

Green supply chain management: exploring research, challenges, and opportunities through bibliometrics

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Abstract. Increasing global pollution and resources scarcity problems in marketplaces have resulted in Green Supply Chain Management (GSCM) being placed as one of the most important themes of corporate strategies. This study explores GSCM and its relationship with sustainable supply chain management (SSCM) in the context of further directing a stream of future research on such dynamic and vital topic. We employ a bibliometric analysis to trace the dynamics of knowledge production in GSCM, specifically looking at its most salient research themes, trends and thought leaders within the field. The information used was obtained from the Scopus database, with a total of 234 documents coming out in years comprising 2020–2024. The analysis finds interesting themes like green practices integration, supply chain resilience and technology role in GSCM's global application. The results underscore a critical need for further study and implementation of GSCM initiatives to both tackle key planetary challenges and safeguard supply chain resilience and sustainability.

1 Introduction

Industrial ecology is motivated by two trends, awareness of environmental issues and the need to compete in a globalizing world. The green supply chain management (GSCM) is a contemporary part of corporate strategy and nowadays, business organizations are more intrigued by the advocacy of sustainability [1]. Practical applications of GSCM could lead to better business performance [2]. GSCM implementation is successful if there is efficient leadership, a supportive corporate culture, and smooth communication with suppliers, operators, and customers [3]. An important field of study is GSCM, which includes environmental concerns in supply chain activities [4]. Earlier investigations in the field have highlighted the causes of the adoption of green practices, such as supply chain integration on both tactical and strategic levels combined with the functional areas of reverse logistics and green purchasing [5], and more researchers have concluded that crescent practice shows a

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growing trend in embedding eco-friendly practices into supply chain management (SCM) processes [6].

Existing research suggests that a multidimensional approach is required for the successful implementation of GSCM. The tools and approaches are intended for the analyses of such processes as possible causes and the factors that lead to more efficiency, particularly functional factors. For the present research, the identified fact might open new perspectives based on which the idea of using GSCM as a part of larger mobility in Sustainable Supply Chain Management (SSCM) is to be addressed. To be more precise, one may consider economic wellness, social wellness, and physical wellness. Additionally, since the research implies the necessity of numerous business decisions in the resource-related sector, it is critical to consider such business tools related to system dynamics and cost-benefit analysis [7]. SSCM aims to improve both social and environmental outcomes for all stakeholders, while simultaneously generating economic value. This is achieved by minimizing environmental harm and reducing the risk of system failure [8]. However, despite the tremendous impact of SSCM on project performance, its value remains overestimated, which also indicates that the global implementation of GSCM is hampered by the complexity resulting from various environmental regulations and cultural views on sustainability [9].

Implementing GSCM is not as simple as possible. Many companies face barriers to their success. First, the start-up costs of any GSCM practice are significant. Such one-time investments encompass infrastructure enhancements, sustainable material sourcing, and technological implementation [9]. Second, few enterprises are capable of ensuring clear and precise data visibility and accuracy to monitor sustainability performance and identify potential improvements. However, an increase in supplier collaboration would positively stimulate many challenges, considering the absence of necessary competencies and sources, creating difficulties, particularly among small suppliers [10]. It is also difficult to determine the financial gains from GSCM, which are often limited to the short term and significantly affect the ability of the majority of organizations to make informed investments [9].

Moreover, GSCM is expensive in the initial phases, but its effective implementation helps the company reduce the costs associated with reducing waste, decreasing energy consumption, and increasing recourse and process efficiency [11]. Thus, new markets and ways to generate income have been created. In addition, GSCM has been beneficial for supply chain resilience, including responsible procurement and less vulnerability to scarce resources [12]. The introduction of global GSCM will be increasingly beneficial as environmental regulations are tightened, enabling them to achieve compliance and avoid fines.

This study also used bibliometrics, which can help identify the best articles, journals, and authors to review a product or message of interest, although skills in using these techniques are required for their effective use. However, to the best of our knowledge, this study has been carried out using Scopus data for one of the GSCM practices and its impact over a sector across all previous studies, in which we explored publication trend analysis, major drivers and barriers, and future research areas. By synthesizing the current state of research on GSCM, this study seeks to highlight opportunities, challenges, and future directions for achieving sustainable SCM in today's complex economic landscape.

