



Supply Chain Flexibility: Unravelling the Research Trajectory Through Citation Path Analysis

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Abstract To counter the uncertainties encountered within a supply chain and enhance its efficiency, it is imperative for a supply chain to be flexible. This paper aims to investigate the trajectory of development in the field of Supply Chain Flexibility (SCF). We perform citation analysis to understand the evolving trajectory. VOSviewer and Pajek software are used to conduct citation path analysis and keyword co-occurrence analysis in the field of SCF. Subsequently, a meticulous evaluation of papers along citation paths is conducted, accompanied by a comparative analysis between the general corpus and a specialized journal focused on flexible systems, namely the Global Journal of Flexible Systems Management (GJFSM). The main path identifies specific themes: SCF, agility, risk and uncertainties, and a holistic view of the SC. The evolving trajectory has origins in 2011, 2014, 2016, 2017 and 2018. We additionally identify specific clusters of research, highlighting their concentration in areas such as SCF, risk management, performance management, and supply chain uncertainties. The research outcomes indicate a congruence between the studies featured in GJFSM and

the broader corpus of SCF. Furthermore, these findings imply that exploring the intersection of Industry 4.0 and SCF presents promising avenues for future research endeavors.

Keywords Citation path analysis · Keyword co-occurrence analysis · Supply chain flexibility · Supply chain management

Introduction

Confronted by rising uncertainty in the environment, supply chains have embraced a flexible approach. Though the concept of flexibility has prevailed for a long time, Supply Chain Flexibility (SCF) has gained importance due to fluctuating demands (Piprani et al., 2022). The supply chains function within a profoundly disruptive environment, encounters a diverse range of challenges that disrupt product flows and financial operations (Badakhshan & Ball, 2023). The evolving customer preferences and fluctuating demands necessitate flexibility of a supply chain. Flexibility is the potential of an organization to perform hypothetical tasks and its ability to adapt to the change in environment ensuring a minimum penalty in cost, time, and effort of performance (Song et al., 2022). Jafari et al. (2022) define SCF as “firm’s ability to adjust, adapt, and transform their resources and processes in coordination with their SC partners to cope with external dynamism”. Maintaining a flexible supply chain requires flexibility within and between all partners in the chain, and the external partners (Fan et al., 2023). Organizations strive to be flexible while linking internally and externally to adapt to the changes. Flexibility entails an ongoing process of continuous improvement to ensure the organization

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remains dynamically balanced (Kazancoglu et al., 2022a, 2022b). Being regarded as a fundamental aspect of the supply chain, flexibility plays a vital role in driving a prolific organizational performance (Cheng et al., 2022).

SCF empowers an organization to respond to a dynamic trading environment and hence become a global player. A significant cause for adopting flexibility in a system is demand uncertainty. A diversified and flexible firm can effectively manage an uncertain demand. Flexibility mitigates uncertainty and risk at intra-firm and inter-firm levels (Wang et al., 2021). Deployment of knowledge management solutions can reduce uncertainty and improve the SC performance of a firm (Singh et al., 2021). The deployment of Knowledge Management (KM) solutions within a firm's supply chain framework primarily reduces uncertainty and this, in turn, helps to improve performance (Sangari et al., 2015). KM solutions such as centralized information systems, collaborative platforms and supplier relationship management systems improve supply chain flexibility. These solutions serve as (1) centralized knowledge repositories which integrate vital information and, (2) collaborative platforms for communication and more informed decision-making. These two important levers of KM solutions help in improving supply chain flexibility.

The concept of SCF reflects the ability to remain operational amidst fluctuating conditions, whether predictable or completely dissimilar from the existing one (Chauhan et al., 2023). This adaptability is necessary for organizations to become efficient by employing just-in-time management techniques; else, the organization becomes economically fragile and vulnerable. Adoption of SCF empowers an organization to take informed production decisions while manufacturing multiple products and/or making promotional decisions amid uncertainties (Pellegriano et al., 2023). The rise in market competition not only expands the market size by creating new opportunities but also results in reduction in a firm's stability (Li et al., 2023). With advancements in modern technology, rapidly changing environments, and intensifying competitiveness, organizations must enhance their adaptability to gain a relative edge over their competition (Sara et al., 2022). Manufacturing plants operating in highly competitive environments have consistently exhibited a higher degree of flexibility in organizing their production processes (Ding et al., 2023). In an uncertain environment, organizations that are more flexible demonstrate better Supply Chain Performance (SCP) compared to less flexible ones. The identification and implementation of strategies that can be cost-effective and maximize flexibility for an increasingly complex and competitive market are key challenges of SCM (Li et al., 2022).

Supply chain flexibility is essential due to its pivotal role in enabling organizations to promptly respond and adapt to

dynamic conditions of the market as well as unforeseen disruptions (Pujawan et al., 2022). Research consistently affirms that a flexible supply chain enhances operational agility, reducing lead times and minimizing costs (Cheng et al., 2022). Additionally, it optimizes inventory levels, which results in the firm having a competitive edge (Yang et al., 2022a). Jafari et al. (2022) posited empirical evidence for the positive effects of the SCF on responsiveness to customers. Additionally, scholar have emphasized that a flexible supply chain is vital for strategic alignment, fostering innovation, and effectively managing complex and diverse supply chain ecosystems, thereby allowing it to thrive in today's volatile business environment (Wilujeng et al., 2022; Zhu et al., 2022).

SCF is a highly burgeoning field of research that has garnered significant interest among scholars across various domains (Dhillon et al., 2023; Prabhu & Srivastava, 2023). With the increasing importance to SCF in practice, this area has also received attention from researchers over the last decade (Bag & Rahman, 2023; Khanuja & Jain, 2022). Holistic approaches have been increasingly employed to examine the importance of flexibility, recognizing the significance of each member firm within the supply chain. As a result, companies are placing greater emphasis on flexibility to ensure their survival and growth.

Research Problem

A few research studies, which review topics related to SCF, have been undertaken in the past. Bibliometric analysis related to flexibility has been performed in the past, but it is vital to understand that Main Path Analysis (MPA) differs from bibliometric analysis. Our study uniquely concentrates on tracing the trajectory of supply chain flexibility as it has evolved over the years rather than citing most frequently cited papers restricted to manufacturing. Singh et al. (2021) employed a network analysis method in their study and included co-occurrences, bibliographic coupling, and co-citation analysis. In contrast, our study centers on global MPA, local forward path analysis, and local backward path analysis. These approaches differ significantly from the networks presented in the paper by Singh et al. (2021), in terms of derivation and insights provided. In another bibliometric analysis, Aissa Fantazy et al. (2009) posited an empirical study by collecting quantitative data through questionnaires and enriching the data by conducting interviews in various industries related to the research hypotheses. In contrast, our study relies on secondary data and does not formulate hypotheses. Instead, insights are gleaned through the analysis of citation paths. There seems to be limited studies, which have looked at the evolution of research in the wider domain of supply chain flexibility. This paper fulfils this gap to understand how

research on SCF has evolved over the past more than two decades.

Second, the authors are curious how this research trajectory compares with the research trajectory on the same topic in journal, which is focused on flexibility. GJFSM is one such prominent journal. The journal is solely focused on publishing research papers related to flexibility which makes it particularly relevant for studying SCF. GJFSM comprises rich data on case experiences, conceptual frameworks and empirical studies that emphasize on SC becoming agile, adaptive, and responsive (GJFSM, 2023). Hence, there is a need to carry out a similar analysis on GJFSM. Such a comparison makes this study particularly unique owing to the richness of analysis.

Third, the existing reviews related to SCF comprise descriptive analysis and review of literature. A citation path analysis will handle the large dataset in a non-biased way through quantitative analysis, which is more objective. Finally, one needs to identify the keywords or clusters around which research in SCF has evolved in order to suggest the future research directions.

In this context, citation path analysis provides visual representation of how ideas and theories in SCF have evolved over time, which helps in understanding the evolution of research paradigms and concepts within a domain. Employing citation path analysis in the context of SCF research can help identify the research trajectory over time. This can help researchers track the progression of the field and identify emerging trends. Secondly, analyzing the citation paths (both main path and local paths) in SCF literature enables researchers to identify gaps in existing knowledge in this domain. This information guides future research directions by highlighting areas, which require further investigation to address unanswered questions or emerging challenges. Thirdly, policymakers and industry professionals can benefit from insights into the most influential research findings and trends when making decisions related to sustainability, supply chain optimization, and resource management. Lastly, SCF often intersects with various disciplines such as logistics, sustainability, and innovation, which is important for interdisciplinary research. Citation path analysis can reveal how research in this area bridges different domains and how ideas flow between them. This can foster collaboration and cross-pollination of ideas.

The research questions of this paper are as follows:

RQ1 How has research in the field of SCF evolved over a period?

RQ2 How does the evolution of research in SCF compare with the evolution of research on the same topic in a journal, which is focused on flexibility, viz, GJFSM?

RQ3 What are the gaps in literature and future research areas that are yet to be explored under SCF?

