress toward meeting SDG targets [33,34]. To include the most recent and pertinent papers, inclusion criteria included those published throughout the selected period (2013–2022). Duplicate records and unrelated materials

were weeded out, leaving only documents directly relevant to the topic of the study. To pinpoint essential patterns, trends, and characteristics in the literature on GSCM, a quantitative analysis of the recovered documents was conducted as part of the bibliometric study. Several bibliometric measures were examined to obtain insight into the general landscape of GSCM research.

A widespread tool for analyzing and visualizing bibliometric networks is VOSviewer. The software creates theme clusters and visualizes the connections between diverse research fields. Bibliometric and science mapping studies are carried out using the methods suggested by Achuthan et al. [35] and Sreenivasan et al. [12] to delve deeper into the topic. The process of conducting research ends with the creation of recommendations for additional research. Numerous disciplines, including "marketing", "management", "services", and "innovation", have made extensive use of bibliometric analysis [36–38]. This approach is valuable for monitoring current research trends and identifying emerging study topics [30,39–41]. This approach's forward-looking nature makes it ideal for identifying new patterns in a particular area [42,43]. The current study used network analysis to pinpoint key research areas, monitor developments, and investigate new areas of inquiry. Country and journal bibliographies were used as part of the research approach to assess how comparable the cited publications were [23]. This study also looked into social network analysis. The actors and the relationships in a given setting are the two main themes of social network analysis, which aims to comprehend networks and their participants [44,45]. The visualizing application VOSviewer, widely used for science mapping purposes, was employed [46–50].

Ours is the first study of its kind, and it examines how GSCM impacts each SDG. While earlier studies have established a link between GSCM and sustainability, this study goes one step further by offering a thorough analysis that links specific articles to each of the 17 different SDGs. Recent studies have looked at the explicit publication mapping from various thematic areas to SDGs, including interpretive structural modeling [12], green hydrogen [39], women entrepreneurs [40], and cyberbullying [35].

Currently, several initiatives link research papers to the SDGs:

1. The SDG-questions effort from the Aurora-Network-Global [51] provides thorough questions for sustainable development research.
2. Through an examination of topic landscapes, patterns of collaboration, and funding sources, Digital Science's SDG mapping program enables a profound understanding of sustainable development research.
3. The University of Auckland's SDG Mapping program visualizes the connection between research results and the SDGs [52].
4. The mapping and monitoring of global progress on sustainable development is a committed objective of the STRINGS effort [53].
5. Elsevier's SDG Mapping Initiative extensively maps publications to each of the 17 SDGs [54].

Because it effortlessly connects with the SciVal database and offers pre-set search queries for each SDG, this study employed the Digital Science SDG initiative for the research [55,56]. Experts and academics have thoroughly reviewed and improved this program, and it is progressively using a machine-learning approach to increase accuracy.

The methodology follows the SPAR-4-SLR protocol established by Paul et al. [57]. The stages of the protocol are illustrated in Figure 1.

Assembling

The first step in the process involves collecting publications for analysis, known as assembling. In this study, the SciVal database was utilized in July 2023 to search for publications that included GSCM and its associated terms. Relevant keywords, titles, and abstracts were used as part of the search parameters. Researchers retrieved 8305 publications from 2013–2022. Of these, 7009 are mapped to SDGs.

Arranging

The next step, arranging, involves organizing and refining the articles through inclusion and exclusion criteria. Several pieces of information, such as the journal title, author name, publication title, country of affiliation, total publications (TP), and total citations (TC), were used as codes to categorize the search data of publications. These codes facilitated the organization and examination of the data in a more structured and systematic manner. The filtering process did not exclude any journals.

Assessing

The last step is the study's assessment phase, which involves reporting and evaluation. The evaluation portion of the article gives a general description of the analysis technique utilized and analyses the study's shortcomings. VOSviewer (version 1.6.18) was the most often used software for evaluation and trend analysis. Since no human subjects or sensitive information was used, no ethics approval was necessary because the review relied on secondary data made publicly accessible through SciVal.

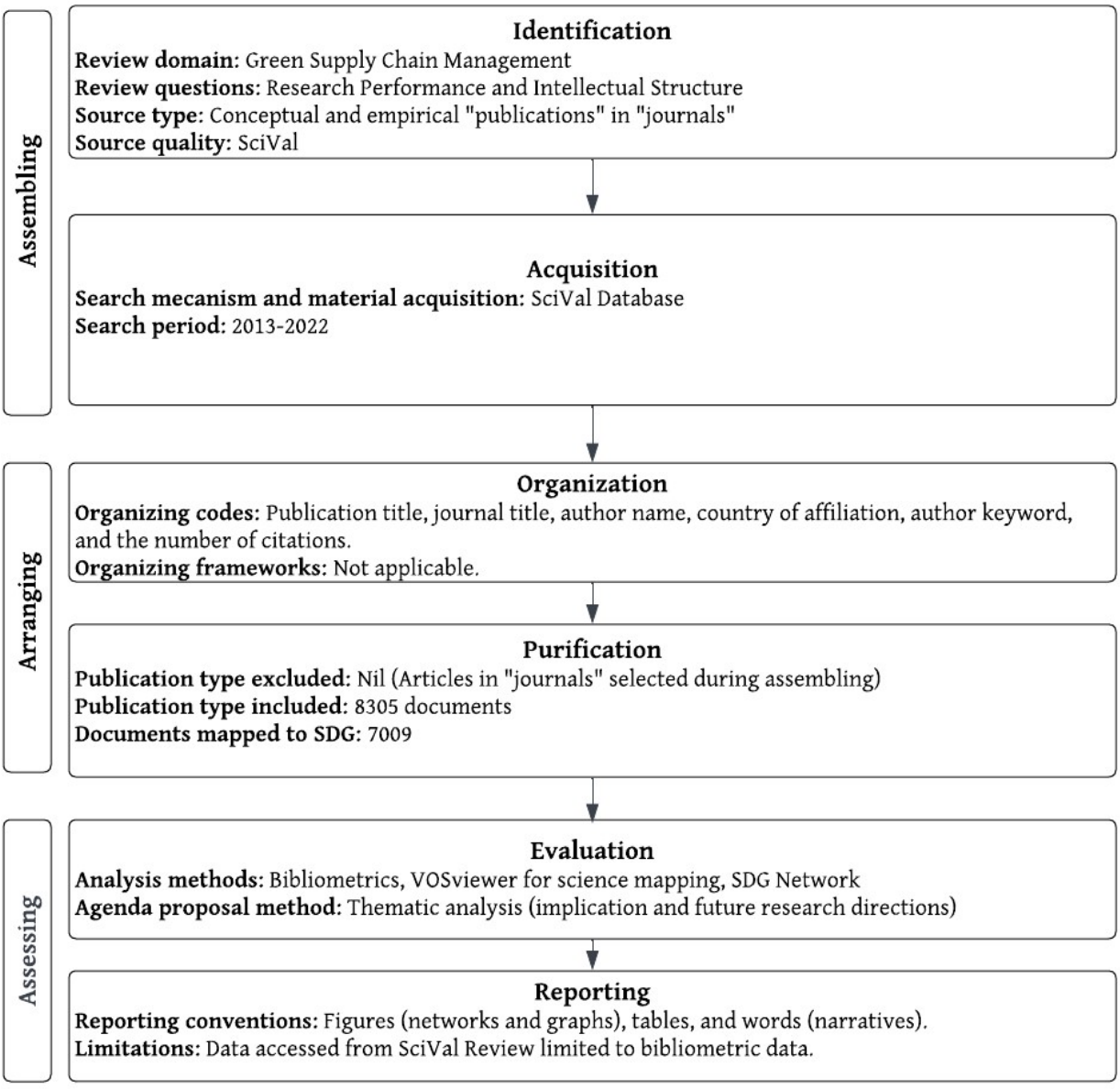


Figure 1. SPAR-4-SLR [57].

4. Results and Discussion

4.1. Thematic Clusters and Their SDG Mappings Based on Keywords

The findings in this section specifically address RQ1: What are the main thematic clusters in GSCM research, and how do they relate to SDGs?

The thematic cluster findings showed that existing GSCM studies concentrate on three clusters. To address the problems caused by climate change and resource depletion, researchers have studied various "sustainable environmental policy management topics", "Industry 4.0", and "green supply chain coordination". The co-occurrence network cluster is shown in Figure 2.