2 Literature Review

2.1 Green Supply Chain Management

GSCM is a strategic approach that focuses on increasing a company's performance and sustainability through the optimization of green supply chains. Despite extensive efforts to

understand and promote ecologically friendly techniques, green logistics adoption remains disappointingly low. It is crucial to note that the successful implementation of GSCM depends heavily on effective leadership, a supportive organizational culture, and strong collaboration with key supply chain partners, including suppliers, carriers, and customers. GSCM is applied to blend environmental elements into the SCM [3]. A review of the literature suggests that GSCM has been studied from the point-of-view of functional initiatives such as reverse logistics, green purchasing [6]. According to the latest research, integrating SCM and green practices is crucial.

2.2 Sustainability in Supply Chain Management

SCM includes the management of various interconnected social, economic and environmental factors in international supply chains as they develop and are maintained. SSCM enables guidance strategies that help in reducing waste and also ensure the longevity of a system throughout time. Good for commerce as it is a broad concept that addresses the overall welfare of everyone involved with product and/or service cycles (1). These factors result in competitiveness rising, environmental impact descending and the risk of failure diminishing [8]. Indeed, the role of to be added managerial perspective on the value of a building project has often been ignored [13].

3 Methodology

This study perform bibliometric analysis to investigate the research landscape of GSCM. Bibliometric analysis is a quantitative technique that can help highlight the most influential articles, journals, authors and themes on a specific research topic by providing an extensive landscape of the development and trends in terms of GSCM topic. We used the Scopus database because the data present in this source is widely recognized and cannot be considered unreliable [10]. The search query was facilitated to fetch papers and used GSCM, sustainability, supply chain as keywords & it resulted 234 relevant documents published between 2020 and 2024. Data can be downloaded via this link: <https://bit.ly/47BYPy8>. Selection of final 96 articles was based upon: landmark work(s), citation impact, soundness of methodological analysis, and relevance to scope. Relevance was assessed based on keyword matches and extensive abstract sifting to remove the studies that added little in terms of understanding GSCM concepts. Upon detailed examination of additional considerations like irrelevance, outdated methods used in the study and insufficient citation impact that it exercised on organ preservation practices ultimately resulted in the other 138 articles being excluded. To illustrate this phenomenon, data are analysed in multiple dimensions using bibliometric analysis tools (e.g., VOSviewer®) to analyse scientific networks such as co-authorship, keywords co-occurrences and publication trends. The purpose of this study is to understand the institutional influence and collaboration structure change in GSCM by using co-authorship networks. The trend analysis by output relies on keyword co-occurrence to reveal the main themes and emerging trends, while the publication trend analysis serves at a high level for tracking research trajectory in GSCM over time. It allows evaluating research in several dimensions, such as the volume output of a scientific community (publication counts) and the size of the scientific impact of a community (citation counts); it also enables some information to be extracted how collaborative networks shape scientific communities. This overall not only showed country-level current status of publications but also represented leading authors and journals giving a clear picture of emerged global GSCM research landscape. Although the scientists who conducted this study found their research items only via Scopus, they note that other possibly meaningful work with implications could have been hidden from them as well because they did not include these other databases. In addition, the

attention paid to publications of 2020-2024 leaves behind older work that has laid the foundation for GSCM and can help understand recent advancements. However, methodological analysis offers a robust scaffolding to evaluate where GSCM research is now and most likely headed.

4 Result and Discussion

4.1 Publications by year

The publishing developments in GSCM topics from 2020 to 2024 portray the transitioning nature of research patterns in this field. In 2020, the scientific team produced a total of 49 research articles, paving the way for further research. Although the number of publications in 2021 had a minor decline to 45, there was a notable surge in interest in 2022, with a peak of 52 papers. This increase in attention is indicative of an increasing focus on sustainable practices. By 2023, there was a notable increase in productivity, resulting in the publication of 46 papers. Subsequently, there was a notable surge in 2024, with 42 publications (Figure 1).