Contributions of the Study

With the application of citation path analysis along with co-occurrences of keywords, the authors posited an evolution of SCF research. The study assesses the impact of SCF research and how it has evolved with interfaces to supply chain management. First, the authors present the applicability of citation path analysis, also referring to previous studies that have employed this method in related disciplines of circular supply chain, food supply chain, supply chain information systems, and SSC management. Referring to previous studies reveals specific applicability of citation path analysis in discovering research trajectories. Such a reference adds credibility to the methodology of citation path analysis. Second, the authors compare the evolution of SCF research to that of research trajectory in the “Global Journal of Flexible Systems Management” (GJFSM). The inclusion of GJFSM, a journal specifically focused on flexibility, adds depth to the analysis by providing insights into how SCF research aligns with the global and broader field of flexibility. Such a comparison enriches the understanding of SCF within the larger context of flexible systems management. The authors hope it will be an informative resource for understanding trends, identifying research gaps and future research directions in the domain of flexibility. Third, the quantitative aspect involved in citation path analysis helps to minimize subjectivity. The entire corpus of SCF studies for two decades including journal papers, conference proceedings, books and other academic sources, has been analyzed. This contributes to sharper understanding of the emergence and diffusion in this important area of academic research. Fourth, the authors complement citation path analysis with co-occurrence analysis of keywords that have shaped SCF research themes. Combining the two helps to discover interrelationships among themes, which have been integrated with research trajectory. This can be of value in understanding interdisciplinary issues and concepts in SCF research and knowledge synthesis. Fifth, the paper underscores the themes and emergence of connected SCF pathways of knowledge, providing future research directions for scholars and practitioners. Thus, this research study contributes to both research as well as practice.

This study aims to study the research trajectory of entire corpus, which constitutes all the journals from 1997 to 2023. In addition, the research trajectory has been found for a specific journal, GJFSM, with a focus on SCF, since its inception in 2001 until date. Our generic corpus database consists of 405 research papers and the database from GJFSM consists of 62 research papers. This research paper



is organized in the following manner. Section 2 reviews the existing literature on SCF; “**Methodology**” section describes the methodology that has been undertaken. “**Analysis**” section discusses analysis of citation path including a subsection on keyword analysis. “**Discussion**” section presents the findings of the paper while implications are discussed in “**Implications of the study**” section. The conclusion is provided in “**Conclusion**” section. Finally, “**Limitations and Future Research Directions**” section gives the future research directions and limitations of research.

Amidst an uncertain and unpredictable operational landscape, supply chains are highly vulnerable to disruptions that can impede seamless operations, necessitating adaptability and Supply Chain Resilience (SCR) to mitigate and navigate such challenges (Ishak et al., 2023). While investigating the importance of SCR in mitigating supply chain disruptions, Kazancoglu et al., (2022a, 2022b) found that supply chain flexibility has a direct influence on the responsiveness of the global supply chain. Piprani et al. (2022) highlighted the substantial impact of multi-dimensional SCF in bolstering SCR amidst turbulent and challenging environments. In a review carried out by Pujawan et al. (2022), it was determined that employing SCF represents a viable approach to alleviate disruptions in the supply chain. Additionally, integrating digitalization can enhance its effectiveness.

Circular Economy (CE) practices and Sustainable Supply Chain (SSC) flexibility play pivotal roles as mediating variables between capabilities of Big Data Analytics (BDA) and performance of a SSC. BDA is shown to propel the adoption of practices of CE. Moreover, practices promoting CE are observed to stimulate flexibility of a SSC, which can be enhanced by support of BDA (Cheng et al., 2022). A resilient supply chain exerts a potent impact on SCP, mediated by the influence of supply chain sustainability (Zhu & Wu, 2022). The implementation SSC flexibility demonstrated a noteworthy and favorable influence on achieving CE targets, eventually promoting sustainability (Bag & Rahman, 2023).

Nayal et al., (2022a, 2022b) demonstrated that both information flexibility and organizational flexibility exert the most significant influence on the adoption of AI-IoT, which affects the performance of a firm. Furthermore, the analysis reveals that CE affects the link between organizational flexibility and AI-IoT adoption (Nayal et al., 2022a). The transparency and security of information provided by blockchain technology significantly affects trust building within a supply chain and enhances SCF. Additionally, it underscores the specific significance of digital leadership in elucidating diverse contributions associated with various digital technologies (Wang & Yang, 2022).

Bibliometric analysis has been extensively utilized in various studies, offering valuable insights by evaluating patterns, trends, and relationships within a specific literature, aiding in a deeper understanding of the subject matter. With an aim to enhance flexibility in business models, Mendiratta et al. (2023) introduced a novel hybrid model, utilizing bibliometric analysis and topic modeling to chart the intellectual landscape of corporate social irresponsibility. Iftikhar et al. (2022) integrated a bibliometric analysis with a structured review to gain insights into the nexus of data analytics, digitalization, and resiliency of a supply chain. Singh and Dhir (2019) conducted a systematic literature review and bibliometric analysis to study social marketing, innovation and international cause-related marketing. The study performs keywords analysis to understand influential authors, evolution, and citations from 1998 to 2019. In another study, the authors employ two-tier analysis combining bibliometric with content analyses to identify intellectual structure in sustainable manufacturing (Bhatt et al., 2020). Their study identifies a framework critical literature paradigm and highlights conceptual and methodological advancements. Together, these reviews contribute valuable understanding to diverse areas of business research with structured analyses of literature trends.

Methodology

Bibliometric techniques such as the citation path analysis also help us in carrying out quantitative analysis of the impact of research studies (Baas et al., 2020). This paper aims to combine citation path analysis with an analysis of co-occurrence of keywords. The analysis, not only uncovers the potential future research areas, but also sheds light on the factors that play a vital role in the research trajectory of SCF. This gives researchers an opportunity to discover interrelationships among various topics of research within the existing studies in the field of SCF (Singh et al., 2022).

For the present study, an extensive literature review has been carried out to discover key research themes and agenda. The reviewed literature contained papers focusing on SCF as well as papers that were interdisciplinary in nature but relevant to SCF. An exhaustive survey method has been adopted based on citation analysis and keyword co-occurrence methods.

This study utilizes bibliographic data collected from the Scopus database. Given the diverse range of papers across journals, the Scopus database has been chosen instead of other databases such as Google Scholar and Web of Science (Zhao et al., 2019). The authors focused more on management research papers since the Scopus database has

more management research and includes more publishers worldwide (Baas et al., 2020; Singh et al., 2023a). Scopus offers an extensive coverage of research articles making it valuable for in-depth research in the desired area of the research field (Singh et al., 2020a). In the field of social sciences and management studies, Scopus indexes 20% more articles compared to Web of Science (Srivastava et al., 2020). Scopus offers a broader range of data fields, particularly concerning comprehensive author information (Singh et al., 2020b, 2023b). Hence, the Scopus database was chosen for this study.

The reviewed literature is limited to well-defined criteria that includes research papers in the field of business management, a decision-sciences, computer science, economics and econometrics social sciences, and literature written in English language. Conferences, books, and chapters in edited volumes were also included in the search to gather more context and a wider background. The search criteria included (1) “supply chain flexibility” AND (2) “flexible supply chain”. The selected keywords were chosen due to their relevance in identifying diverse perspectives in supply chain flexibility. Inverted commas were used to ensure presence of “supply chain flexibility” AND “flexible supply chain”. The keywords have been chosen after checking the relevant corpus extracted using keywords such as agility, resilience, and robustness. SCR pertains to a system’s capacity, such as that of a supply chain, to absorb shocks, swiftly recover from disruptions, and effectively restore normal operations (Tukamuhabwa et al., 2015). Supply chain robustness has been characterized as the extent to which a supply chain maintains satisfactory performance both during and after an unforeseen event that disrupts one or more logistics processes (Durach et al., 2015).

Keeping this study focused on supply chain flexibility helped us to distinctly delineate and capture relevant literature within the database. No specific beginning time has been fixed to enable since we wanted to capture all the relevant scholarly works that search strategy may provide. In the search outcome, we observed that the studies/scholarly works were from 1999 onwards. The end time period chosen was the most current one (June 2023 in this case). The choice of this time frame enabled identification of pivotal shifts and/or developments in this important area of research. The strategy’s focus on exact phrases was designed to provide a refined and specific set of literature. Although, there could be limitations in potential exclusions of non-English publications.

The bibliometric data for both “supply chain flexibility” and “flexible supply chain”, was transferred to a separate comma-separated values (CSV). The search yielded 314 documents for “supply chain flexibility” and 101 documents for “flexible supply chain”. Both search results were

then combined into a single file for analysis. De-duping was done using a Python program. The 12 duplicate entries were removed from the consolidated file. After removing duplicates, the consolidated file consisted of 405 studies which have been analyzed in the presented research. Table 1 comprises the number of articles appearing in each journal of the generic corpus. The maximum papers on supply chain flexibility appear in GJFSM making it an appropriate journal to be compared with.

Main Path Analysis

According to Nalimov and Mulchenko (1969) “*scientometrics is a cybernetic approach to the ‘development of science’ using quantitative methods of research*”. This overcomes the shortcomings of existing studies based on different methods of conducting a review (Mas-Tur et al., 2020; Varma et al., 2023). This paper presents the use of scientometric analysis by utilizing MPA to analyze research on the topic of SCF. MPA is an effective technique for mapping trajectories of existing research, investigating flow of knowledge in literature, and reviewing the literature. With the help of MPA, scientific knowledge and technological fields can be traced chronologically (Liu et al., 2019).

The impact of research papers can be measured using citation analysis of sources in VOS Viewer (Van EckJ & Waltman, 2021). The average citation score was taken as the basis for ranking the journal instead of using the h-index. The h-index seems to favor older and more prolific authors. This makes it less sensitive to recent changes in research output. Moreover, increasing h-index is not a linearly scaled process. A researcher who has an h-index of 4 needs to publish a 5th paper and have all his papers cited five times in order to attain an h-index of 5. However, an author with an h-index of 30 needs to publish a 31st paper and have all his papers cited 32 times so that he reaches an h-index of 32. The top 15 journals were selected based on citation score. GJFSM is ranked 13 in this list of journals. The selection of journals is shown in Table 2.

