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Looking back and moving forward: A temporal literature review and comparative analysis of barriers to sustainable supply chain management

回顧與前瞻：永續供應鏈管理障礙的時間性文獻回顧與比較分析

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Abstract: Industrial activities increasingly threaten environmental sustainability and human well-being. Addressing these challenges necessitates integrating sustainability into operations and supply chains, primarily through Sustainable Supply Chain Management (SSCM). However, practitioners encounter numerous barriers throughout SSCM adoption and implementation. Overcoming these impediments is a formidable challenge for most organizations, but current understanding of these barriers remains fragmented. This study examines the temporal context of barriers in SSCM, conducting a thorough literature review using temporal analysis. It seeks to identify similarities, differences, trends, and directions of barriers across different time spans. This approach advances existing literature and offers insights for early-stage SSCM practices. Notably, our study uniquely considers the temporal aspect, a dimension previously overlooked in evaluating these barriers. By analyzing barriers across different time frames, our research elucidates their progression, enabling a clearer understanding of similarities and differences. This understanding facilitates the tracking of improvements and the identification of trends in early SSCM implementation. This paper contributes significantly by delineating temporal patterns and trajectories in SSCM-related barriers.

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Keywords: Barriers, manufacturing, sustainability, sustainable supply chain management, temporal analysis.

摘要：工業活動日益威脅環境永續性與人類福祉，應對這些挑戰需要將永續性納入營運與供應鏈管理之中，特別是透過永續供應鏈管理（Sustainable Supply Chain Management, SSCM）。然而，實務工作者在採行與實施 SSCM 的過程中面臨諸多障礙，克服這些障礙對多數組織而言是一項艱鉅挑戰，但目前對於這些障礙的理解仍相當零散，本研究透過時間性分析進行全面性的文獻回顧，檢視 SSCM 障礙的時間脈絡，旨在辨識不同時期中的相似性、差異性、趨勢與發展方向。此方法不僅推進了現有文獻，也為 SSCM 初期實踐提供洞見。值得注意的是，本研究特別將時間性作為一個維度加以考量，而這一面向在過往對障礙的評估中往往被忽略。透過分析不同時期的障礙，本研究揭示了其演變歷程，使得相似性與差異性得以更清晰地理解，這種理解有助於追蹤改善情況，並辨識 SSCM 初期實踐的趨勢。本研究的重要貢獻在於描繪出 SSCM 障礙的時間模式與發展軌跡。

關鍵詞：障礙、製造業、永續性、永續供應鏈管理、時間性分析。

1. Introduction

Global industrial advancements have flourished, but often at the expense of adverse effects on both the environment and human well-being. Numerous studies (Bai *et al.*, 2019; Chen, 2008; Gupta *et al*., 2020; Narayanan *et al*., 2019) underscore the detrimental impacts of industrial activities on sustainability. Historically, conventional supply chain management primarily prioritized economic aspects, neglecting ecological and social considerations (Wu *et al*., 2011). Recognizing the imperative to mitigate environmental threats, greater emphasis has recently been placed on integrating sustainability into operational frameworks and supply chains, particularly within the manufacturing sector (Bai and Sarkis, 2010; Lo *et al*., 2018). Presently, sustainability has become integral for industry practitioners across diverse business sizes and natures (Kaur *et al*., 2018), steering the shift from traditional supply chain management to sustainable

supply chain management (SSCM) (Gollagher *et al*., 2010). Beyond focusing solely on financial performance, SSCM embraces the Triple Bottom Line (TBL) concept, encompassing economic, environmental, and social concerns (Kumar and Goswami, 2019; Nazam *et al*., 2020).

However, the adoption, implementation, and expansion of SSCM have often been hindered by numerous obstacles that can lead to adverse effects (Al Zaabi *et al*., 2013). Recent studies have highlighted that effectively promoting SSCM can pose a significant challenge (Abdallah *et al*., 2012; Faisal, 2010). Consequently, it is crucial for researchers, practitioners, and governments to comprehensively identify and analyze these barriers. This thorough examination is necessary to understand the specific impacts of each barrier during the SSCM implementation (Al Zaabi *et al*., 2013; Nazam *et al*., 2020).