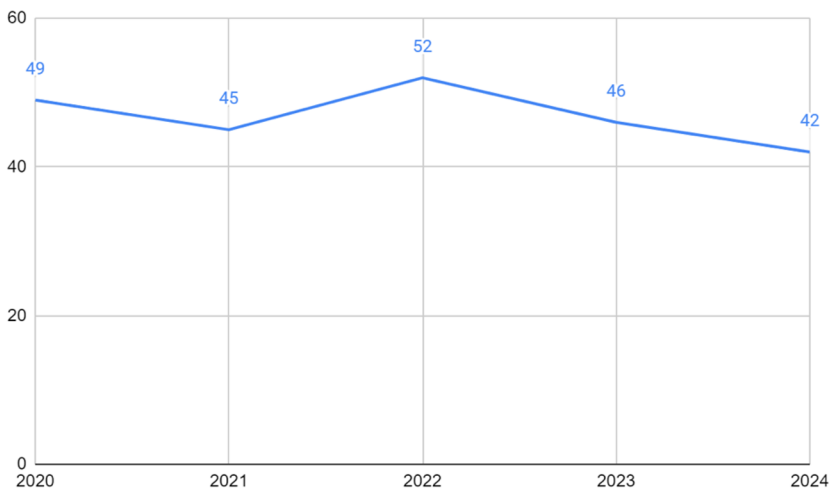


Fig. 1. Publications by year

A sustained stream of research has underscored the mounting significance of GSCM. The authors explore the challenges and opportunities of incorporating sustainability into the supply chain, demonstrating a strong dedication to innovation and effectiveness. The data unambiguously reveal a persistent growth trajectory and sustained interest, indicating a profound transition towards the implementation and promotion of sustainable SCM solutions. This consistent growth can be attributed to the increasing awareness and importance of sustainability, especially in advanced and emerging economies where the industry is adapting to environmental regulations and market demands.

4.2 Publications by country

The distribution of scientific articles on GSCM exhibited notable variations across countries (Fig. 2).

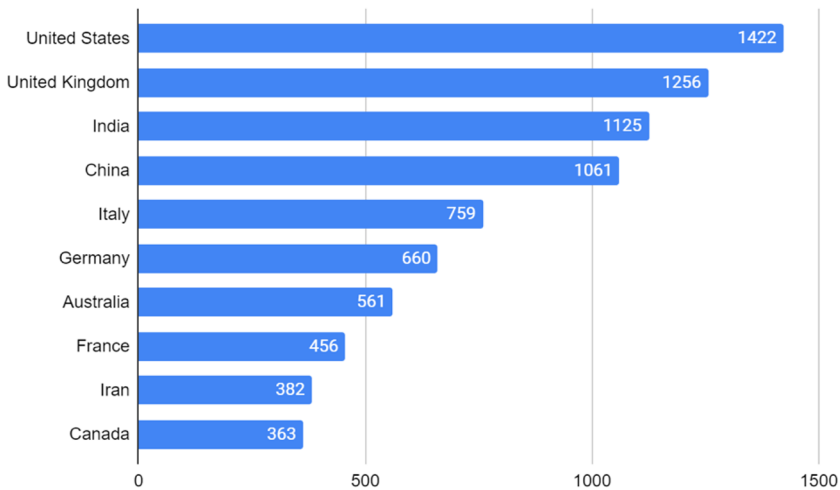


Fig. 2. Publications by country

According to available data, the United States has an impressive total of 1,422 publications, establishing it as the global leader in this area. According to the data, the United Kingdom has 1,256 publications, making it the second most abundant. India has a total of 1,125 books, which is a significant number. China has exerted a substantial impact on the field, with a total of 1,061 studies. Italy, Germany, Australia, and France made substantial contributions through the publication of 759, 660, 561, and 456 works, respectively. The disparities in research productivity among countries suggest the presence of varying degrees of research output. Iran and Canada have made significant contributions to this industry. Iran has 382 publications and Canada reports a total of 363 papers. The data from this study paints a clear picture: interest in and concern for sustainability issues are on the rise. Internationally, there is a continuum of strategies and perspectives on sustainable innovation in supply chain operations. Because the United States and other countries, such as the UK and China, have larger numbers of publications that are published relatively more frequently than in countries with lower volumes such as (e.g., Australia), it is likely that they have stronger GSCM sectors than do some less advanced industrialized countries; government policy promoting sustainability may be another important element here, along with the more general availability of research funds. It also refers to the role of economic/regulatory drivers in shaping research outputs, which in turn contributes to the emergence and dissemination of GSCM practices worldwide. In fact, the industrialization of a number of Asian countries, particularly China, even as they are becoming increasingly conscious of sustainability, has resulted in numerous publications on GSCM. Likewise, the US offers a rich history of environmental awareness and advancing technology that renders plentiful research into GSCM. These contributions contribute to the development of norms and benchmarks and influence company policy and strategy worldwide.