Two steps are necessary in identification of the most important citation chain in the network. The first step is the calculation of the “traversal count” of every citation link according to its structural position. This is followed by determination of citation chain based on traversal count’s value (Yu & Fang, 2023). Citation path analysis may be divided into three broad categories: global MPA, local path analysis (forward and backward) and global key-route path analysis. Local path identifies the local maximum, hence, choosing the most influential links. Forward local path is represented by obtaining maximum number of followers, whereas the papers adapting ideas from a greater number of studies are given more weightage in the backward local



Table 1 Number of articles appearing in each journal of the generic corpus

Journal Name	Number of papers
Global Journal of Flexible Systems Management	26
International Journal of Production Research	22
International Journal of Production Economics	18
Supply Chain Management	11
International Journal of Supply Chain Management	10
Sustainability (Switzerland)	10
International Journal of Operations and Production Management	9
International Journal of Logistics Management	8
Uncertain Supply Chain Management	7
Procedia CIRP	6
International Journal of Services and Operations Management	6
International Journal of Logistics Systems and Management	6
European Journal of Operational Research	5
Organisational Flexibility and Competitiveness	5
Production Planning and Control	5
Annals of Operations Research	4
Benchmarking	4
Business Process Management Journal	4
Computers and Chemical Engineering	4
Journal of Modelling in Management	4
Management Science	4
Industrial Management and Data Systems	4
International Journal of Business Excellence	4
International Journal of Business Information Systems	4
International Journal of Integrated Supply Management	3
International Journal of Agile Systems and Management	3
Congress Proceedings—CLC 2012: Carpathian Logistics Congress	3
International Journal of Physical Distribution and Logistics Management	3
International Journal of Productivity and Performance Management	3
Journal of Cleaner Production	3
Journal of Enterprise Information Management	3
Journal of Industrial and Production Engineering	3
Journal of Manufacturing Technology Management	3

path. Based on the largest overall traversal count, the main path is formed. However, even after combining the local (backward and forward) and main paths, a few highly influential nodes may not be highlighted. Therefore, conducting a key-route path analysis is necessary for a

comprehensive understanding of evolution of SCF research. These paths denote the various topics into which the research related to SCF has Diverged.

The citation path analysis has been carried out in two ways. First, the technique has been applied for the whole corpus of shortlisted papers covering various journals. Second, the same technique has been used for papers published only in GJFSM. A comparison of the two citation paths is then carried out to assess the commonalities and the differences.

Keyword Co-occurrence Analysis

This study also carries out keyword co-occurrence analysis. This technique depicts the number of documents containing a given keyword. This study uses VOSviewer to form a keyword map consisting of various keywords that form the nodes and the inter-nodal relations depicted by the connecting link. The strength of a link connecting the nodes is determined by an arithmetic value, lesser this value, weaker is the link (Kaiser et al., 2017). Each cluster comprises a set of keywords indicating a different characteristic of SCF and the respective weights of links are an indicator of their significance to the keyword. Also, the prominence of nodes, i.e., their sizes give an indication of weight of graph (Van Eck & Waltman, 2021).

The network visualization for keywords considering all the journals is shown in Fig. 1 and that considering only GJFSM is shown in Fig. 2. Clusters should be formed in a way that they do not appear to be cluttered and at the same time not sparsely populated. To ensure such a spread, a threshold value of 5 was used for the occurrence of keywords. This ensured heterogeneity among the clusters formed as well as homogeneity within each cluster. Keyword co-occurrence analysis yielded 5 clusters and 565 links. For further analysis, the formed clusters were exported to MS Excel.

Analysis

Citation Path Analysis

The authors first discuss the citation path analysis for the complete corpus of short-listed papers. This consists of the global main path and the local paths. Subsequently, the citation path analysis for the GJFSM journal is discussed.

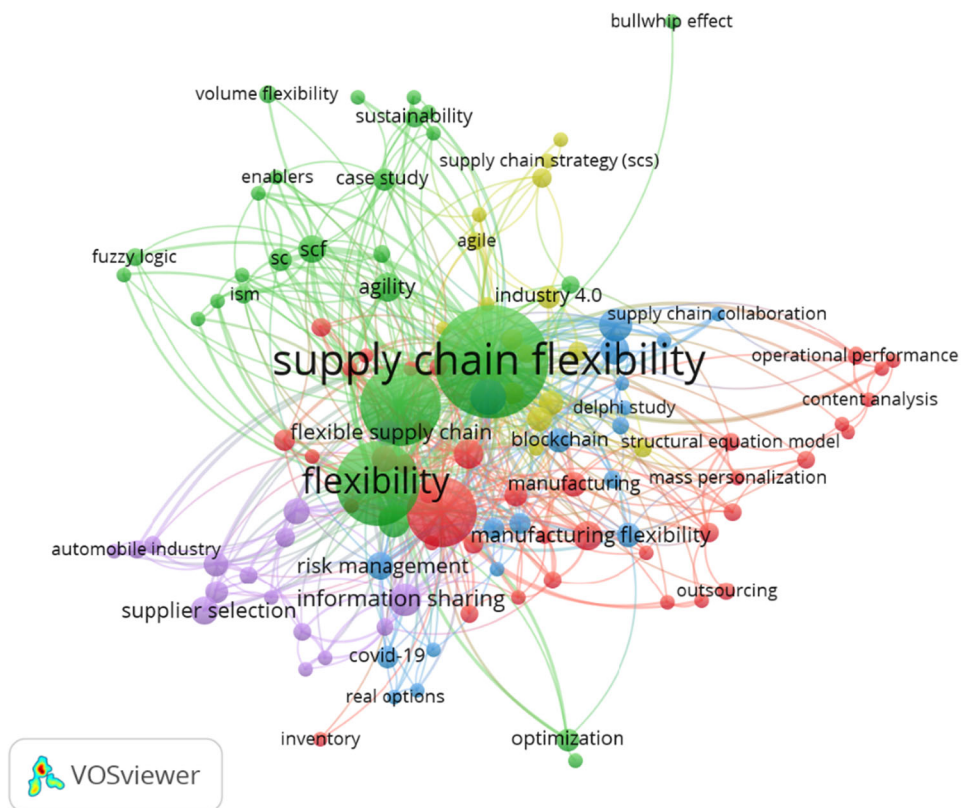
Global Main Path (Complete Corpus)

The MPA is shown in Fig. 3. Vickery et al. (1999) presented different types of flexibility strategies that can improve the performance of an organization. The study

Table 2 List of journals publishing SCF articles

Rank	Name of journal	Average publication year	Average citations
1	Journal of supply chain management	1999	477
2	International journal of operations and production management	2007	449
3	Industrial management and data systems	2003	328
4	International journal of production economics	2020	131
5	International journal of production research	2013	78.5
6	Journal of purchasing and supply management	2016	60
7	Production planning and control	2013	48
8	International journal of logistics management	2017	38
9	International journal of business excellence	2008	33
10	International journal of services and operations management	2010	29.5
11	Logistics	2021	18
12	Business strategy and the environment	2022	15
13	Global journal of flexible systems management	2013	13
14	Applied sciences (Switzerland)	2021	12
15	International journal of logistics systems and management	2012	5

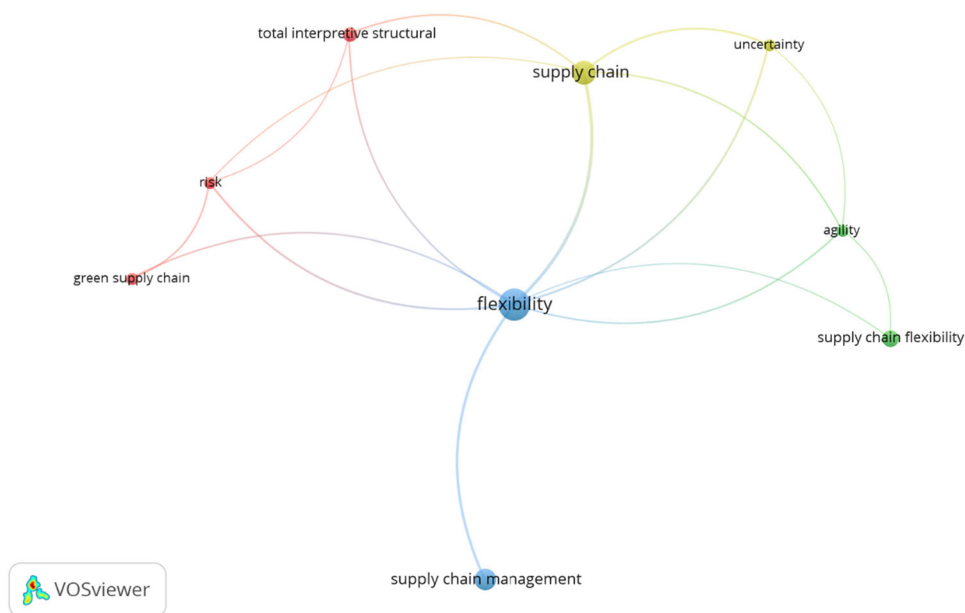
Fig. 1 Network visualization considering all journals



posited that market and financial performance are substantially impacted by volume flexibility, market flexibility, and product launch flexibility. Extending the study from an intra-organization context to a cross-organization context, Duclos et al. (2003) proposed a conceptual framework to extend flexibility strategies beyond the

boundaries of an organization. Further, the supply chain characteristics were explored, and a significant impact of visibility to customer demand, synchronization of delivery schedule, and smooth flow of information across the supply chain was stated (Lummus et al., 2003). The study by Lummus et al. (2003) was a part of the Proceedings of the