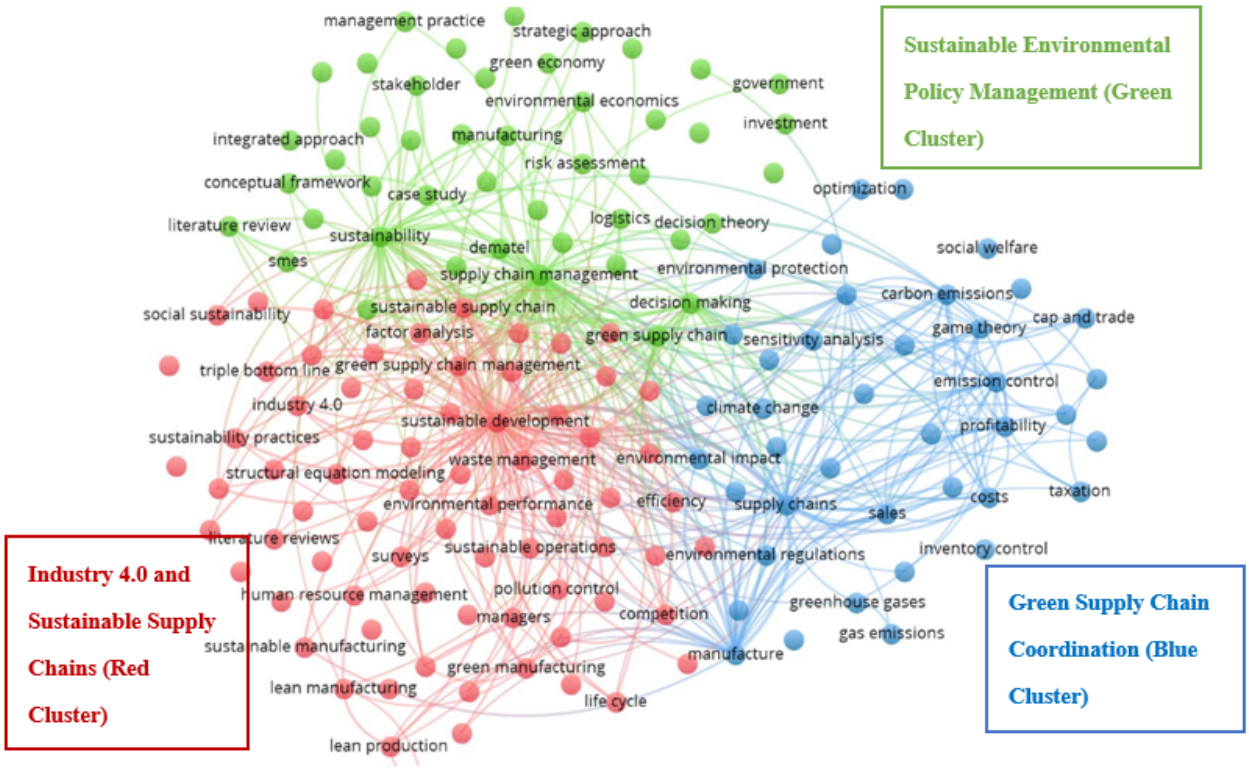


Figure 2. Thematic clusters and their SDG mappings based on keywords.

Table 2 shows the co-occurrence network cluster theme and top ten keywords.

Cluster 1-Sustainable Environmental Policy Management:

Managing sustainable environmental policies in supply networks is this research cluster's key area of interest. The evaluation and improvement of supply networks' economic and environmental performance is the main objective of the studies in this cluster. Companies are strongly encouraged to adopt green designs, apply green purchasing practices, and incorporate GSCM principles into their operations by external forces, including legislative responsibilities and stakeholder expectations.

Cluster 2-Industry 4.0 and Sustainable Supply Chains:

This study explores the meeting point between Industry 4.0 and sustainable supply networks. It examines how digitalization and cutting-edge technologies affect supply chain operations, emphasizing manufacturing and industrial facilities. The main issues within this cluster are the environmental sustainability of supply chains and the production of sustainable value. The study also investigates how Industry 4.0 may support and facilitate green supply chain practices while enabling sustainable production in diverse industries and nations. By looking at these issues, the cluster intends to shed light on the possible advantages and opportunities that result from incorporating Industry 4.0 ideas into sustainable supply chain management. Industry 4.0 and artificial intelligence (AI)

propel a significant change in global supply chain management. They improve productivity, visibility, sustainability, and flexibility, but also highlight new workforce development and cybersecurity difficulties. By implementing these technologies, businesses can improve their supply chains' responsiveness, agility, and sustainability, giving them a competitive advantage in the current global marketplace. Large volumes of data from many sources, such as sensors, Internet of Things devices, and historical data, can be processed by AI. This skill makes improved inventory optimization, risk management, and demand forecasting possible. Automation and robots are two examples of Industry 4.0 technologies for material handling, packaging, and quality control duties. Throughout the supply chain, blockchain technology provides safe, open, and verifiable record-keeping. This guarantees that all participants may trust the data and that it is unchangeable. The workforce needed to operate and maintain innovative technologies in GSCM is a prerequisite for their acceptance. Employee upskilling and training are essential to ensure the technology is used efficiently.

Table 2. Co-occurrence network cluster details.

Cluster Theme	Top Ten Keywords	SDG Mappings
Sustainable Environmental Policy Management (Cluster 1-Green)	Economic performance Environmental performance External pressures Green designs Green purchasing Green supply chain management Environmental management Total quality management Cause-and-effect relationships Supply chain management	
Industry 4.0 and Sustainable Supply Chains (Cluster 2- Red)	Industrial plants Industry 4.0 Consumer Goods Industrialized countries Manufacturing equipment Sustainable manufacturing Value creation Environmental sustainability Green supply chain Sustainable supply chains	
Green Supply Chain Coordination (Cluster 3- Blue)	Carbon emissions Carbon reduction Efficient technology Environmental policy Inventory management Operational decisions Supply chain collaboration Climate control Sustainable development Product redesign	

Cluster 3-Green supply chain management coordination

The third research area focuses on the cooperation and coordination needed to accomplish the goals of a green supply chain. In order to cut carbon emissions and advance sustainable development, it highlights the need for operational and technological efficiency. Investigations in this cluster focus on how supply chain collaboration can be used to create efficient climate control plans and achieve carbon reduction goals. This cluster also looks at methods for inventory control and product redesign that can improve environmental per-

formance. The research attempts to explore strategies to enhance the overall environmental sustainability of supply chains through efficient coordination, technological development, and creative practices by addressing these factors.

Cluster 1-Sustainable Environmental Policy Management:

The articles in this cluster examine the connection between leadership, operational practices, and environmental performance and offer frameworks for efficient green supply chain practices. A proactive approach to enhancing environmental performance inside organizations is known as GSCM. Companies are pressured to improve their GSCM practices due to mounting stakeholder and regulatory pressures. Green purchasing, green design, product recovery programs, and encouraging cooperation with customers and suppliers are some variables that influence these practices. Fuzzy DEMATEL is used by Lin [58] in a groundbreaking study on GSCM techniques that provides insightful information. According to Lin [58], GSCM is a proactive strategy that businesses use to enhance their environmental performance. Environmental regulations and growing stakeholder demand make this strategy more critical. Businesses increasingly realize the importance of including eco-friendly practices in their supply chains. This article maps to SDG 9 (Industry, Innovation) and SDG 12 (Responsible Consumption). In addition to fostering innovation within industries and their infrastructure (SDG 9) and actively promoting responsible consumption, production, and resource efficiency throughout the supply chain (SDG 12), the article uses fuzzy DEMATEL to assess GSCM practices. The paper significantly advances the cause of sustainable development and environmental stewardship by addressing these essential SDGs.

The relationship between environmental taxes, the adoption of green technologies, and sustainable development is examined by Krass et al. [59]. Their study makes an important discovery about how tax rises affect businesses. It implies that a company's reaction to an initial tax hike might not be predictable. A temporary tax rise might encourage the company to use greener technologies in some circumstances. Their study argues that one method to mitigate the non-monotone tax effect and increase the parameters over which enterprises choose green technology is to supplement environmental taxation with fixed-cost subsidies and consumer refunds. These policy tools can accomplish economic and environmental goals concurrently, as they frequently move social welfare closer to the centralized solution. This article maps to SDG 1 (No Poverty), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work), and SDG 17 (Partnerships). Environmental taxes and the adoption of green technologies can significantly alleviate poverty by encouraging sustainable economic growth and the creation of green jobs, which can result in improved livelihoods and income prospects for marginalized people (SDG 1). The article's emphasis on environmentally friendly technology supports SDG 7 because it seeks to encourage the use of cleaner and more sustainable energy sources. Environmental taxes can promote the switch to renewable energy sources and energy-saving technologies, helping to ensure that everyone has access to inexpensive, clean energy (SDG 7). Examining the connection between environmental taxes and adopting green technologies has consequences for fair employment and economic development.

Green technology can help sustainable economic growth by generating new employment possibilities in renewable energy and other green industries (SDG 8). Governments, industries, and other stakeholders must work together to address environmental issues and encourage the use of green technology. Sustainable development initiatives and partnerships for achieving the SDGs can be funded through environmental levies (SDG 17). Dubey et al. [60] explore how institutional forces, operational practices, and leadership styles affect environmental performance in the GSCM framework. This article maps to SDG 9 (Industry, Innovation) and SDG 12 (Responsible Consumption). An empirical study on the connections between supplier relationship management, total quality management, leadership, institutional pressures, and environmental performance was carried out by Dubey et al. [60]. Understanding these dynamics is aided by the study's methodology, data analysis, and conclusions, especially regarding green supply chain networks. It supports

current ideas and literature by highlighting institutional forces and leadership's role in influencing environmental performance inside enterprises. The article does support SDG 9: "Industry, Innovation, and Infrastructure". The research supports broader global efforts to develop resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation that benefits society and the environment by fostering sustainable industrialization and innovation within GSCM. SDG 9 aspires to promote infrastructural development and technical breakthroughs that support sustainable practices and economic growth while enhancing the sustainability and efficiency of the industry. Additionally, it promotes responsible consumption and production by adopting ecologically friendly operational practices throughout the supply chain, which supports SDG 12. These efforts collectively represent significant advances toward realizing the more general objectives of sustainable development and environmental preservation.