4.3 The Co-authorship network based on authors

The co-authorship network provided in this study reveals the significant effect of scholars such as Wang [14] and Zhang [15], who act as critical intermediates between divergent research groups (as shown in Fig. 3). The widespread collaboration among these academics, particularly those in the red group, demonstrates the existence of a strong and important network accelerating major progress in this subject. Conversely, Khan [16] heads a

distinctive group that concentrates on green research domains, necessitating specialized expertise. The existence of discrete groups, such as the blue and purple groups, highlights emerging or specialized areas within the broader subject. This visualization underscores the significance of prominent academics and their extensive collaborations, effectively mapping the current research landscape in GSCM.

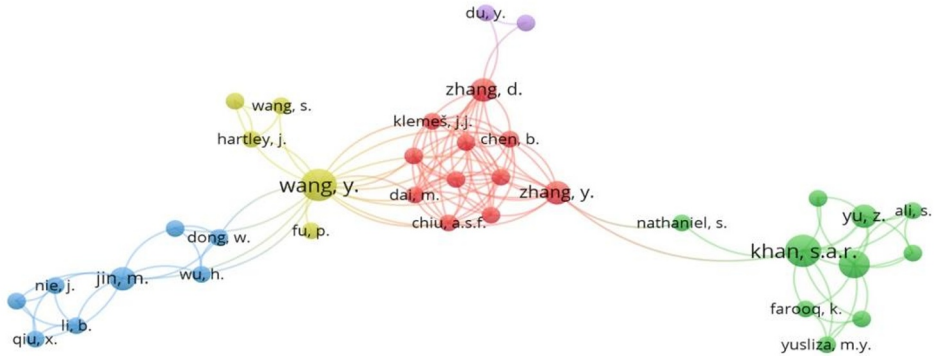


Fig. 3. The Co-authorship network based on authors

Note: The network was visualized using VOSviewer®. The minimum number of co-authorship networks based on the authors was set to five.

The extensive collaboration among these researchers, especially in the red group, illustrates the existence of a robust and influential network that is propelling significant advancements in this field. In contrast, Khan [16] led one of the unique groups to target specialized knowledge in green research domains. The influential authors Wang Y [14] and Zhang Y [15] are said to be highly active, largely because of their long-term research involvement and the general usability of their works from different perspectives of GSCM, which allows them to maintain their high reputation and attract many collaborations. The presence of blue and purple clusters serves to reinforce the fact that these subcategories emerged or became more specialized in disparate aspects related to the broader topic. This illustrates the central role of popular researchers and their large networks, reflecting the current academic climate in GSCM.

4.4 Keyword co-occurrence network analysis

The text network of keywords provides a detailed picture of not only the research landscape but also how different themes are associated. In the network, there are important terms such as SCM, GSCM, and green supply chain, which appear to be nodes with a high reputation in relation to the red cluster (see Figure 4). This shows that this area of research is very influential in academic work and forms part of the core knowledge system for several interdisciplinary fields. A myriad of links exist around these central tenets and illustrate a rich body of knowledge that weaves many parts of SCM into aspects related to environmental sustainability. The criterion is related to GSCM, focusing on fundamental words, such as manufacturing enterprises, business performance, and financial performance. This underscores the importance of determining how "green" actions affect a company's operations and financial position. This emphasis highlights the importance of green supply chains to remain competitive and sustainable.

Along the same lines as before, life cycle assessment, global warming, and environmental protection are key terms detected in some official documents that suggest the environmental dimensions associated with green supply chain analysis (blue cluster). In the face of global environmental issues, the green supply chain is a topical solution, as shown by the clusters' emphasis on sustainability and ecological aspects. The frequency of these words underlines a strong determination to assess and decrease the carbon footprint of supply chains.

The orange group represents specific interests such as developing countries, the construction industry, or the triple bottom line (TBL). Currently, professionals from different sectors and countries assess the adoption of green supply chain concepts. The implementation of the triple bottom-line concept, which unites economic, social, and environmental performance, demonstrates a holistic approach taking into account that considers both general welfare issues and broader sustainability goals.