Fig. 2 Network visualization for GJFSM



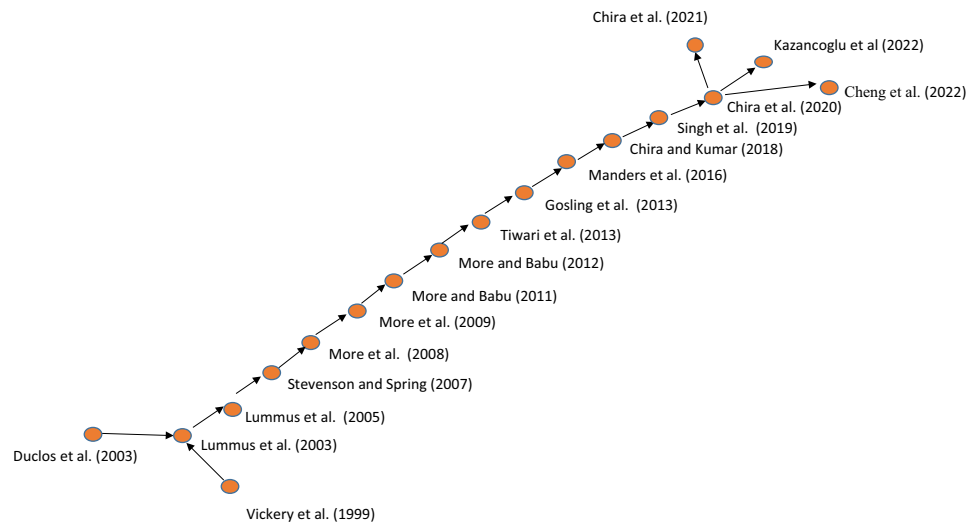
Annual Meeting of the Decision Sciences Institute and was later published in the International Journal of Production Research in 2005 (Lummus et al., 2005). Hence, this paper has been included twice in the citation path.

While previous studies were related to the attributes of the network, subsequent discussions dwelled on investigating several issues and mitigation strategies for the supply chain. Stevenson and Spring (2007) studied the impact of flexibility in supply chains by applying flexibility strategies, consequently contributing to uncertainty reduction. SCF was proposed as a probable solution to problems such as poor product quality, issues related to supplier reliability, and competitors' actions. The uncertainty quantification was further examined to find flexibility trends in a dynamic supply chain. The SCF varies from company to company since business turnover, and the business processes differ. Enablers and triggers for making an organization adopt SCF were identified (Babu et al., 2008). The perception identification by Babu et al. (2008) was followed by More and Babu (2009) identifying various issues faced in implementing SCF and establishing their interrelationships. The major concerns included the occurrence of uncertain events and poor performance measures.

Considering the various issues, a supply chain faces, More and Babu (2011) identified the various SCF types and situations where different types of SCF may be applied. The study investigated the contextual relationship by knowing the interdependency between the various types of SCFs. The authors studied implementing of the different flexibility types at different levels, such as operational, tactical, and strategic. Apart from just implementing SCF to mitigate risks, measuring SCF is also crucial for further

improvement. More and Babu (2012) proposed a flexibility scorecard, using a balanced scorecard approach, to assess an organization's flexibility. To mitigate the uncertainty faced by a supply chain, Gosling et al. (2013) have proposed a four-step framework, i.e., classification of the supply chain, analysis and identification of uncertainties, optimization of pipelines, and strategic development flexibility for an organization, this helps the operation managers make a customized strategic road map for re-engineering the supply chain to improve supply chain efficiency and achieve flexibility. Supplier and buyer relationships are significant when dealing with disruption risks and uncertainty in demand and lead time. To make the supply chain more robust in any possible scenario, Tiwari et al. (2013) proposed a mathematical flexibility model that helps both parties against supply chain disruptions with the minimum penalty; and suppliers can swap the order from one buyer to another to ensure a continuous supply. Paying attention to the need to mitigate risks in a supply chain, Tiwari et al. (2015) studied the implementation of SCF, and the strategic benefits reaped because of a flexible supply chain. This study was exclusive only to forward main path shown in Fig. 4.

An interactive approach suggested by Manders et al. (2016) helps to analyze SCP in situations when more than the dyadic perspective is needed. The authors highlight that studying and interpreting the shared information received from suppliers, distributors, and retailers is crucial for the FMCG sector, as SCF priorities differ according to the levels in the supply chain. Kazemian and Aref (2016) attempted to optimize capacity bottlenecks to enhance SCF. Manders et al. (2017) conducted a literature review of SCF and highlighted the various perspectives of SCF: the

Fig. 3 Global main path for generic corpus

organizational, economic, and manufacturing perspectives. The authors highlighted the need further to study the integration between the different flexibility perspectives.

In the context of Indian automobile industry, SCF has been modelled under the sales promotional scheme environment. Different strategies significantly impact a firm's performance, viz. enhancing the volume flexibility, innovating for improving the manufacturing flexibility, ensuring supplier flexibility, may be by ordering from multiple suppliers, and encouraging supplier collaboration flexibility (Chirra & Kumar, 2018). Variability in demand due to uncertainty is also a concern for SCF. At the same time, dealing with these variations requires optimum utilization of the available resources and capacity utilization to avoid idle time while maintaining the flexibility to cater to the ever-changing variations of the customers. To cater to varieties of different sizes, distinct appearances, and packaging variations, Singh et al. (2019) proposed a framework for reducing uncertainty and improving operating performance in soap manufacturing. The framework consisted of a distinctive approach to assessing the degree of SCF required. It concluded with recommendations to improve SCF by varying the order rate, inventory size, backlog production gap, and lead time.

Further studies focussed on the SCP improvement. In a sales promotional scheme environment, procurement flexibility has a superior impact compared to organizational flexibility on organizational performance. Organizational culture and supplier relationships with other supply chain members significantly improve organizational performance (Chirra & Kumar, 2020). Chirra et al. (2021) studied the barriers to SCF during sales promotional schemes and revealed that the supply chain's procurement function significantly impacted the SCF function.

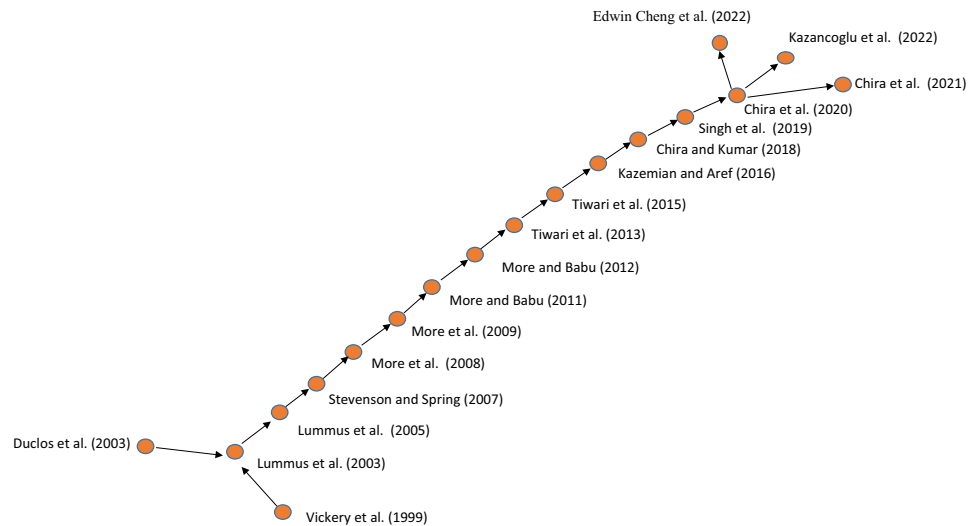
Local Path Analysis (Complete Corpus)

The authors also found that there are distinct paths emerging out of the main paths. To deepen our understanding of these relationships, the authors conducted a local path analysis. The following section elucidates a discussion on the local backward and forward originated from the main path topics but are interdisciplinary in nature.

The authors performed the backward and forward local path analysis to understand the dependency of research outcomes. The backward path analysis search begins with sink papers and ends with source papers. A paper which is cited by other studies, but itself does not cite any other paper on the path is termed a source, whereas a paper that cites other papers but is not cited by any research study is termed a sink paper (Singh et al., 2022).

The local backward main path, as shown in Fig. 5, covers literature from the latest research to the earliest conducted research, emphasizing the studies conducted in the latest year. A few papers were specific only to the local backward path. Delic and Eysers (2020) proposed a conceptual framework to examine relationships between additive manufacturing adoption and SCF and its SCP. A conceptual model was developed and additive manufacturing flexibility characteristics were mapped to various mitigation strategies in case of uncertain events (Alogla et al., 2021). In the case of a shipbuilding supply chain, SCF turns out to be an effective solution to face uncertainties. Zhu et al. (2021) found domestic procurement, cooperation among different supply chain echelons, vigilant supervision by the supplier and emergency response construction as significant design requirements for a ship building supply chain. Progressing toward the digital era, Meidute-Kavaliauskiene et al. (2021) investigated the

Fig. 4 Local forward path for generic corpus



effect of blockchain technology on a supply chain and revealed the improved SCP in terms of its transparency, flexibility, and security. The revolution of BDA in digital supply chain-enabled organizations is of crucial business significance for developing a sustainable and competitive supply chain. SCF significantly fosters BDA-based proposed models and the CE to enhance SCP (Cheng et al., 2022). BDA did not directly impact sustainable performance; it motivated people to help and implement CE, and CE increased the SSC flexibility. Nayal et al. (2022b) empirically investigated the connection between flexibility, the adoption of AI and IoT technologies, and the SCP of firms within the context of the circular economy environment. The findings of the study reveal that information and organizational flexibility exert the most significant influence on the adoption of AI and IoT. Notably, organizational flexibility fully mediates with AI and IoT, directly influencing the performance of firms. Additionally, the analysis suggests that CE will affect the relationship between AI-IoT adoption and organizational flexibility.