Prior comprehensive literature reviews indicate that numerous relevant studies have predominantly employed specific methodologies to identify and outline the most critical barriers affecting the implementation of SSCM (Al Zaabi *et al*., 2013; Bai and Sarkis, 2020; Dhull and Narwal, 2016; Gupta *et al*., 2020; Kaur *et al*., 2018; Kumar and Goswami, 2019; Narayanan *et al*., 2019; Nazam *et al*., 2020). Some of these studies have also suggested recommendations or solutions aimed at addressing these identified barriers (Gupta *et al*., 2020). Furthermore, several studies have utilized diverse methodologies to scrutinize and discern the influence and interrelationship between these barriers (Al Zaabi *et al*., 2013; Kumar and Goswami, 2019).

Yet, as far as our understanding extends, no prior study has considered the temporal context in evaluating and analyzing barriers. Incorporating the temporal context could provide a comprehensive understanding of the similarities and differences across various time spans. This approach would enable researchers to readily discern the progress made in addressing these barriers and identify trends and directions for the initial implementation of SSCM. Moreover, existing literature reviews on SSCM barriers have predominantly focused on cataloguing and synthesizing barriers identified in prior studies (Alayón *et al*., 2022; Govindan *et al*., 2014; Narimissa *et al*., 2020). However, because these reviews

typically aggregate findings across studies spanning wide time ranges, the reported barriers often appear static, with little indication of variation or transformation over time. As a result, the dynamic evolution of barriers has been underexplored, resulting in limited insights into how challenges have shifted, persisted, or been mitigated across the different phases of SSCM development. By explicitly integrating a temporal lens, this study aims to fill this gap and reveal how barriers to SSCM have evolved, offering more nuanced insights into both persistent obstacles and emerging challenges.

The manufacturing industry represents a particularly critical context for examining barriers to SSCM. Globally, manufacturing accounts for a substantial share of resource consumption, energy use, and carbon emissions, making it central to sustainability transitions (Edomah, 2019). Moreover, as manufacturing firms often operate in multi-tier and globally dispersed supply chains, they face heightened complexity in implementing SSCM practices compared to other industries (Nath and Eweje, 2021). Prior studies have highlighted that sustainability challenges, including high cost burdens, weak supplier capabilities, limited consumer awareness, and inadequate infrastructure, are particularly pronounced in manufacturing-intensive economies (Alayón *et al*., 2022). At the same time, the manufacturing sector plays a central role in shaping sustainable industrial ecosystems, as it directly influences upstream suppliers, downstream distributors, and end consumers (Das and Dey, 2021). For these reasons, analyzing the barriers to SSCM within the manufacturing industry is both timely and essential, offering insights that are not only academically valuable but also practically significant for one of the world's most resource-intensive sectors.

Given that each organization operates with its unique business model, objectives, and capabilities, every facet and participant within the supply chain can impact the implementation of SSCM. Additionally, the assessment of barriers becomes challenging due to the intangible and uncertain attributes associated with them, as highlighted in previous research (Chithambaranathan *et al*., 2015). Consequently, these barriers cannot be accurately quantified using precise numerical values. The intricate interplay among these barriers complicates the

efforts of researchers, practitioners, and governments to gain a clear understanding of their dynamics. As previously mentioned, to fully understand the barriers influencing the field of SSCM, it is imperative to employ a systematic research methodology.

Building on these observations, this study advances the understanding of barriers to SSCM in the manufacturing industry in three key ways. First, it introduces a temporal perspective that has been largely absent from prior SSCM studies. While earlier works typically present barriers as static lists, this study systematically compares them across different time periods, thereby uncovering how obstacles evolve as manufacturing firms progress through distinct stages of SSCM maturity. Second, the study reframes these barriers as manifestations of underlying dynamic capability gaps, highlighting that firms at different stages face specific challenges in governance, knowledge, technology, financial resources, and ecosystem alignment. Third, the temporal mapping of barriers enhances managerial relevance by enabling practitioners and policymakers to distinguish between long-standing systemic obstacles, such as cost pressures and infrastructural deficits, and newly emerging challenges related to digitalization and multi-tier supplier governance. Accordingly, this study aims to enrich the understanding of barriers to SSCM in the manufacturing sector by explicitly incorporating a temporal lens. Specifically, it seeks to: (1) Systematically map the evolution of SSCM definitions and barriers across different time periods. (2) Identify persistent versus emerging barriers, and interpret them as evolving manifestations of dynamic capability gaps. (3) Provide actionable insights for managers and policymakers in manufacturing by distinguishing which challenges require long-term systemic solutions and which demand anticipatory capability development.