Cluster 2-Industry 4.0 and Sustainable Supply Chains:

In the framework of Industry 4.0, Stock and Seliger [61] undertake a groundbreaking study on sustainable manufacturing. Stock and Seliger [61] discuss how globalization has made sustainability more important than ever and how Industry 4.0 offers a chance to develop sustainable manufacturing techniques. The article reviews Industry 4.0 and uses real-world examples like retrofitting to show how integrating data-driven methods and cutting-edge technologies might lead to more environmentally friendly industrial practices. This subject is especially pertinent in solving social and environmental issues while satisfying demands on the world economy. This article maps to SDG 9 (Industry, Innovation) and SDG 12 (Responsible Consumption). The paper examines the use of Industry 4.0 techniques and technology to advance environmentally friendly production. Sustainable manufacturing contributes to sustainable industrialization using environmentally friendly procedures and resource-saving production techniques. Industry 4.0, which incorporates cutting-edge technology, symbolizes a paradigm leap in production. The article emphasizes the possibilities for applying sustainable practices provided by these technologies, which aligns to encourage innovation for sustainable development (SDG 9). Increasing the efficiency of production processes can result in more sustainable manufacturing in Industry 4.0. The article improves resource efficiency by using cutting-edge technologies to expedite manufacturing and reduce resource usage (SDG 12). GSCM is the focus of a thorough review and bibliometric analysis by Fahimnia et al. [23] that emphasizes its importance for sustainable development. Fahimnia et al. [23] use network analysis and bibliometric approaches to provide a distinctive and perceptive evaluation of green supply chain management. This method thoroughly explains the field's history, necessary fields of study, and significant figures. The study's conclusions guide further investigation, supporting continuous efforts to improve the sustainability of supply chain management techniques. This article maps to SDG 9 and SDG 12. SDG 9 aspires to advance inclusive and sustainable industrialization, boost innovation, and create resilient infrastructure. The GSCM article is pertinent to this objective since it emphasizes sustainable business practices, particularly in supply networks.

Industries can lessen their adverse effects on the environment, encourage resource efficiency, and support sustainable growth by implementing green practices. The SDG 12 objective is related to the GSCM article, which examines methods and strategies for promoting ethical consumption and production. A comparative literature review is provided by Ahi and Searcy [62] to define the terms "green" and "sustainable" supply chain management. Ahi and Searcy's [62] methodical analysis and comparison of the current definitions of GSCM and SSCM is a valuable contribution to supply chain management and sustainability. They clarify the meanings and applications of these words and offer a revised definition for SSCM to remedy the dearth of thorough explanations in the literature. This study is an invaluable resource for academics and industry professionals who wish to learn more about and utilize the concepts of sustainability in supply chain management. This article maps to SDG 9 and SDG 12. The SDG 9 goal is addressed in the article on comparative literature analysis of green and sustainable supply chain management def-

initions. It deals with understanding and enhancing industry practices, particularly in supply chains, to make them more environmentally friendly and sustainable. SDG 12's objective aligns with the article on a comparative literature study of green and sustainable supply chain management definitions, which examines various viewpoints and methods for achieving ethical production and consumption in supply chains.

Cluster 3-Green supply chain management coordination

The cluster also looks at techniques for product redesign and inventory management to improve environmental performance. Using straightforward models, Benjaafar et al. [63] study the idea of carbon footprint in supply chains and offer insights. They offer helpful guidance on how businesses might consider carbon emissions when making supply chain management choices. They stress that supply chain cooperation and operational changes can be successful tactics for lowering carbon emissions without resulting in appreciable extra expenses. The study also shows how various legal frameworks affect supply chain management choices and incentives for cooperation, making it pertinent to companies trying to compromise between sustainable objectives and bottom-line concerns. This article maps to SDG 12 (Responsible Consumption) and SDG 13 (Climate Action). As it covers the environmental impact of supply chain activities, notably concerning carbon emissions, the article on carbon footprint and the management of supply chains aligns with this objective. The article undoubtedly highlights the value of responsible consumerism by pushing companies to evaluate and lessen their environmental impact throughout the manufacture and distribution of goods and services by looking at the carbon footprint of supply chains (SDG 12). SDG 13 focuses on taking swift action to mitigate the effects of climate change. The article on supply chain management and carbon footprint analysis aligns with this objective because it discusses the contribution of supply chains to carbon emissions and the possibilities for reducing climate change through supply chain management techniques.

Focusing on quantitative models used in sustainable supply chain management, Brandenburg et al. [64] explore numerous analytical and mathematical models supporting green supply chain practices decision-making. The growing significance of sustainability in supply chain management is emphasized their article through the examination of the use of formal models and operations research techniques to solve sustainability issues in the forward supply chain. The report emphasizes how research is concentrated in particular publications, how popular analytical methodologies are, and how frequently tools like "Analytical Hierarchy Process", "Analytical Network Process", and "Life Cycle Analysis" are used. It implies that there is room for more development and diversity in the discipline of the approaches and elements considered during formal modeling endeavors. This article maps to SDG 9 (Industry, Innovation), SDG 12 (Responsible Consumption), and SDG 17 (Partnerships). Investigating cutting-edge methods for enhancing supply chain sustainability supports SDG 9. Promoting sustainable production, waste reduction, and responsible sourcing practices across supply chains addresses SDG 12. The article also contributes to SDG 17 by highlighting the value of stakeholder cooperation and knowledge exchange in achieving sustainable supply chain goals. Overall, it provides insightful information about promoting sustainability in supply chains and coordinating them with international development objectives.

Ghosh and Shah [65] discuss the role of customer demand in sustainable supply chains. They investigate the impact of consumer demand for environmentally friendly items on supply chain dynamics. The difficulties and problems with coordination that can arise in green supply chain projects are also discussed. Using a game theory framework, they investigate the potential effects of cost-sharing contracts on critical supply chain choices. Their work advances the field of environmentally friendly supply chains and highlights how important it is for supply chain participants to work together while pursuing sustainability goals. It maps to SDG 9 (Industry, Innovation), SDG 12 (Responsible Consumption), and SDG 13 (Climate Action). Investigating supply chain analyses and creative strategies in the context of environmentally conscious customer demand supports SDG 9. By looking at how supply chains may adapt to consumer demand for more ecologically friendly products, SDG

12 is addressed. The article supports SDG 13 by examining the effects of environmentally conscious customer demand on the carbon footprint and supply chain impact. The paper advances global objectives for business, responsible consumption, and climate action by offering insights into sustainable supply chain management and environmentally friendly practices. Table 3 shows the top nine papers under each cluster theme.

4.2. Temporal Evolution of Keywords

The findings in this section specifically address RQ2.

The mapping overlay approach was utilized to understand the progression in expanding the journals of the category in front of the knowledge domains [66]. This visualization helps answer RQ2 VOSviewer's overlay visualization analysis [46] and can identify fading and new themes. Using cutting-edge analysis techniques, this study shows how the interests of academics studying emerging organizations have changed since 1991 [67,68]. The graphic representation uses the colors green and yellow to reflect current study themes in the field of GSCM and dark blue to show areas of interest from the past. The color bar shows that before 2008 and after 2014, blue and red keywords were primarily used, indicating a shift in the study focus. After the SDGs were adopted in 2015, the overlay visualization findings of co-occurring terms are shown in Figures 3–6.

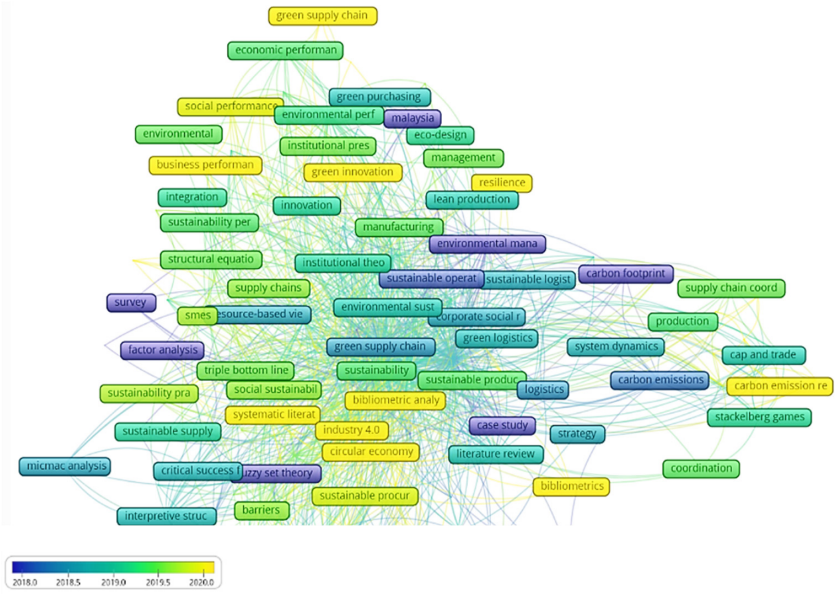
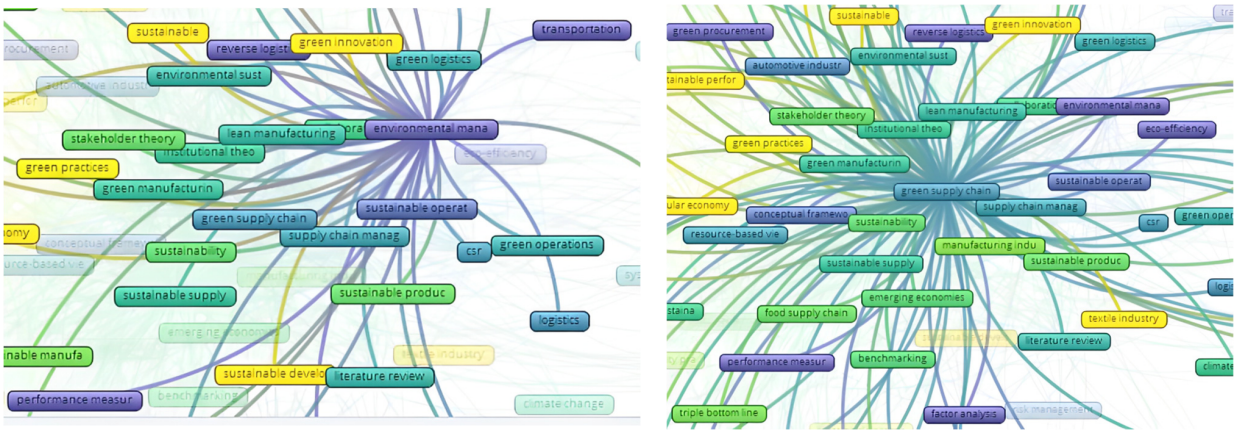


Figure 3. The overlay visualization results of co-occurred keywords after SDG adoption in late 2015.