The SCP can be adversely affected by disruptions caused by environmental conditions. The global supply chain must be agile, flexible, and responsive to withstand disruptions such as the COVID-19 pandemic. Supply Chain Agility (SCA) was found to be directly impacted by flexibility while responsiveness of the global supply chain was impacted by SCA and SCF (Kazancoglu et al., 2022a, 2022b). Elrefae and Nuseir (2022) developed a framework to study the link between SCF and use of blockchain and information sharing. The study revealed the impact of blockchain technology and information technology on SCF, consequently impacting an organization's competitive advantage. SCF was also positively impacted by information sharing and strategic partnerships in the context of Chinese enterprises (Yang et al., 2022b).

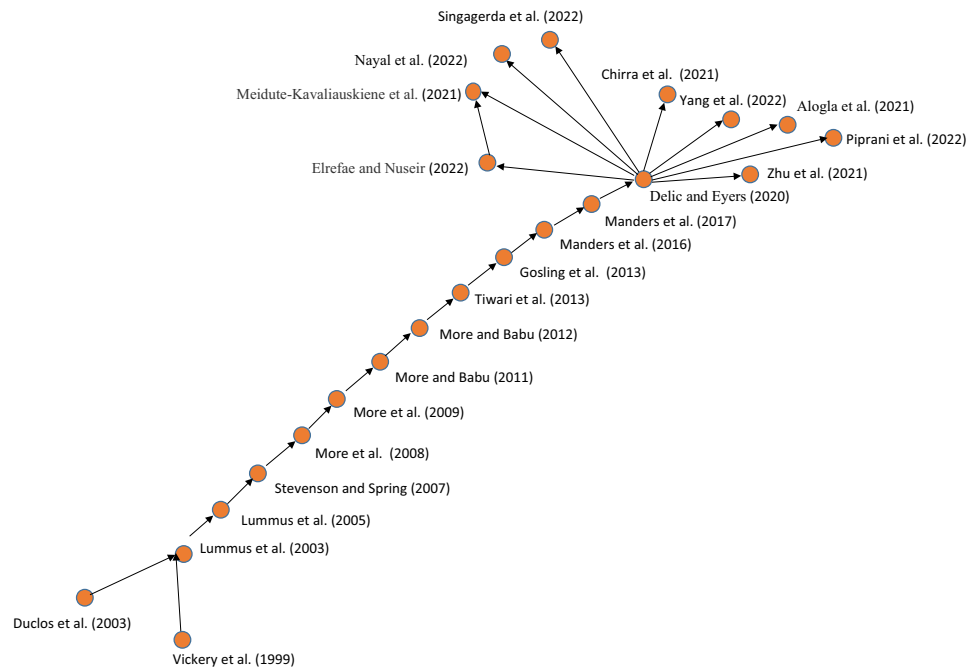
Singagerda et al. (2022) studied the impact of enhancing visibility across a supply chain and its impact on SCF. A study by Piprani et al. (2022) revealed that multi-dimensional SCF significantly contributed to ameliorating SCR.

Key Route Path Analysis (Complete Corpus)

The authors also performed key-route path analysis. Performing a key-route path analysis is necessary as some significant nodes may not be captured even after combining the local and the main path. Therefore, key-route path analysis completes the detailed elaboration for trajectory of evolution of a topic. It was found that key-route analysis, in this case, coincides with forward MPA. The evolving research trend in this area is sequential in time; therefore, the key route and main path coincide. The list of papers which appeared during MPA is provided in Table 3 along with their contribution toward SCF.

The papers which appear on the main path focus specifically on the flexibility of a supply chain, its conceptual framework, and its impact in an organization. On the other hand, the papers appearing in the local paths highlight inter-disciplinary studies done on SCF. For example, the implementation of Industry 4.0 technologies such as AI and IoT enhances the execution of Supply Chain Finance (SCF). Furthermore, the environmental aspect has been integrated into the discourse on SCF, with the incorporation of circular economy principles into the discussion. In summary, the global main path offers a high-level view of the major trends and developments in a research field, showcasing the significant milestones and influential contributions. Conversely, the local path provides a more detailed and focused analysis, zooming into specific subsets or clusters to uncover intricate relationships and patterns within a smaller context. Both

Fig. 5 Local backward path for generic corpus



approaches are valuable in scientometrics, offering complementary insights into the evolution and impact of scientific knowledge.

Keyword Discussion for Global Main Path (Complete Corpus)

The essence of SCF papers is discussed in the global main path. Though based on the same theme, the papers are distinct in terms of the aspect of SCF being studied. Stevenson and Spring (2007) bring in the discussion of uncertainty in organizations and the role of information systems in mitigating it. The issue of uncertainty is extended to demand uncertainty and lead time uncertainty by Tiwari et al. (2013) and role of flexibility in managing uncertainty is elaborated. Uncertainty in SC is discussed by Gosling et al. (2013) from construction sector point of view and in the context of automobiles by Chirra et al. (2021). Other crucial aspects such as performance of an organization, dynamic supply chain and management of a multi-product multi-echelon SC have also been highlighted (More & babu, 2009, 2011; Singh et al., 2019). Recent trends show the inclination of research themes on BDA, CE and SSC (Cheng et al., 2022; Kazancoglu et al., 2022a, 2022b). Implementing flexibility for improving SCP is incomplete without a flexibility measure. More and Babu (2009), proposed a Balanced Scorecard technique for assessment of SCF. The keywords of papers occurring in the global main path are listed in Table 4.

Global Main Path Analysis for GJFSM

Figure 6 shows the global main path for GJFSM. Some papers appearing in the citation paths of complete corpus belong to the GJFSM, which confirms our choice for contrasting the journal's citation path with the citation path of the complete corpus of papers.

The various components of SCF were explored and a conceptual model was proposed by Lummus et al. (2003). A review conducted by Singh and Acharya (2013) highlighted various dimensions of flexibility in a SC and its crucial role in optimizing activities in every stage of the SC. The review reveals the ease of achieving flexibility in a lean SC. A mixed integer linear programming model was presented by Kazemian and Aref (2016) to propose an approach for designing SC networks to optimize its total cost. The study integrates bottlenecks into flexible capacity planning and helps managers take strategic decisions in order to reap financial benefits. Chirra and Kumar (2018) linked SCF with sales promotional schemes and helps field specialists take strategic decisions. Strategies such as volume flexibility, manufacturing flexibility and supplier collaboration flexibility are highlighted as most significant in decision making for enhanced performance. Singh et al. (2019) addressed the complexity in a soap SC due to variation in size, flavor, color and packaging requirements. Flexibility solutions in the SC proved to have a positive impact on its performance. Apart from financial progress, in the recent past, performance of industries has included environmental impact as well. A review was conducted by Dhillon et al. (2023) to integrate the findings from a

Table 3 Papers contributing to SCF

Author	Paper contribution towards SCF
Vickery et al., (1999)	The study focused on different dimensions of supply chain flexibility, such as volume, target, and market flexibility. It exhibits the relationships among functional interfaces, environmental uncertainty, and business performance
Lummus et al., (2003)	It proposed a new model that specifies important characteristics required within and between each supply chain node to improve flexibility in the supply chain network
Lummus et al., (2005)	For Collecting information, expert opinion is considered a method to determine the importance of various customer demand characteristics. Subsequently, it developed a model and framework for future studies
Wadhwa et al. (2008)	The paper contributed to the role of different types of flexibility, such as no, partial, and full flexibility, in a dynamic supply chain. The author emphasizes that each node should be involved during decision-making to improve cost reduction and key performances substantially
Stevenson and Spring (2007)	This paper explored the supply chain as a unit of analysis by proactively combining different flexible supply chain strategies to reduce unwanted uncertainty and focused on the roles of its design, collaboration, and inter-organizational information systems
More and Subash Babu (2008)	This paper used ANOVA and factor analysis to determine the various trends. The results implicated how various organizations perceive and practice different policies for SCF differently
More and Babu (2009)	This paper has given importance to financial flows in addition to material flow and information flow to improve the financial performance of an organization
More and Babu (2011)	The research focused on identifying and analyzing relationships among the supply chain flexibility types. It established a contextual relationship for identifying relevant factors in various SCF types and evaluated their dynamics
More and Babu (2012)	Data Envelopment Analysis (DEA) approach is introduced as a benchmarking tool to be competitive by building enough flexibility in SCs for quickly responding to disruptions, emerging as a new business strategy
Tiwari et al., (2013)	This paper analyzed to attain robust supply in all feasible scenarios at the supplier–buyer interface for supply chain flexibility. Proposed a mathematical model considering the procurement costs by analyzing demand and lead time uncertainties
Gosling et al., (2013)	This paper contributed to establishing a relationship with the field and concepts by proposing a framework for integrating supply chain structures, uncertainty, flexibility, and new products in pipeline management
Liao and Marsillac (2015)	This paper was developed and tested empirically by integrating external knowledge awareness with product innovation in supply chains and examining organizational awareness
Manders et al., (2016)	This paper integrated logistic services and retailers to explore the flexibility of supply chains
Chirra and Kumar (2018)	This paper highlighted the sales promotional schemes and their effect on supply chain flexibility to keep the supply chain competitive globally
Singh et al. (2019)	This author applied a system dynamics model to access the flexibility of the supply chain and its improvement during the fulfillment of backlog orders and variation in demand
Chirra et al., (2021)	They established a relationship by applying the IPR approach to verify flexibility in the supply chain in SPS performance in the other function, such as procurement flexibility and organizational flexibility
Cheng et al. (2021)	This paper analyzed the impact and variability of sustainable supply chain flexibility by adopting a big data analytics approach in digital supply chains
Bag and Rahman (2021)	The author proposed that data analytic capability plays to identify a critical operation level of capabilities in the circular economy to develop dynamic capabilities
Kazancoglu et al., (2022a, 2022b)	The authors have drawn a relationship between agility and flexibility for the global supply chain during the pandemic, such as covid-19, to make the global supply chain resilient during disruption

flexible green SC, to bridge the gap between environmental impact and financial performance.