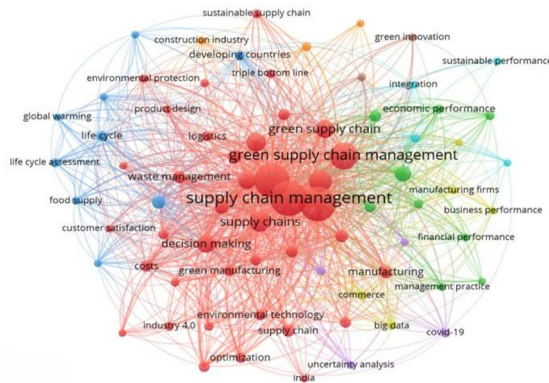


Fig. 4. VOS Viewer Output

This study examines their impact on GSCM strategies in the manufacturing sector in China and presents two cases to illustrate how Industry 4.0 enables sustainability through digital transformation. The growing era of the strategy is also evident from themes such as Industry 4.0, big data, and now COVID-19, as these directly reflect the adaptability of the sector towards modern trends and contemporary challenges. The embodiment of advanced technologies, in addition to the bevy of discussions about the fallout from local management and global events such as the COVID-19 pandemic, address points promoting a vibrant research ecology.

4.5 Challenges

The price burden is a vital barrier to GSCM deployment, including the costs of infrastructure enhancement and procurement of environmentally friendly products, as well as technology adoption and a high initial cost barrier [9]. Additionally, companies often struggle to collect high-quality and timely data company-wide [17]. Without openness, it is difficult to know what areas need improvement and whether the sustainability measures we take are working. This is particularly challenging when it comes to enabling supplier collaboration, as suppliers can be reluctant to adopt environmentally friendly practices [10]. Smaller providers may not have arms and legs or infrastructure or systems to effectively implement changes in this magnitude. The evaluation and validity of economic gains from GSCM operations are difficult to measure [9]. Although the long-term benefits are substantial, they may not always form something that immediately results in fiscal gains. In addition, the implementation of

Global Supply Chain Management at the global level may be complicated by environmental regulation differences and different perspectives on sustainability expression among various cultures. Study A case study in an MNE revealed that integrating renewables into the supply chain was very costly initially but led to long-term savings and improved reputational health [18]. This instance highlights the initial deprivation but the long-term gains achieved with GSCM.

4.6 Opportunities

GSCM provides large opportunities for companies. Improving brand image and Reputation As consumers become more attuned to environmental problems, companies with legitimate sustainability programs are better recognized by customers [11]. The implementation of GSCM leads to better perception of the brand by consumers, which can generate customer loyalty and differentiate it from competition. Moreover, although there are some upfront costs of GSCM adoption, they may lead to considerable cost savings in the long term (decreasing waste, energy use, and improving resource efficiency) [11]. It assists in developing environmental products and processes, thereby supporting innovation [12]. Innovation enables users to wade untapped markets and establish other revenue streams. Furthermore, GSCM is responsible for sourcing and may decrease the need for uncertain resources, which will lead to resilience and SSCM [12]. Incorporating GSCM enhances a firm's ability to achieve a high degree of compliance with tougher environmental policies, thus lowering the risk associated with penalties. Unilever has improved efficiency, corporate image, and reduced cost assets by adopting GSCM practices [19]. It is an example of how being sustainable translates into resilience and a competitive edge, and long-term investment in GSCM can ripe a resilient supply chain that is able to withstand the disruption and have business continuity [19].

5 Conclusion

The integration of GSCM with conventional SCM is very important, as these concepts are linked with each other and cannot survive separately, and sustainable supply chain operations can be achieved by incorporating GSCM practices within the functions of the organization and its manufacturing activities. The findings of this study accentuate the transformative and interdisciplinary nature of GSCM research, which is essential for a more globally minded discipline, reinforcing the increasing need to include environmental concerns in SCM practices. The ongoing growth in the number of articles published, expanded global collaboration, and emergence of new areas of research underscore the dynamic nature of the field. These are obstacles to the potential benefits of GSCM in minimizing costs, promoting innovation, and enforcing compliance; however, the fundamental nature of SCM suggests that this approach is required for continued evolution. This research contributes to the academic discussion and demonstrates how a transition can be made by using GSCM with its transformative potential. As such, it underscores the need for refined policy guidance toward greening supply chains, particularly in developing economies where sustainability problems are severe. This study summarizes the characteristics of different phases of GSCM research and provides recommendations for future study directions, arguing that GSCM is needed to apply the right strategies in specific situations but also urges generalized GSCM conceptual frameworks that cause a paradoxical situation. These learnings offer pathways to practitioners in overcoming implementation challenges and help steer global supply chains towards the adoption of sustainable practices. Policymakers should use this research to support the creation of regulatory frameworks that provide incentives for GSCM practices, such as tax holidays or grants to companies focusing on green innovations.

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