(**a**) (**b**)

Figure 4. (**a**) Co-occurred keywords for the year 2017. (**b**) Co-occurred keywords for the year 2018.

Table 3. Top articles under each cluster theme and their mapping to SDGs.

Cluster	Authors	Paper Title	Year	Citations (TC)	TC/Year	SDG Mappings
Cluster 1 (Green)	[58]	"Using fuzzy DEMATEL to evaluate the green supply chain management practices".	2013	493	54.78	
	[59]	"Environmental taxes and the choice of green technology"	2013	483	53.67	
	[60]	"Exploring the relationship between leadership, operational practices, institutional pressures, and environmental performance: A framework for the green supply chain".	2015	481	68.71	
Cluster 2 (Red)	[61]	"Opportunities of Sustainable Manufacturing in Industry 4.0"	2016	1130	188.33	
	[23]	"Green supply chain management: A review and bibliometric analysis"	2015	1033	147.57	
	[62]	"A comparative literature analysis of green and sustainable supply chain management definitions".	2013	902	100.22	
Cluster 3 (Blue)	[63]	"Carbon footprint and the management of supply chains: Insights from simple models".	2012	900	90	
	[64]	"Quantitative models for sustainable supply chain management: Developments and directions".	2014	860	107.5	
	[65]	"Supply chain analysis under green sensitive consumer demand and cost-sharing contract"	2015	542	77.43	

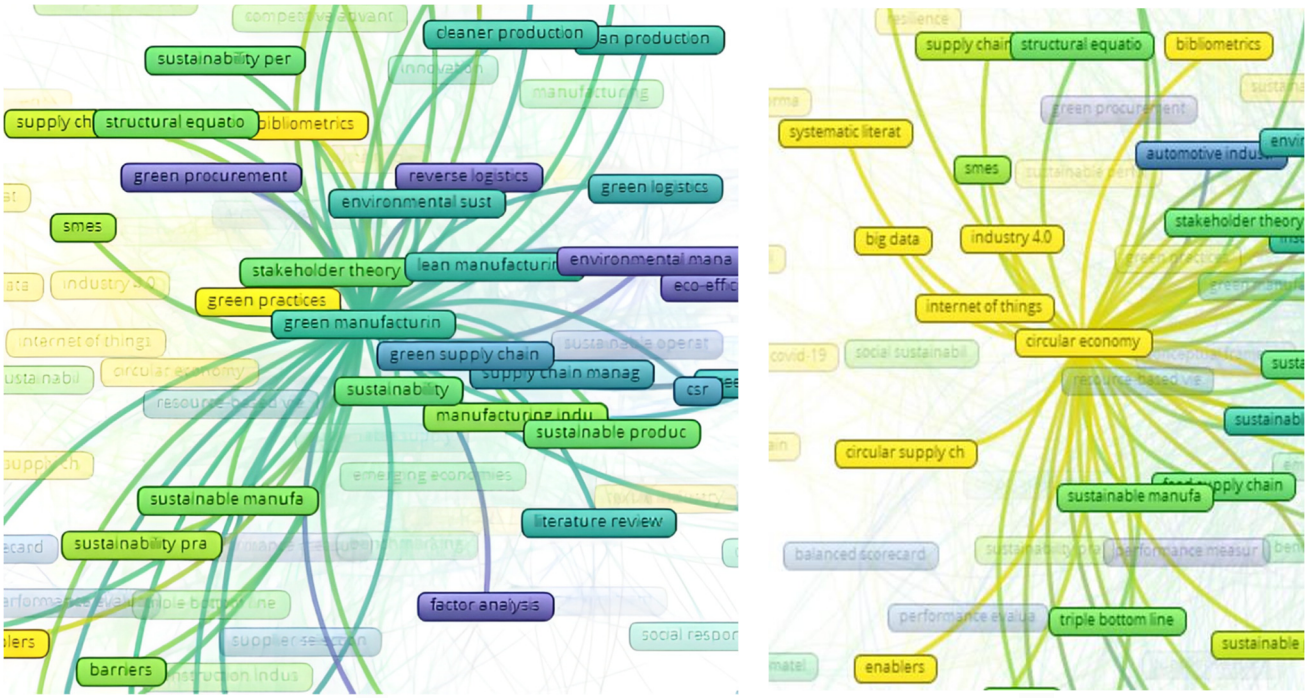


Figure 5. (**a**) Co-occurred keywords for the year 2019. (**b**) Co-occurred keywords for the year 2020.

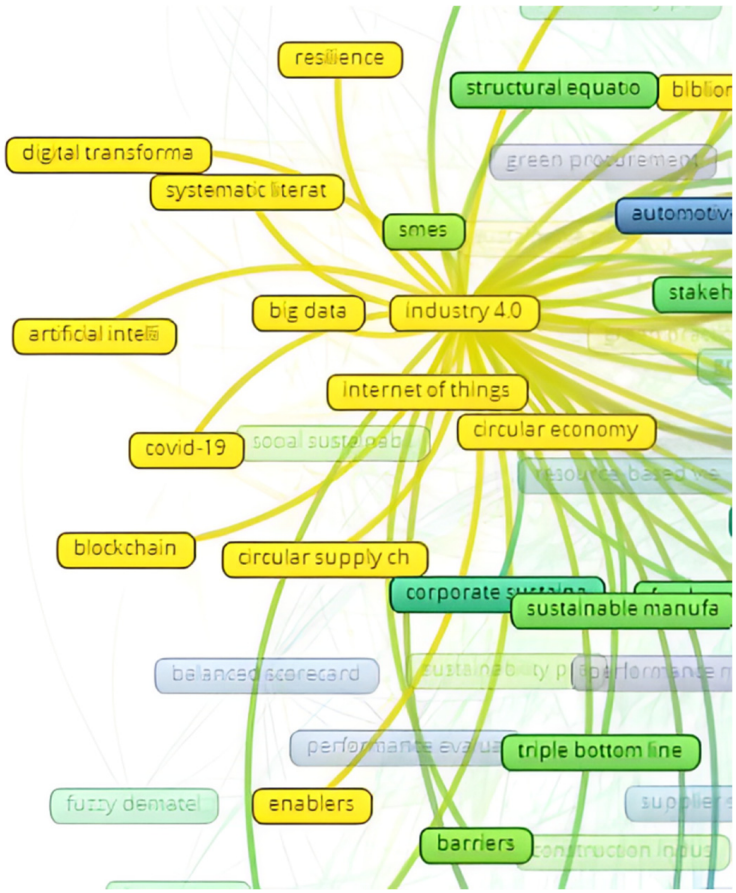


Figure 6. Co-occurred keywords for the year 2021.

In Figure 3, the overlay visualization shows the growth of the top keywords in GSCM from 2017 to 2021. The visualization is based on keyword co-occurrence, which shows how frequently different keywords occur together in the same papers in order to show how they are related.

The temporal evolution of co-occurring keywords for 2017 is shown in Figure 4a, and for 2018 is shown in Figure 4b.

After the SDGs were adopted in late 2015, initial research in 2017 mainly concentrated on essential elements like environmental management, performance evaluation, and reverse logistics. There is an increasing focus on sustainable practices and effective operations, as seen by the themes of carbon footprint, factor analysis, eco-efficiency, transportation, and multi-objective optimization (Figure 4a).

2018 saw an increase in the emphasis on "green supply chain" and "sustainable supply chain", indicating a paradigm shift towards integrating environmental issues into the entire supply chain process; "lean manufacturing" was also widely used, indicating a growing focus on resource optimization and waste reduction. Along with the investigation of "Interpretive Structural Modelling" and "Analytic Hierarchy Process" for decision-making in GSCM, Corporate Social Responsibility (CSR) attracted attention as a critical component of sustainable practices (Figure 4b).

The temporal evolution of co-occurring keywords for 2019 is shown in Figure 5a, and for 2020, it is shown in Figure 5b.

As crucial pillars of GSCM, "green manufacturing" and "sustainability" were the focus of research topics in 2019. "Environmental performance" and "sustainable manufacturing" were intimately related to these ideas, emphasizing the dedication to environmental responsibility. The phrase "triple bottom line" became an essential framework, denoting a greater acceptance of social and economic issues in addition to environmental ones. To monitor and evaluate sustainability performance, techniques including "DEMATEL" and "MCDM" were applied, reflecting a developing body of GSCM research (Figure 5a).