The Local Main Paths for GJFSM

The local forward and backward paths specific to GJFSM are shown in Figs. 7 and 8 respectively. Lummus et al. (2003) proposed a conceptual model for SC flexibility considering the existing literature on flexibility and the then available scant literature on SCF. This was among the

first studies that focused on flexibility in a SC thus contributing to a less researched area. Following Lummus et al. (2003), exploration into SCF accelerated. A review of literature evaluating SCF was carried out by Singh and Acharya (2013). Its primary focus was the dimensions of flexibility that provided a comprehensive scenario. A case study analysis was carried out by Mahajan et al. (2013) that unearthed the flexibility issues faced in a corn manufacturing SC. The analysis of the case bridges the gap of flexibility by suggesting remedial actions. Kazemian and

Table 4 Keywords for papers occurring in the main path of generic corpus

Authors	Author keywords
Vickery et al. (1999)	
Duclos et al. (2003)	Flexibility Supply chain management
Lummus et al. (2003)	Delphi method Flexibility Strategy Supply chain management
Lummus et al. (2005)	Delphi study Supply chain Supply chain flexibility
Stevenson and Spring (2007)	Flexible organizations Information systems Supply chain management Uncertainty management
More and Subash Babu (2008)	Indian manufacturing industries SCF Supply Chain Flexibility
More and Babu (2009)	Flexibility Performance assessment State-of-the-art survey Supply chain management
More and Babu (2011)	Flexibility types Hierarchical relationship structure Interpretive structural modeling Relationship dynamics Supply chain flexibility
More and Babu (2012)	Balanced scorecard Flexibility metrics Flexibility scorecard Supply chain Supply chain flexibility
Tiwari et al. (2013)	Demand uncertainty Flexibility measure Lead time uncertainty Plant disruption Procurement cost Risk Supplier selection Supply chain Supply contract
Gosling et al. (2013)	Construction decoupling point flexibility pipeline structured methods supply chain uncertainty

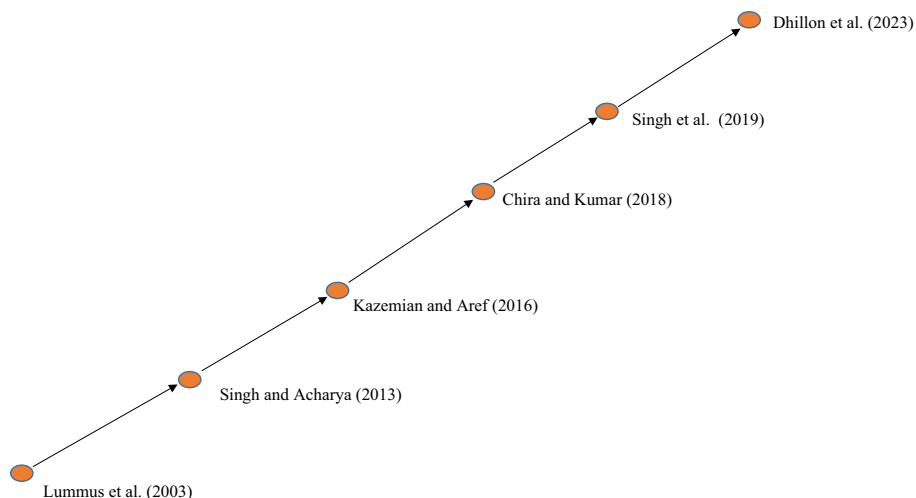
Table 4 continued

Authors	Author keywords
Manders et al. (2016)	Flexibility dimensions FMCG food supply chain Goals; Network theory Stakeholder theory Supply chain flexibility
Chirra and Kumar (2018)	Automobile industry Demand uncertainty Fuzzy DEMATEL Sales promotional schemes Supply chain flexibility Supply chain risk management
Singh et al. (2019)	Soap manufacturing Supply chain flexibility Supply chain performance System dynamics
Chirra and Kumar (2020)	Automobile industry Interpretive ranking process Performance measures Sales promotional schemes Supply chain flexibility automobile industry
Chirra et al. (2021)	graph-theoretic and matrix approach sales promotional schemes Supply chain flexibility supply chain sustainability
Cheng et al. (2022)	Big data analytics circular economy supply chain flexibility supply chain performance Sustainable
Kazancoglu et al., (2022a, 2022b)	Agility Digital technologies Flexibility Resilience Responsiveness Sustainable supply chains

Aref (2016) suggested an optimization model for improving flexibility and reducing the SC cost in a multi-echelon SC. Considering an automobile industry, fourteen SCF strategies were identified among which manufacturing flexibility, volume flexibility, supplier collaboration flexibility and supplier flexibility were ranked as being the most crucial activities impacting an organization's performance (Chirra & Kumar, 2018). Singh et al. (2019) studied



Fig. 6 Global main path for GJFSM



flexibility with respect to the personal care SC. The study unveiled the considerable positive influence of flexibility strategies on performance of a soap producing unit. A review conducted by Pérez-Pérez et al. (2019) posited a framework to guide managers in making decisions that increase flexibility in their organization.

Since decades, goal of any organization has been to improve its performance but its environmental impact has not been given equal importance. Shibin et al. (2015) highlighted the barriers and drivers for a green and flexible SCM in a closed loop system. Dhillon et al. (2023) carried out a literature review on flexible and green SCM and revealed the lack of attention paid to flexible and green SCM in emerging economies.

Keyword Discussion for GJFSM's Global Main Path

The Table 5 shows the keywords of papers occurring in the global main path of GJFSM. Flexible SC is the common topic of discussion among all these papers. What differs is the dimension of the SC that is discussed in the context of flexibility.

A study by Lummus et al. (2003) revolves around theory building for flexibility measurement whereas Singh and Acharya (2013) posit research incorporating the uncertainty faced by a SC and the role of flexibility in overcoming any uncertain event. Extending the study to multi-echelon SC, Kazemian and Aref (2016) focus on the bottlenecks within the SC and showcase the role of flexible network designs in overcoming the uncertainties. Chirra and Kumar (2018) include the sales promotion schemes in an automobile SC and emphasize the various flexibility

Fig. 7 Local forward path for GJFSM

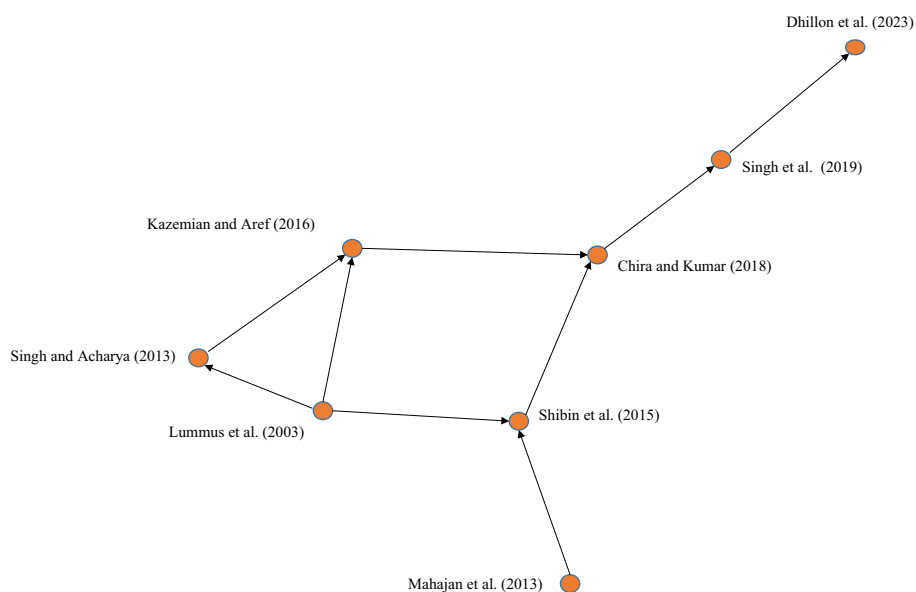
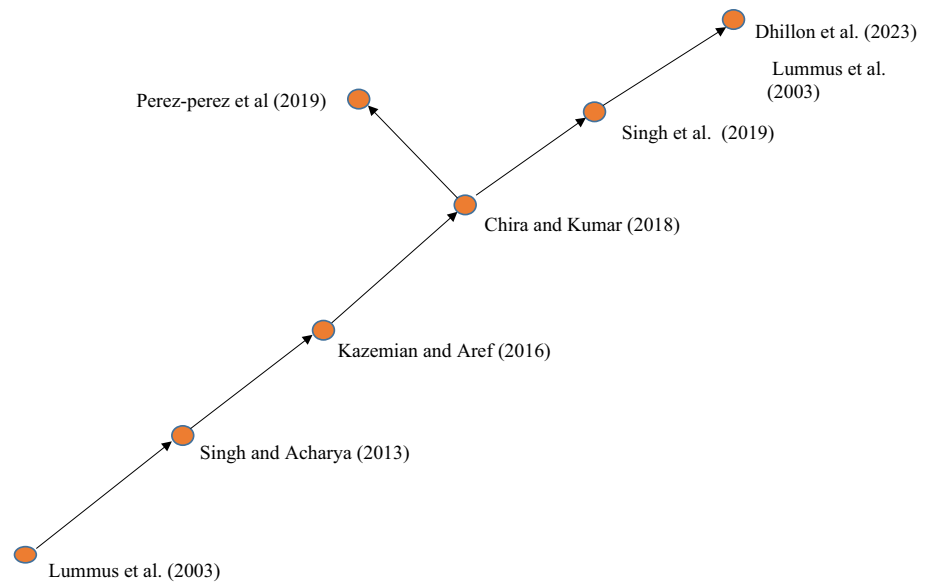


Fig. 8 Local backward path for GJFSM

strategies for implementing risk management. Challenges of a multi-product multi echelon SC was discussed by Singh et al. (2019). The discussed papers elaborate the uncertainty, risk and performance dimensions of a supply chains. The environmental impact which is the need of hour, is discussed by Dillon et al. (2016). Their study discusses the enablers and barriers that emerging economies face in the implementation of flexible and green SC. It also provides strategies for mitigating the negative environmental impact in supply chains.