While the TBL framework provides a valuable foundation by highlighting the economic, environmental, and social dimensions of sustainability (Fauzi *et al*., 2010), it offers limited explanatory power for understanding why firms succeed or fail in implementing SSCM. To deepen this analysis, the resource-based view (RBV) offers an appropriate theoretical lens. According to

RBV (Barney, 1991), firms achieve competitive advantage when they possess valuable, rare, inimitable, and non-substitutable resources. In the SSCM context, these resources may include specialized green technologies, managerial expertise in sustainability, and cross-functional integration mechanisms. Conversely, the absence or weakness of such resources manifests as barriers that hinder SSCM adoption.

Building on RBV, the dynamic capabilities perspective (Teece *et al*., 1997) extends the analysis by emphasizing that firms must not only possess resources but also continuously reconfigure and renew them to adapt to evolving environments. This perspective is particularly relevant for SSCM, where regulatory requirements, technological innovations, and stakeholder pressures evolve rapidly. Dynamic capabilities such as the ability to integrate digital technologies, foster supplier collaboration, and redesign business models become critical to overcoming emerging barriers.

By explicitly drawing on the RBV and dynamic capabilities perspectives, this study reframes barriers to SSCM as evolving capability deficits rather than static obstacles. This theoretical grounding provides a robust basis for interpreting how barriers persist or emerge over time, thereby linking the temporal analysis of SSCM challenges to broader debates in strategic management.

This study makes interrelated contributions. Theoretically, it advances SSCM research by reframing barriers in manufacturing not as static obstacles but as evolving dynamic capability deficits, thereby linking the barrier literature to the dynamic capabilities perspective. By introducing a temporal lens, the study clarifies the developmental trajectory of SSCM barriers and proposes a new typology distinguishing between persistent and emerging challenges. Methodologically, this study applies a temporal literature review focused on the manufacturing sector. It extends conventional review approaches by incorporating time as a central analytical dimension and provides a replicable framework for future SSCM reviews in industry-specific contexts. Practically, it provides actionable implications tailored to manufacturing firms by tracing the

evolution of barriers and offering a roadmap for prioritizing interventions across different stages of SSCM maturity. For policymakers, the study highlights institutional and regulatory deficiencies specific to manufacturing supply chains, offering empirical evidence to support more effective interventions that foster SSCM adoption and scaling.

2. Methods

To investigate the temporal evolution of SSCM barriers in the manufacturing sector, a systematic literature review (LR) was employed, offering a rigorous and transparent approach for synthesizing prior research and generating insights (Seuring and Müller, 2008). The LR methodology is particularly suitable in this context as it enables the identification of research gaps, the consolidation of conceptual foundations, and the detection of emerging trends that shape SSCM development (Meredith, 1993; Seuring and Müller, 2008; Khan *et al*., 2020).

2.1 Identification and selection process of articles

Following the approach outlined by Jabbour *et al*. (2020), the review process began with a clear definition of the research scope, which is particularly critical in conducting a literature review (Seuring and Müller, 2008). The review specifically aimed to analyze the evolution of SSCM definitions across different time periods and to identify and classify the barriers to SSCM adoption and implementation, with a particular focus on the manufacturing industry.

2.1.1 Search strategy

To ensure rigor and transparency, the search was conducted across multiple academic databases, including Scopus, Web of Science, ProQuest, Emerald Insight, SpringerLink, ScienceDirect, and Wiley Online Library. The following search string was applied:

TITLE-ABS-KEY (“sustainable supply chain”)

AND TITLE-ABS-KEY ("manufacturing")

AND (TITLE-ABS-KEY ("barriers") OR TITLE-ABS-KEY ("obstacles") OR TITLE-ABS-KEY ("challenges"))

Prior studies indicate that SSCM has been consistently practiced since 2004 (Khan *et al*., 2020). Consequently, SSCM has attracted increasing attention in both academic and industrial contexts from 2004 onwards (Khan *et al*., 2020). Therefore, the present review focuses on publications within the period 2004–2025. Only English-language, peer-reviewed journal articles were considered.

Inclusion criteria: (1) Articles that focus on SSCM in the manufacturing industry. (2) Articles that explicitly address barriers, obstacles, or challenges to SSCM implementation. (3) Articles that are empirical, conceptual, or review studies published in peer-reviewed journals. Exclusion criteria: (1) Editorials, book chapters, monographs, conference abstracts, and short notes. (2) Articles that address general sustainability issues without a specific focus on SSCM barriers. (3) Studies that are not related to manufacturing contexts.