Moving forward, 2020 saw the emergence of the "circular economy" as a vital issue, highlighting the significance of closing the loop and fostering resource efficiency throughout supply chains. The emphasis on "green innovation" and "sustainable performance" shows increased interest in evaluating unique sustainable practices. The "circular supply chain" gained popularity and aligns with the circular economy idea. The convergence of "big data" and the "Internet of Things" (IoT) also demonstrated the expanding significance of digital technology in promoting sustainable practices. The concept of a "low-carbon supply chain" became notable, showing the industry's dedication to lowering carbon emissions (Figure 5b).

The temporal evolution of co-occurring keywords for the year 2021 is shown in Figure 6.

In 2021, GSCM research shifted toward adopting cutting-edge technology and tackling global concerns. As a result of the industry's push to implement advanced solutions for sustainable supply chain practices, terms like "Industry 4.0" and "digital transformation" have gained popularity. The COVID-19 pandemic, a significant global disruption, highlighted the need for resilient and adaptable supply chains and became a key study topic. The SDGs have retained significance, showing a continued commitment to supply chain practices aligning with sustainability goals. The terms "blockchain" and "artificial intelligence" were also hot topics since they may provide answers for boosting GSCM efficiency, transparency, and traceability.

The sector has advanced substantially by fusing environmental management, performance monitoring, and cutting-edge technologies like Industry 4.0 and artificial intelligence while supporting the SDGs. These developments highlight the sector's unwavering commitment to sustainability and the implementation of advanced techniques to build a more robust and sustainable supply chain ecosystem.

4.3. Bibliographic Coupling of Countries

The findings in this section explicitly address RQ3.

The GSCM articles' past context of bibliographic connection shows that the area has received increased interest and international cooperation over time, and this answers RQ3. International cooperation is a critical factor in developing global supply chain management. It facilitates information sharing, encourages creativity, advances international standards, and tackles environmental issues worldwide. International cooperation in GSCM will become more crucial as supply chains become globalized and integrated, improving supply networks' resilience, effectiveness, and sustainability worldwide. The details of the bibliographic coupling and temporal evolution are shown in Figure 7.

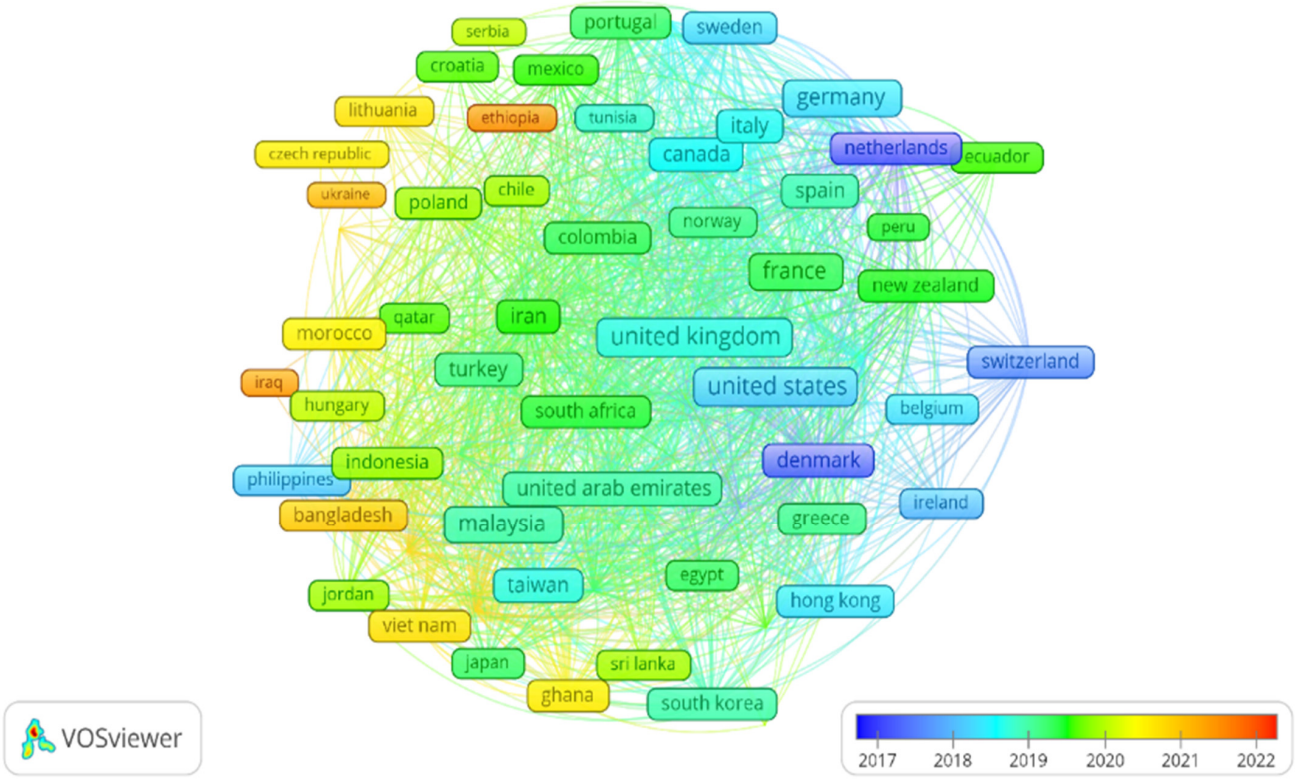


Figure 7. Bibliographic Coupling of countries and temporal evolution.

The trajectory of GSCM research over the last five years does point to significant advancements toward the SDG 2030 targets set by the UN. Research has expanded its geographic scope and developed and developing countries have been participating more and more. This participation and involvement reflect the accomplishment of the SDGs and the worldwide commitment to sustainability.

The bibliographic coupling of countries for the year 2017 is shown in Figure 8.

In 2017, the GSCM research landscape was primarily dominated by European nations, such as Denmark, the Netherlands, and Switzerland, followed closely by Singapore. This period signifies the initiation of sustainable practices within the supply chain management domain, primarily by developed nations.

The bibliographic coupling of countries for the year 2018 is shown in Figure 9.

The subsequent year, 2018, saw a considerable expansion of research to Western countries, namely the United Kingdom, United States, Germany, Italy, and Australia. This represents a growing awareness and commitment towards sustainability within these developed nations, significantly contributing to the global discourse on GSCM.

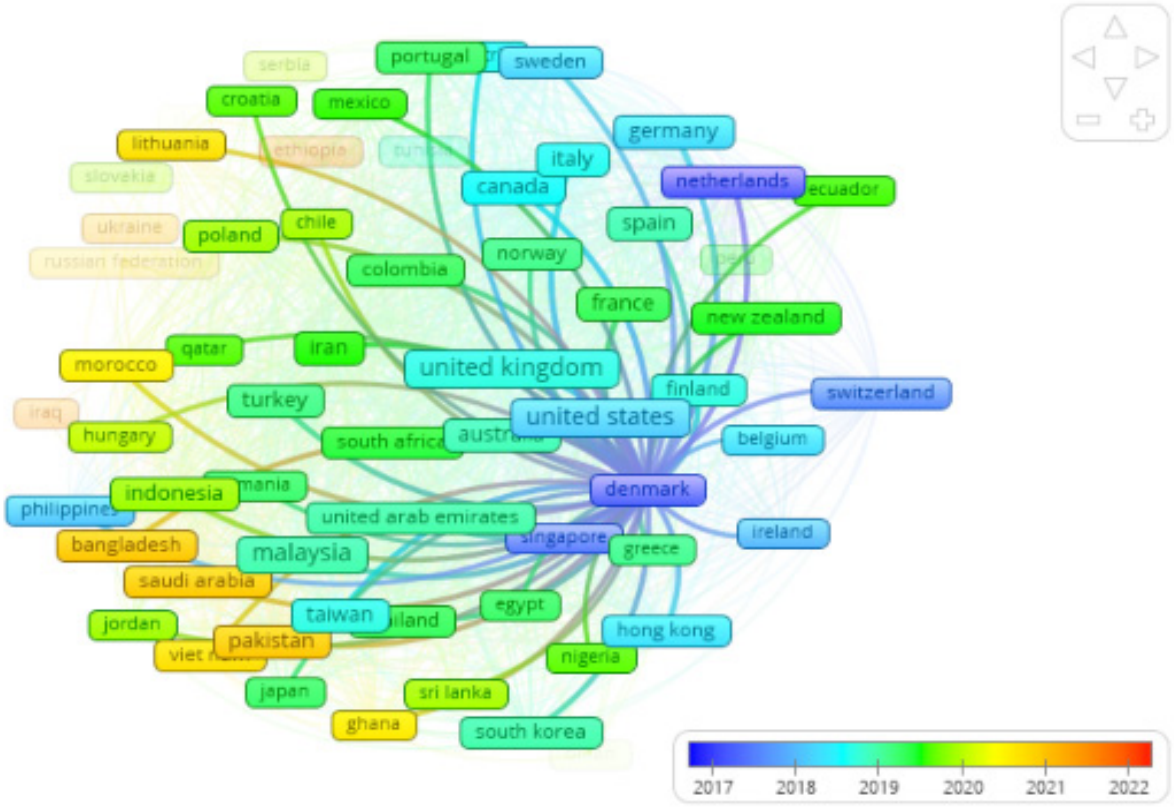


Figure 8. Bibliographic coupling of countries for year 2017.