Cluster Analysis

Cluster Analysis (Complete Corpus)

The cluster analysis for the complete corpus of short-listed papers from various journals is discussed in the following sections. Five clusters have been identified.

Cluster 1: Supply Chain Management (SCM) The first cluster gives a holistic view of SCM. Keywords such as SCF, SC integration and its dynamic capabilities form the first cluster. Discussion about SCP indicators is prevalent in literature (Anjomshoae et al., 2019; Jha et al., 2022). SCF enhances its agility and resilience, which eventually improves the SCP (Ramos et al., 2023). The contribution of SC integration in strengthening its flexibility and resilience, especially during pandemic, has been widely discussed (Shen & Sun, 2023). Gu et al. (2021); Juan and Li (2023) posit the role of resilience from the supplier as well as the customer in improving a SCP.

Cluster 2: Flexibility The primary focus of the second cluster is on flexibility and uncertainty of a SC. Unlike the

first cluster that discusses a holistic view of the SCP indicators. Several researchers (Shukor et al., 2021; Singh et al., 2019) have emphasized and assessed SCF as one of the key factors addressing uncertainty in a SC. Be it destruction due to pandemic (Dohale et al., 2023; Sarker et al., 2021) or natural calamity like flood or earthquake (Durach et al., 2022), SCF has always come to the rescue. The role of SCF in implementing a CE has also been explored (Bag & Rahman, 2023; Bai et al., 2020).

Cluster 3: Agility, Resilience and Risk Management The third cluster focuses upon SCP with respect to SCA, its resilience and risk management. Keywords include SCP, SCR and SCA. Literature discusses strategies to improve SCR, especially when it is facing uncertainties (Naghshineh & Carvalho, 2022). The role of Industry 4.0 technologies such as blockchain and AI-IOT are proven to have a positive impact of the SCP (Ozdemir et al., 2022). Wicaksana et al. (2022) reviewed leading ‘supply chain risk management’ journals and revealed the newly surfaced risks along with approaches to mitigate them.

Cluster 4: Environment and Uncertainty Environmental uncertainty and achieving competitive advantage while facing uncertainties is the primary focus of the fifth cluster. Keywords such as Industry 4.0, lean SC and CE are included in this cluster. Galvoa et al. (2022) reveal how implementing CE may be converted to a competitive business model. Combination of sustainable and green SC and lean technology is proven to enhance competitiveness of an organization (Mathiyazhagan et al., 2022; Teixeira et al., 2022).

Table 5 Keywords for papers occurring in the main path of GJFSM

Lummus et al. (2003)	Flexibility Measurement Supply chain Theory-building
Singh and Acharya (2013)	Dimension Flexibility Supply chain Theoretical framework Uncertainty
Kazemian and Aref (2016)	Bottleneck Flexibility Multi-echelon Network design Supply chain Uncertainty
Chirra and Kumar (2018)	Automobile industry Demand uncertainty Fuzzy DEMATEL Sales promotional schemes Supply chain flexibility Supply chain risk management
Singh et al. (2019)	Soap manufacturing Supply chain flexibility Supply chain performance System dynamics
Dhillon et al. (2022)	Drivers and barriers Emerging economies Flexible supply chain management Green supply chain management Strategies and practices Systematic literature review

Cluster 5: Supply Chain Risk Management The fifth cluster lays emphasis on management of SC risk. The cluster entails keywords such as information sharing, demand uncertainty and supplier selection. Scholars have discussed various approaches for risk management and handling uncertainties in a SC (Waqas et al., 2023; Wicaksana et al., 2022). This includes information sharing and collaboration (Baah et al., 2022; Munir et al., 2020; Wang et al., 2022), use of Industry 4.0 technologies (Chowdhury et al., 2022; Nayal et al., 2022a, 2022b).

Cluster Analysis (GJFSM)

The network visualization for keywords used specifically considering GJFSM is shown in Fig. 2. To ensure an even spread, a threshold value for occurrence of keywords was set to 3. Setting the threshold value too high would have

resulted in missing significant clusters and setting a very low value would have blurred the line of demarcation between clusters. Hence, the chosen threshold ensures heterogeneity among the clusters formed as well homogeneity within each cluster. Using keyword co-occurrence analysis 4 clusters were identified with 16 links. For further analysis, the clusters were exported to MS Excel.

Cluster 1: Risk in Green SC Cluster 1 focused on risk within a SC, specifically for a green SC. Evaluation of risks in a green SC as well as their mitigation have been discussed (Dhillon et al., 2023; Mangla et al., 2014).

Cluster 2: Agility in SC SCA is the primary focus of cluster 2. GJFSM discusses agility in various contexts. Topics such as impact of Information Technology (IT) capabilities and transformational leadership on enhancing organizational agility have been discussed in recent times (Awwad et al., 2022; Prabhu & Srivastava, 2023). The journal also discusses handling of agility issues while stressing on the necessity for an agile SC (Alnoor et al., 2023; Bengono, 2022).

Cluster 3: Flexibility in SC Cluster 3 emphasizes flexibility in a SC. Impact of a flexible SC on an organization's performance and role of technology in reaping benefits of a flexible SC are explored in GJFSM (De la Gala-Velásquez et al., 2023; Wided, 2023). The journal gives various managerial implications to implement a more adaptive and a flexible SC (Bengono, 2022; Singh et al., 2021).

Cluster 4: Uncertainty in SC Cluster 4 focused on uncertainties within a SC. Uncertainty could be in form of a SC that is not flexible enough to hedge risk in the volatile, uncertain, chaotic, and ambiguous world (Sushil, 2017). A less agile SC may not be robust enough to face disruptions during uncertain times (Hasan et al., 2023; Settembre-Blundo et al., 2021).

Discussion

Citation Path Analysis

The global main path encapsulates the overarching trajectory through which knowledge unfolds within a specific research domain. It delineates the primary themes, pivotal contributions, and crucial milestones that have steered the course of a particular area of research over time. Analyzing this global main path provides a panoramic view, offering insights into the general progression of knowledge and the fundamental research directions that have significantly

influenced the field, painting a broad canvas of scholarly evolution.

Conversely, the local path within scientometrics delves into a more focused and confined perspective within the broader research domain. It zeroes in on specific relationships, interactions, or influences among variables; be it authors, papers, keywords, or concepts, within a distinct subset or cluster of research articles or studies. This localized analysis offers a granular examination of the interconnections and dynamics within a particular topic, subfield, or group of researchers, shedding light on intricate relationships and patterns within a smaller, more defined context. Together, the local and the main path approaches complement each other, presenting a comprehensive understanding of the progression and impact of scientific knowledge across different scales of analysis.

Main Path Analysis

The MPA has enabled understanding of the evolution of research focused on SCF, over the last two decades. The research has also covered interdisciplinary papers which are related to SCF. SCF is the central theme discussed in the primary literature pathway on a global scale. Although centered around SCF, the papers diverge in the specific aspect of SCF that they focus on. Uncertainties in different sectors, such as automobile sector, construction sector, and in the context of organizations have been discussed. Other pivotal aspects such as organizational performance, dynamic supply chains, and management of multi-product multi-echelon supply chains have been emphasized. SCF has been crucial in mitigating disruptions during uncertainties of demand and supply. Recent trends indicate a growing research interest in BDA, CE and SSC. Strategies to enhance the SCP through flexibility are not complete without a comprehensive measure of flexibility. Balanced scorecard is one such technique that has been used for assessing the flexibility of a supply chain.

The trajectory of SCF began with discussions on attributes of a network of flexible supply chains (Duclos et al., 2003; Lummus et al., 2003). Strategies for SCF framework extended to uncertainty measurement and risk mitigation strategies. Babu et al. (2008) studied trends in a dynamic supply chain for quantification of uncertainty and uncertainty reduction was studied in-depth by Stevenson and Spring (2007) with the application of flexibility strategies. Later several studies focused on analyzing and improving SCP Manders et al. (2016) by optimizing bottlenecks (Kazemian & Aref, 2016) and integrating SCF with different functions of an organization (Chirra & Kumar, 2018; Manders et al., 2017).