The initial database search yielded 258 records. After removing 53 duplicates, 205 unique records were remained for further screening based on titles, abstracts, and keywords. Of these, 98 articles were excluded because they did not address SSCM barriers or were unrelated to the manufacturing context. The remaining 107 full-text articles were assessed for eligibility. After detailed evaluation, 89 articles were excluded due to reasons such as lack of focus on manufacturing SSCM, insufficient analysis of barriers, purely conceptual discussions without empirical or analytical evidence, non-manufacturing contexts (e.g., agriculture), or non-English publications. Ultimately, 18 articles met all inclusion criteria and were incorporated into the qualitative synthesis for this study. The overall process is illustrated in Figure 1.

Although the final sample of 18 articles allows for an in-depth analysis, it is acknowledged that the relatively small number may limit the representativeness of the findings. This limitation reflects the scarcity of focused studies on SSCM barriers in the manufacturing sector. Nonetheless, the systematic selection process ensures that the included articles are highly relevant, offering valuable

insights into the evolution of SSCM barriers in the manufacturing industry over time.

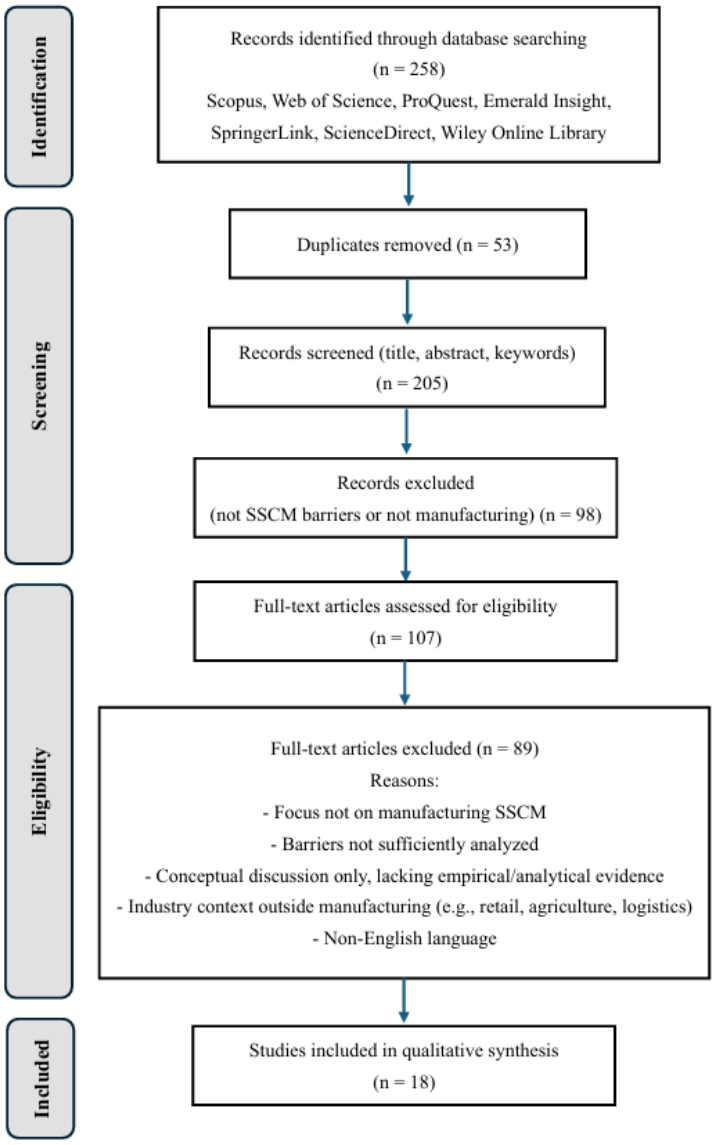

Figure 1
Overview of literature search strategy

2.2 Data analysis

To ensure a rigorous and systematic examination of the selected literature, this study adopted a structured review framework. This framework facilitates a comprehensive temporal and thematic analysis of SSCM research by linking conceptual development with observed implementation challenges. The framework includes six dimensions: (1) Journals, referring to the publication outlets of the selected studies and providing insights into disciplinary focus, research rigor, and scholarly influence. (2) Authors, highlighting key contributors and patterns of collaboration within the SSCM field. (3) Publication year, indicating the temporal distribution of studies and enabling the identification of trends, shifts in research focus, and the evolution of SSCM practices over time. (4) Country of research, reflecting regional variations in SSCM adoption and research priorities. (5) SSCM definitions, including their core focus and key characteristics, to capture the evolution of principles and defining features. (6) Barriers to SSCM, illustrating how challenges have evolved alongside SSCM maturity and providing a basis for linking barriers to capability gaps.