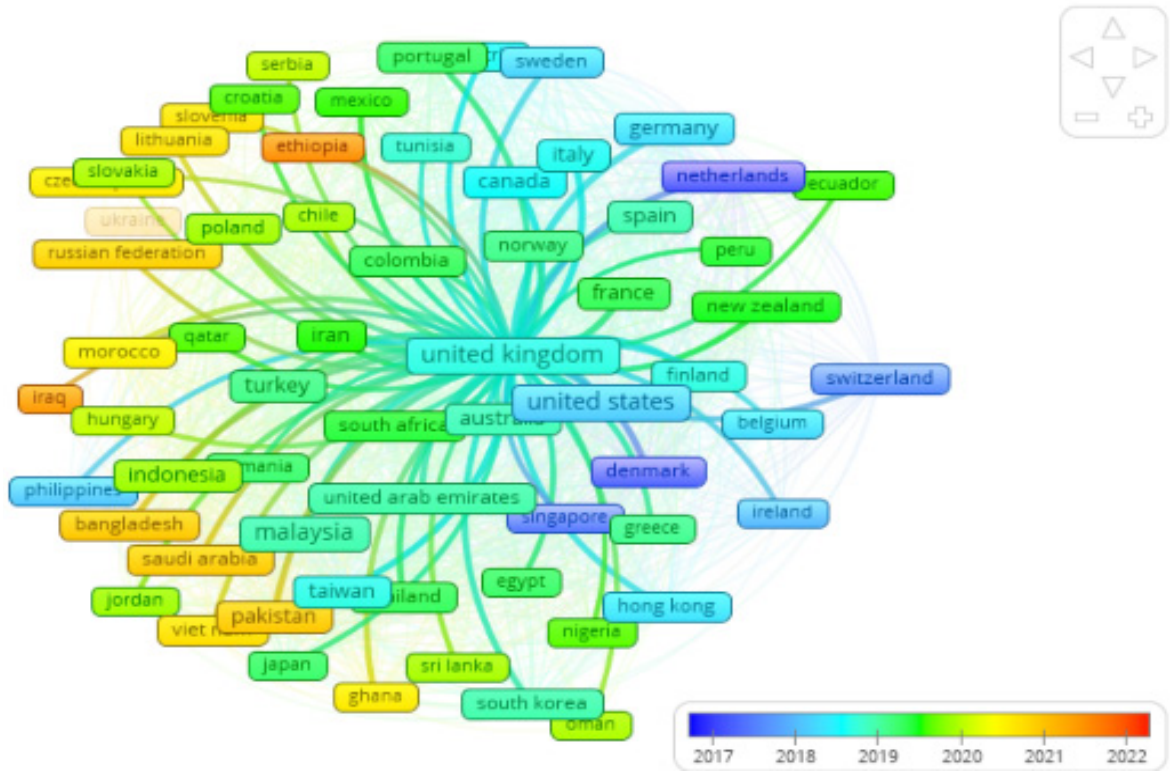


Figure 9. Bibliographic coupling of countries for the year 2018.

The bibliographic coupling of countries for the year 2019 is shown in Figure 10.

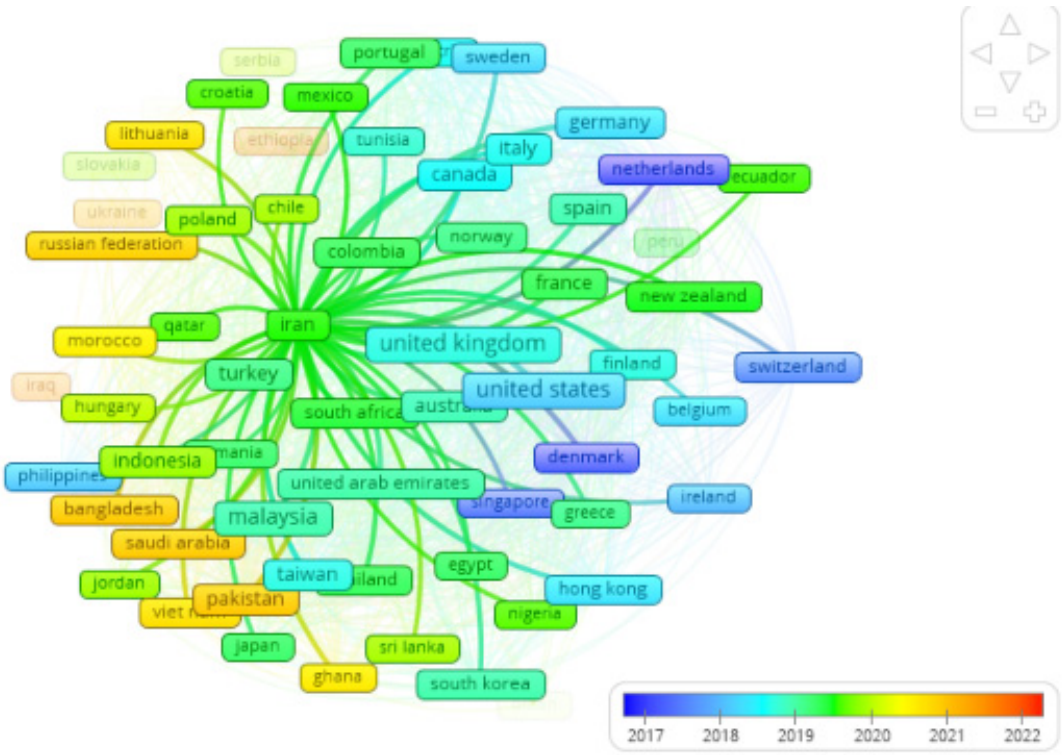


Figure 10. Bibliographic coupling of countries for the year 2019.

By 2019, GSCM research had extended its reach to the Middle East and Southeast Asia, with active contributions from countries like Indonesia, Iran, Turkey, the United Arab Emirates, and Thailand. This expansion indicates a shift in attention towards developing countries, demonstrating their engagement in sustainability practices and pursuit of SDGs.

The bibliographic coupling of countries for the year 2020 is shown in Figure 11.

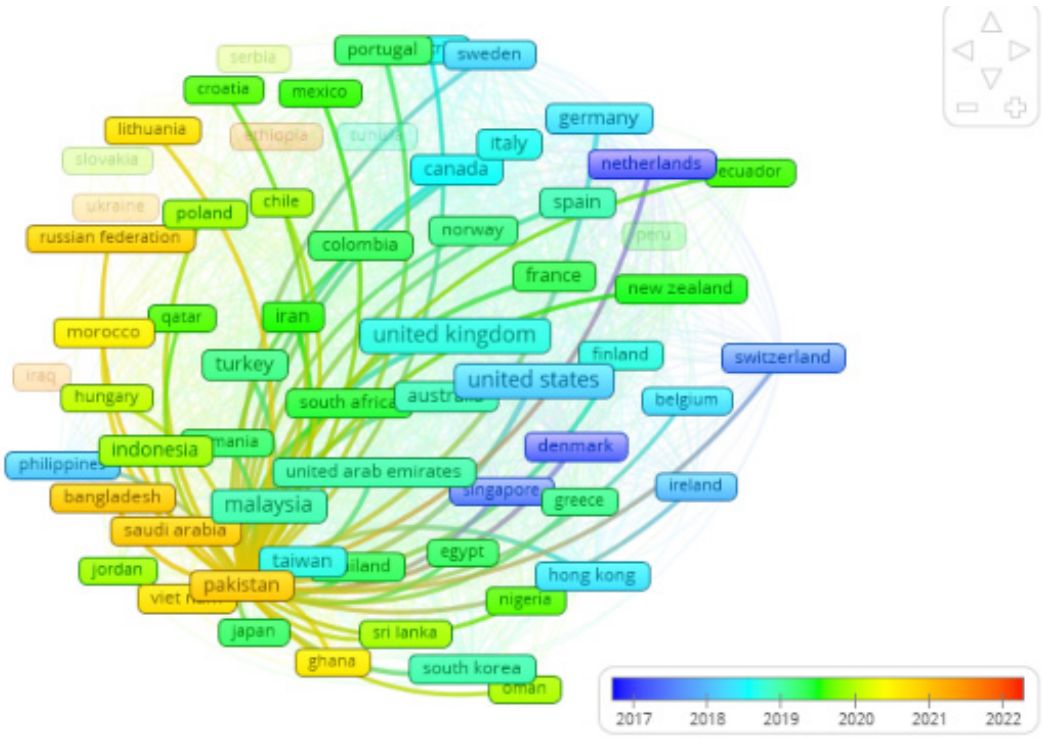


Figure 11. Bibliographic coupling of countries for the year 2020.

In 2020, the focus became truly international, with contributions from nations such as Pakistan, Morocco, Saudi Arabia, Bangladesh, Ghana, Vietnam, and Lithuania. This growing diversity in research participation underscores the global nature of the SDGs and the necessity for worldwide cooperation and commitment.

The bibliographic coupling of countries for the year 2021 is shown in Figure 12.