Cluster Analysis

A cluster analysis performed on a corpus yields a cluster of research articles that are homogenous within a cluster and heterogenous across different clusters. Five clusters were formed after performing cluster analysis on the generic corpus of papers. These clusters take a holistic view of the supply chain and not simply focused on SCF. The SCM cluster focuses more on performance indicators prevalent in literature which may be used to assess the enhancement of SCP due to introduction of flexibility. The cluster named flexibility posits SCF to be one of the key factors for mitigating disruptions in a supply chain. There is an urgent need for transition from a linear economy to CE and flexibility has a significant role in this. The third cluster focusing on agility, resilience and risk management emphasizes the qualities a supply chain should possess to attain flexibility. SCR and SCA play a vital role in enhancing the performance of a supply chain. Studying the nexus of three streams of literature and analyzing their impact on enhancing SCP would be highly beneficial. The role of environment and the benefit of implementing SCF for CE is highlighted in the cluster 4 which focuses on the environment and uncertainty. Environmental and social sustainability metrics could be integrated into SCF metrics to analyze the vital role of environment in enhancing flexibility. The fifth cluster lays emphasis on management of SC risk. Psychological and behavioral dimensions influencing the perception of risk in a flexible supply chain could be examined. All the five clusters capture the different aspects of a supply chain. Incorporating flexibility, assessing associated risks, managing disruptions, and ultimately evaluating SCP for further enhancement are aspects effectively addressed through cluster analysis.

Unlike the clusters created from the generic corpus of papers, the clusters formed from corpus of GJFSM specifically capture the flexibility aspects of a supply chain, rather than taking a holistic view of the supply chain. The first two clusters discuss the contribution of agile and green supply chains in enhancing the SCP. The third cluster is specifically dedicated to SCF and the benefits reaped from flexibility of a supply chain. Uncertainties and an ambiguous environment led to disruption in a supply chain. The fourth cluster suggests Lean supply chain and SCF as ways to deal with such uncertainties. Exploring the impact of geopolitical uncertainties on supply chain flexibility and suggesting strategies to navigate such situations is a worthwhile endeavor.

Benefits of SCF

Flexible supply chains have the capability to mitigate supply disruptions during demand fluctuations while



maintaining the same customer service levels (De la Gala-Velázquez et al., 2023). Adopting SCF can result in greater customer satisfaction and minimized levels of inventory (Gijsbrechts et al., 2022). SCF has the ultimate aim of providing satisfaction to the customer (Oliveira-Dias et al., 2022). The concept of lean in the SC ensures quick product delivery to the end customer while minimizing waste that can lead to enhancement in responsiveness of the company as well as an improved business performance (Abdelilah et al., 2023). Therefore, SCF can be easily achieved by operating in a lean system. Hence, it is imperative to embrace SCF and proactively respond to customers' needs (Sara et al., 2022).

Implications of the Study

This research paper is an attempt to trace the trajectory of evolution in the domain of SCF. The citation path analysis provides theoretical perspectives on supply chain flexibility, its application across industries, and its multifaceted bearing on SCP thus providing useful insights for researchers and practitioners.

Theoretical Implications

- The study underscores the significance of flexibility strategies, including market flexibility, volume flexibility, and product launch flexibility, in improving the SCP. It also draws attention to the extension of flexibility strategies from intra-organizational to cross-organization contexts.
- The study examines the categorization and interdependence of flexibility types, examining their applicability at the strategic, operational, and tactical levels.
- Application of cluster analysis to the complete corpus of identified journals has identified thematic areas such as SCF, SCA, SCR, risk management, environment and prevailing uncertainty in the supply chain. Similarly, cluster analysis specifically applied to GJFSM has identified risk, agility, flexibility and agility as important themes for research.
- The study also emphasizes flexibility as a potential solution to address issues such as product quality, supplier reliability and competitive challenges.
- The study reveals that dynamic capabilities can be either knowledge based or resource based. Knowledge based dynamic capabilities can be absorptive, knowledge management or organizational learning type while resource based dynamic capabilities could be sensing, seizing or transforming type capabilities. The significance of knowledge is more than that of resources for mitigation of risks in disruptive situations. Further, the

findings reveal the importance of different type of capabilities in driving financial performance.

Implications for Researchers

- For researchers, the paper outlines the evolution of research on SCF and the trajectory which it has followed. It can help researchers understand major concepts related to SCF.
- Initial studies commenced with defining SCF (Stevenson & Spring, 2007; Vickery et al., 1999), proposing a conceptual model for SCF (Duclos et al., 2003), identifying its various dimensions (Lumus et al., 2003) and studying its impact assessment (Moore and Babu, 2011).
- Later, researchers focused on SCF in the FMCG sector (Manders et al., 2016), dynamics modelling (Singh et al., 2019), sales promotional schemes in the automobile industry (Chirra & Kumar, 2020).
- The latest studies are focusing on SCF's contribution to transitioning to CE (Cheng et al., 2022), role of SCF in reverse logistics (Kazancoglu et al., 2022a, 2022b).
- Research gaps on the main path indicate scope for research that integrate digital technologies to enhance SCF and delve into the role of a flexible supply chain for transitioning to CE. This indicates research directions for future.
- The main path indicates papers which have been cited often and hence have had substantial impact on research. This analysis can help researchers improve the quality of papers by identifying relevant literature and assessing the impact of their work in comparison with other researchers.

Implications for Practitioners

- For practitioners, the study can provide useful inputs for implementing SCF in an organization. Industry has to thrive in a volatile, uncertain, complex, ambiguous (VUCA) world and flexibility in the supply chain is a pre requisite for long-term survival of any firm today.
- Studies included in this paper can be of immense value to industry practitioners, especially studies on enablers and barriers to implementing SCF and performance measurement of SCF. Both these topics can help industry to enhance SCF in the organization. Enablers can help companies formulate policies at the firm level and promote SCF in the firm. Measurement is necessary for bringing about performance improvement. Studies on performance measurement can help a company measure the flexibility in its supply chain.

- This study can also guide companies identify potential research projects which can be executed to enhance SCF in the organization.
- With respect to the automobile sector in India, the study identifies key strategies, including volume and supplier collaboration flexibility, as essential drivers of performance. Variability in demand is recognized as a challenge that requires resource optimization and capacity utilization. The importance of robust supplier and buyer relationships in mitigating disruption risks and demand uncertainties has also been emphasized.

Conclusion

This study has reviewed the SC flexibility literature by systematically collecting publications from the Scopus database and applying MPA to understand evolving research trajectories in this critical area. Next, analyzing keyword co-occurrence, major themes along with their interrelationships have been identified. The study also enumerates authors and papers appearing in the citation paths (global main, forward, backward, and key route). Organizations strive to implement SCF while leveraging best practices in technology and management. Citation path analysis reveals an evolving research trajectory that draws attention towards information flows, financial flows, sectoral attention, SC collaboration, industrial IoT, data analytics, and big data. The most recent research focuses on the impact of SCF and SCA during the COVID-19 pandemic, and the ability of the supply chain to avoid disruptions.

Initial studies highlight various benefits of adopting flexibility in the SC. From the findings related to the construction, automobile, and FMCG industries, it has been clearly stated that flexibility significantly impacts logistics, product innovation, procurement, and sales promotion. The application of big data analytics, which was also studied in the main path, revealed that it plays a critical role in developing a SSC in an organisation as it embarks on the journey of digitization and CE. Only a few studies have been carried out on reverse logistics and impact of CE on performance of the organization in terms of flexibility. Also, there lies an opportunity to study the impact of Industry 4.0 technologies such as blockchain, AI, IoT, on the implementation of SCF.

Discussion in the GJFSM follows the same trajectory. Initial studies explained the concept of SCF using a theoretical framework. The in-depth review of SCF literature was followed by a discussion on mitigation of uncertainty issues faced in different SCs like the automobile and soap manufacturing industries. SCF was proposed as a probable

solution to overcome SC uncertainty. Out of six papers appearing in the global main path of GJFSM, four papers are common to the citation paths discussed in the generic corpus. In other words, 66.67% of the papers in GJFSM main path coincide with the citation path of the generic corpus. Moreover, the global path of GJFSM includes a latest paper of 2023 by Dillon et al. (2023) while the generic corpus does not. The paper emphasizes the deteriorating environmental condition and the need to transition to a CE. However, such papers connecting CE to SCF are just a handful.

Limitations and Future Research Directions

This paper utilizes data available in Scopus. Some of the research work in this area may be available in WoS database but not available in Scopus. Such research papers have been excluded from the study and need to be included in future studies. Moreover, this paper provides a qualitative discussion on the research trajectory of SCF. Future research could provide a quantitative discussion on this trajectory.

Results from this paper point towards the need to lay more emphasis on emerging technology and management perspectives. Trends in MPA highlight the research progressing towards Industry 4.0, especially adopting BDA and blockchain technology. The establishment and use of information can be more focused on the return on infrastructure investment.

A more comprehensive view is required to understand the various types of uncertainties that can affect the adoption of smart SC networks. Future research can progress in developing interfaces between smart factories, systems, and members involved in the SC by considering emerging technologies, such as digital twins, IoT, and 5G, that are likely to inspire future supply chains. This can result in performance enhancement of a firm with respect to experiencing greater responsiveness as well as improved product/service quality. Future studies could focus on cross industry comparative analysis of performance indicators in context of a flexible supply chain. Moreover, there is a need to propose designs of SC that are fit for CE while also excelling in terms of flexibility. The harm inflicted on human population can be reduced by transition to CE and studies pertaining to application of SCF in transitioning to a CE can be helpful. Also, the role played by reverse logistics in making a supply chain flexible can be explored.

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Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Key Questions Reflecting Applicability in RealLife

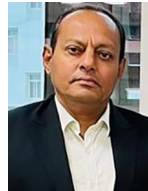
1. How is flexible supply chains impact the adoption of circular economy?
2. How innovation in technology can help in realizing the benefits supply chain flexibility?
3. How supply chains can be made more flexible to mitigate disruptions?

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