By integrating these dimensions, the review framework not only structures the literature but also facilitates a temporal mapping of SSCM's conceptual and practical evolution. Guided by this framework, this study systematically analyzed the selected articles with a focus on barriers to SSCM adoption and implementation, rather than on solutions. This temporal examination reveals patterns, commonalities, and variations in barriers, providing a dynamic perspective on how SSCM challenges emerge and transform alongside shifts in conceptual definitions and organizational capabilities. The analysis highlights both recurring and period-specific obstacles, identifies evolving trends, and points to future research directions, offering actionable theoretical and practical insights for advancing SSCM practices.

In conducting the temporal literature review, we employed a systematic qualitative coding process to ensure rigor and transparency. First, we developed an initial coding framework based on prior SSCM studies, focusing on two

dimensions: (1) definitions and conceptualizations of SSCM across different time periods, and (2) barriers to SSCM adoption and implementation, which were further interpreted through the RBV and dynamic capabilities perspectives. This theoretical grounding allowed us to classify barriers not only as discrete obstacles but as evolving capability deficits across governance, knowledge, technology, financial resources, and ecosystem alignment. Two researchers independently reviewed and coded each article according to this framework. After the initial round of coding, discrepancies were resolved through discussion and consensus, and the coding categories were iteratively refined to capture emerging themes. This iterative process enabled the coding framework to evolve in line with the temporal structure of the analysis. To further enhance credibility, the coding results were cross-validated against representative examples from each period and compared with classifications proposed in prior SSCM reviews.

3. Results

The results are presented in two sections. The first section offers a descriptive analysis, outlining the distribution of the reviewed articles by publication outlets, authorship, years of publication, and countries of research (Gao *et al*., 2017). The second section presents the findings of the content analysis, with particular emphasis on the temporal evolution of SSCM definitions and the barriers to their implementation. Together, these analyses provide a systematic account of how conceptualizations of SSCM and the associated implementation challenges have progressed and evolved over time.

3.1 Descriptive analysis

In the descriptive analysis section, Table 1 provides a summary of the articles reviewed. As shown in Table 1, the selected articles were published in the following journals: Journal of Manufacturing Technology Management (5 publications), Journal of Cleaner Production (4 publications), Resources, Conservation and Recycling (2 publications), The International Journal of Advanced Manufacturing Technology (1 publication), Uncertain Supply Chain

Management (1 publication) and Cogent Business & Management (1 publication), Journal of Global Operations and Strategic Sourcing (1 publication), International Journal of Sustainable Engineering (1 publication), Asian Journal of Science and Applied Technology (1 publication), Sustainability (1 publication).

Regarding the authors of the selected articles, they are: Al Amin and Baldacci (2024), Al Zaabi *et al.* (2013), Bag *et al.* (2021), Bai and Satir (2020), Chen *et al.* (2022), Dhull and Narwal (2016), Gupta *et al.* (2020), Kaur *et al.* (2018), Khan *et al.* (2021), Mangla *et al.* (2017), Narayanan *et al.* (2019), Nazam *et al.* (2020), Piyathanavong *et al.* (2019), Shisara *et al.* (2021), Sindhwani *et al.* (2019), Singh *et al.* (2020), Sivakumar *et al.* (2018), and Zhu and Geng (2013). It is clear that the articles reviewed are from 18 different authors. Thus, the barriers analyzed in this study reflect diverse perspectives rather than a narrow set of viewpoints.

In terms of publication year, as shown in Table 1, there has been a clear upward trend in articles investigating the barriers to SSCM implementation. The most commonly adopted method among the selected studies is the literature review. Specifically, a few studies have employed approaches such as DEMATEL (Kaur *et al*., 2018), multi-case analysis (Bai and Satir, 2020; Narayanan *et al.*, 2019), among others. The significant presence of reviews indicates that barriers to SSCM are attracting growing scholarly, managerial, and policy attention.