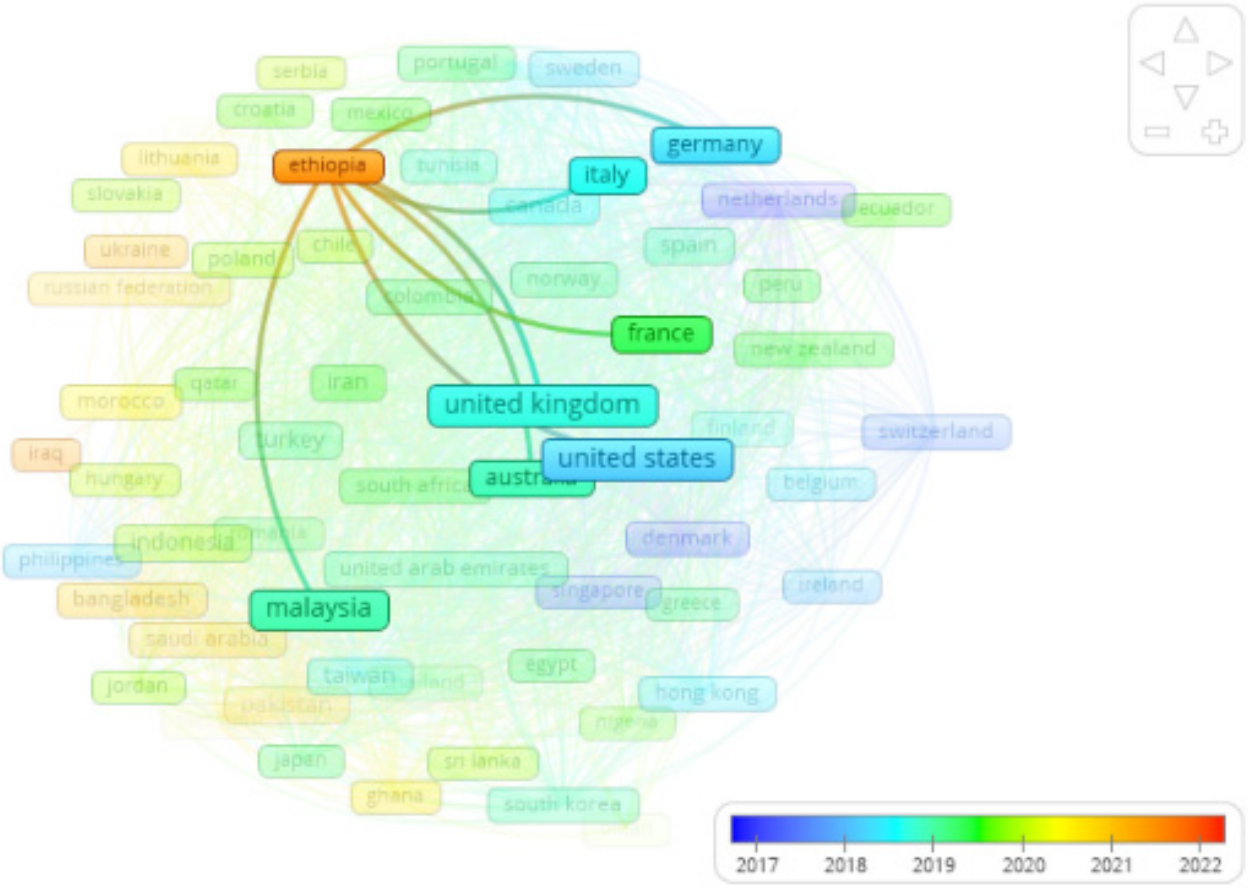


Figure 12. Bibliographic coupling of countries for the year 2021.

Finally, in 2021, GSCM research grew more inclusive, involving perspectives from Africa and Eastern Europe. With active research contributions from countries like Ethiopia, Iraq, and Ukraine, this inclusivity is crucial for realizing the UN's SDG 2030 goals.

From 2017 to 2021, countries that contributed to review papers on GSCM showed a steady rise in interest and collaboration in the topic, according to a bibliographic coupling study. From a small number of European nations, the research landscape has grown to include contributions from many other parts of the world. This development denotes the expanding significance of global environmental and sustainability issues in supply chain management.

Regarding Jeff Sachs' Sustainable Development Report (SDR), we can see that the nations participating in GSCM research have various rankings in the SDG Index [69]. Regardless of each country's specific level of development, this diverse engagement strengthens the global community's obligation to work towards the SDGs. Thus, the growth of GSCM research is a step toward the SDGs and emphasizes the broad applicability and significance of sustainable practices, particularly in supply chain management.

In conclusion, the globalization of GSCM research is a sign that the SDG 2030 objectives of the UN are being met. It emphasizes the necessity of a coordinated strategy for sustainability in which developed and developing countries cooperate to achieve the shared aim of a sustainable future.

4.4. SDG Network

The findings in this section specifically address RQ4.

RQ4: How are GSCM practices interconnected with specific SDGs, and how do these connections impact businesses' sustainable practices and supply chain management strategies?

This section helps in answering RQ4. Modern business practices now critically emphasize mapping GSCM to SDGs. Understanding the connections between certain SDGs and GSCM practices is crucial as businesses work to align their operations with global sustainability goals. Creating an SDG network that highlights two separate clusters that symbolize the interconnected SDGs is one method for visualizing these linkages. In this regard, this study provides the "Red Cluster" and the "Green Cluster", each consisting of a collection of SDGs with ties to GSCM projects. Figure 13 shows the SDG network.

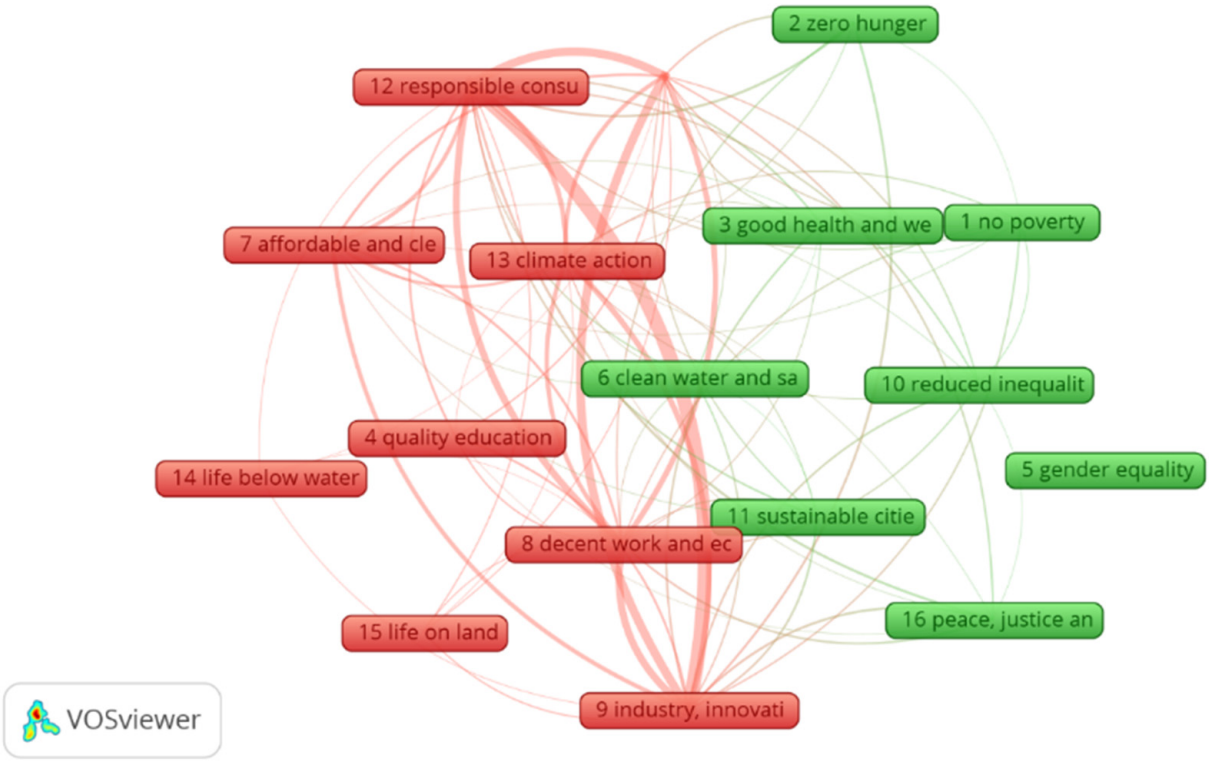


Figure 13. SDG Network of GSCM.

The red cluster represents a group of SDGs closely connected to GSCM techniques. These SDGs cover numerous environmental and social factors that complement businesses' sustainable practices and supply chain management strategies. SDG 4 (Quality Education) promotes lifelong learning opportunities for all. GSCM practices require training and education of employees in sustainable methods, thus contributing to this goal. These methods consider social and ethical issues in addition to environmentally sustainable procedures. Businesses help achieve this goal by funding employee education and training in sustainable practices. Furthermore, GSCM frequently cooperates with research institutes and universities, promoting innovation and knowledge exchange. SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) can be advanced through GSCM by optimizing energy consumption, utilizing renewable energy, and reducing greenhouse gas emissions in the supply chain. The optimization of energy use throughout the supply chain is encouraged by GSCM. Businesses that use GSCM policies have a higher propensity to use renewable energy sources, invest in energy-efficient equipment, and cut down on energy waste. This immediately advances the objective of clean, inexpensive energy. Reducing greenhouse gas emissions and lessening the effects of climate change are the goals of GSCM strategies. By implementing sustainable packaging, waste reduction strategies, and trans-

portation optimization, companies can effectively mitigate their carbon footprint across the whole supply chain. This aligns with SDG 13's goals to mitigate the effects of climate change. SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation, and Infrastructure) are connected to GSCM by creating green jobs, fostering innovation in green technologies, and building resilient infrastructure. SDG 12 (Responsible Consumption and Production) is directly linked to GSCM principles, encouraging companies to reduce waste, recycle materials, and produce sustainably. Finally, SDGs 14 (Life Below Water) and 15 (Life on Land) can be supported by GSCM through the minimization of pollution and waste, preservation of biodiversity, and responsible use of terrestrial and aquatic resources in the supply chain. By prioritizing sustainability, companies can contribute to these SDGs and play a significant role in achieving the 2030 Agenda.

The Green Cluster is made up of SDGs that are linked to GSCM initiatives and cover both social and economic facets. Building robust and sustainable supply chains, fostering social well-being, and fostering economic growth depend on achieving these objectives. GSCM is vital in advancing several SDGs. By championing fair trade and sustainable sourcing, GSCM supports SDG 1 (No Poverty) by promoting sustainable livelihoods and SDG 2 (Zero Hunger) by bolstering food security. The fair trade and sustainable sourcing methods that GSCM advocates can aid in creating long-term employment opportunities for supply chain participants. This, in turn, creates prospects for steady income generation, which advances the goal of eliminating poverty. Simultaneously, reducing harmful emissions and waste within GSCM safeguards environmental health, contributes to SDG 3 (Good Health and Well-being), and supports SDG 6 (Clean Water and Sanitation) by minimizing water usage and contamination. The commitment of GSCM to minimize waste and hazardous emissions protects the environment. Through the mitigation of environmental elements that can be harmful to human health. Environments that are healthier support general well-being. Clean water and sanitation are goals that are supported by GSCM activities, which reduce water consumption and contamination in their operations. Reducing pollution and water use contributes to the preservation of this essential resource. GSCM's commitment to equal opportunities can drive progress towards SDG 5 (Gender Equality), while practices of fair trade and non-discrimination can help address SDG 10 (Reduced Inequalities). Promoting sustainable resource use by GSCM contributes to SDG 11 (Sustainable Cities and Communities), and ethical business practices intrinsic to GSCM foster transparency and accountability, indirectly bolstering SDG 16 (Peace, Justice, and Strong Institutions). Thus, GSCM, while primarily associated with environmental sustainability, intertwines with numerous facets of global sustainable development. While these connections might not be as direct as with other SDGs, GSCM, when implemented thoughtfully, can positively contribute to a broad range of SDGs.

5. Future Research Directions

The primary goal of future research should be to perform experimental evaluations to look at how GSCM practices directly affect the achievement of particular SDGs.

Circular economy integration in GSCM:

Examine the circular economy framework's smooth integration of GSCM practices. The studies can investigate methods for eliminating waste from supply chains, maximizing resource efficiency, and closing the loop [70]. Focus areas include creating cutting-edge reverse logistics systems, evaluating the financial and environmental advantages of product refurbishing and remanufacturing, and pinpointing obstacles to adopting the circular economy in various sectors and geographical areas. Businesses may actively support SDGs, particularly those connected to responsible consumption, sustainable production, and climate action, by integrating GSCM with circular economy concepts.

Sustainable sourcing and supply chain resilience:

Examine how sustainable sourcing techniques can improve supply chain robustness and reduce environmental concerns [71]. The future study may examine how supplier involvement tactics affect the supply chain's overall promotion of sustainability [72]. A

supplier's sustainability performance may be evaluated using various techniques, and responsible sourcing and long-term collaborations with suppliers who support the SDGs may also be encouraged. To achieve the SDGs for sustainable economic growth, decent jobs, and responsible consumption, it is essential to understand the connections between sustainable sourcing and supply chain resilience.

Digital transformation in GSCM for enhanced environmental performance:

Analyse how digital technology could transform GSCM procedures and spur environmental advancements. The study can concentrate on how technology can boost traceability, enhance supply chain operations, and promote environmental reporting and compliance [73]. Businesses may fulfil SDGs related to climate action, innovation, and sustainable infrastructure by leveraging the power of digital transformation in GSCM. The incorporation of machine learning and artificial intelligence (AI) offers substantial promise for enhancing both the sustainability and efficiency of supply chain operations, aligning them more closely with the United Nations Sustainable Development Goals (UN SDGs). In light of this, one avenue for future research could involve the development of a sophisticated predictive analytics model that integrates environmental impact assessments. This would be an extension of existing decision support systems, specifically tailored for configuring spare parts supply chains while considering various manufacturing technologies. Incorporating environmental metrics within such a predictive analytics model would permit the evaluation of different production technologies and materials, thereby aiding enterprises in supply chain optimization. This approach aligns with the tenets of Green Supply Chain Management (GSCM) [74], offering a synergistic framework that combines technological innovation with sustainability imperatives.

Inclusivity and social impact of GSCM:

Examine the social aspect of GSCM and how it affects sustainable development results. How GSCM practices may promote social inclusion, strengthen local communities, and defend human rights throughout supply chains can be the subject of future research. One of the focus topics is examining how fair labor practices, social auditing systems, and community engagement programs affect supply chain stakeholders [75,76]. Understanding how GSCM affects society helps achieve SDGs for partnerships for sustainable development, reduction of disparities, and decent employment.

The global supply chain management field is expected to undergo constant adaptation and evolution in order to furnish firms with inventive approaches and tactics for constructing supply chains that are more sustainable, conscientious, and robust. Cooperation between government agencies, businesses, and academic institutions will be crucial to advance these research directions.

6. Conclusions

This study used bibliometric analysis and science mapping to investigate the relationship between GSCM and SDGs. It successfully answered research questions and provided information on the connections between GSCM and SDGs, knowledge gaps, new trends, and how different SDGs are aligned with GSCM. The literature on GSCM identified three main areas of focus: Industry 4.0 and Sustainable Supply Chains, Green Supply Chain Management Coordination, and Sustainable Environmental Policy Management. By comparing several GSCM themes to certain SDGs, these clusters emphasize the significance of incorporating environmental sustainability into supply chain activities to progress SDGs.

The overlay keyword visualization addressed RQ2 and showed that innovative technologies and sustainable practices that support the SDGs are being more widely adopted. It also showed that research interests in GSCM are changing. The transition in the supply chain process from environmental management to total sustainability represents a paradigm shift in favor of comprehensive measures. Bibliographic coupling between nations demonstrated interest in and cooperation with GSCM research worldwide, extending outside of Europe and demonstrating the awareness of global sustainability issues, addressing RQ3. The SDG network study demonstrated the relationships between particular

SDGs and GSCM activities. The red cluster concentrated on environmental and social factors, while the green cluster addressed SDGs about social and economic dimensions. This analysis addressed RQ4 and highlighted how GSCM can support the 2030 Agenda and several SDGs.

The study furnishes a nuanced analysis with significant implications for sustainable commerce and global development, thereby making it pertinent to both practitioners and the broader society. This information equips supply chain management professionals with insights into how their strategies could contribute to achieving these global benchmarks for sustainability.

Knowing the thematic areas, practitioners can make informed decisions on resource allocation to maximize their impact on sustainability and SDG alignment. Moreover, the article elucidates how GSCM integrates advanced technologies such as AI and Industry 4.0 to enhance environmental performance, thereby informing technology adoption and investment strategies. The study also serves to augment public comprehension of the significance of the UN's SDGs. It underscores the global commitment to address critical challenges such as responsible consumption, environmental conservation, and industrial innovation. By illustrating the linkage between GSCM practices and these objectives, the study emphasizes the societal benefits accrued through responsible manufacturing and consumption, among them, improved air quality, waste reduction, and more effective natural resource conservation.

Businesses and policymakers alike may find great value in the results of a bibliometric analysis. They can support innovation, encourage sustainability, guide strategic decision-making, and offer a framework for coordinating corporate operations with the UN Sustainable Development Goals. By using this knowledge, businesses and legislators may collaborate to create a more sustainable and successful future. Regional differences in the adoption of GSCM are a complicated and diverse problem that calls for specialized solutions from industry, government, and the global sustainability community. In order to advance the global sustainability agenda and guarantee that no region is left behind in the shift towards more sustainable supply chains, these variations must be acknowledged and intelligently addressed. International cooperation and knowledge-sharing initiatives can benefit from understanding regional differences in GSCM uptake. Organizations and nations can apply the lessons from areas with effective GSCM processes worldwide. Acknowledging regional differences is essential to solving global environmental issues. The fact that GSCM adoption may be delayed in some areas should be considered by policymakers and organizations as it may have an impact on international efforts to meet sustainability targets. The alignment of GSCM with SDGs for environmental responsibility is emphasized in this paper. For sustainable supply chains, GSCM should be given top priority by businesses and legislators. The findings support a more sustainable future through sustainable habits and technologies and serve as a future research and strategy development roadmap. It's critical to recognize the limits of the research, including the potential exclusion of grey literature and the deletion of pertinent papers found through keyword searches. Moreover, the analysis only considered papers published after 2013. Notwithstanding these limitations, the encouraging results of this investigation can guide further research. Building on this work, a more thorough literature review or meta-analysis on the GSCM technique can offer further insights into its applicability. Future research should focus on experimental assessments that measure the effect of GSCM directly on particular SDGs. This could entail using state-of-the-art technologies to improve resource efficiency and traceability, supporting the SDGs for industry innovation, ethical consumerism, and mitigating climate change. Examining closed-loop supply networks and circular economy concepts can support SDGs focusing on waste reduction and resource conservation. Future research efforts should also focus on supply chain resilience, geopolitical and climate change threats, and sustainable sourcing and procurement strategies that promote the SDGs while benefiting local populations and biodiversity.

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