However, this study distinguishes itself by adopting a temporal literature review approach. Rather than providing a static aggregation of existing findings, the analysis explicitly incorporates a time-series perspective to compare barriers across different periods. This approach uncovers the evolution and trajectories of SSCM barriers, introducing the temporal context as a central analytical dimension. Unlike prior research, which has seldom examined barriers within specific timeframes, this study provides a dynamic, comparative perspective that traces how obstacles emerge, transform, or persist over time. By doing so, it addresses the fragmented understanding in the existing literature and highlights the developmental trajectory of SSCM barriers. This temporal perspective not

only enriches academic understanding but also equips practitioners and policymakers with insights to track progress, identify persistent challenges, and anticipate future trends in SSCM implementation.

With respect to the country of research, the selected articles in this review are predominantly conducted in India. Prior studies indicate that rapid urbanization and rising living standards in developing countries bring serious sustainability challenges and negative environmental and social impacts (Jia *et al*., 2018). Consequently, an increasing number of researchers in these countries have focused on SSCM-related topics (Al Zaabi *et al.*, 2013; Bai and Satir, 2020; Dhull and Narwal, 2016; Gupta *et al.*, 2020; Kaur *et al.*, 2018; Kumar and Goswami, 2019; Mangla *et al.*, 2017; Narayanan *et al.*, 2019; Nazam *et al.*, 2020). Moreover, given that a substantial share of extraction, production, and manufacturing operations is located in developing nations, these countries play a critical role within global supply chains. Accordingly, it is essential to examine and analyze the barriers faced by manufacturing industries in implementing SSCM practices. Building on this understanding, the present study further investigates the temporal evolution of these barriers, providing insights into how challenges and capabilities have developed across different periods.

3.2 Contents analysis

This section presents the findings in two parts, focusing on the manufacturing industry. First, it traces the evolution of SSCM definitions, showing how the concept has progressed from environmentally oriented practices to a multidimensional, technology-enabled, and strategic competitive framework. This longitudinal perspective establishes SSCM as a dynamic construct in manufacturing. Second, it classifies barriers to SSCM adoption and implementation in manufacturing firms over time. By mapping these barriers across capability domains and distinguishing between persistent and emerging challenges, the analysis reveals how obstacles have shifted from early cost and resistance concerns to more complex issues of institutionalization, innovation, and multi-tier governance. Together, these findings provide an integrated view of

Table 1
Summary of the articles reviewed

No.	Authors / Year	Country	Journal	Keywords
1	Al Zaabi *et al.* (2013)	Abu Dhabi	The International Journal of Advanced Manufacturing Technology	Traditional supply chain management, Sustainable supply chain management, Barriers
2	Zhu and Geng (2013)	China	Journal of cleaner production	Extended supply chain practices, Energy saving and emission reduction, Drivers, Barriers, Chinese manufacturers
3	Dhull and Narwal (2016)	India	Uncertain Supply Chain Management	Government regulations, Environment management, GSCM
4	Mangla *et al.* (2017)	India	Journal of Cleaner Production	Sustainable consumption and production, Barriers, Supply chain management, Fuzzy analytic hierarchy process, Multi criteria decision making
5	Kaur *et al.* (2018)	India	Journal of Manufacturing Technology Management	Sustainable supply chain, Multicriteria decision-making, Sustainability, Supply chain management, Green supply chain management, DEMATEL, Barriers
6	Sivakumar *et al.* (2018)	India	Journal of Manufacturing Technology Management	Decision making, Sustainable production, Environmental management, Interaction
7	Narayanan *et al.* (2019)	India	Journal of Manufacturing Technology Management	Analytical hierarchy process, Supply chain management, Fuzzy sets
8	Piyathanavong *et al* (2019)	UK	Journal of Cleaner Production	Environmental sustainability, Manufacturing, Operations improvement, Implementation
9	Sindhwani *et al.* (2019)	India	Journal of Manufacturing Technology Management	Lean manufacturing, Green manufacturing, Agile manufacturing, Barriers, Multi-criteria decision analysis, Analytical hierarchy process, Fuzzy AHP, Two-way assessment method
10	Bai and Satir (2020)	China	Resources, Conservation & Recycling	Green supplier development, Grey-DEMATEL, Grey-ISM Barriers analysis, Structural analysis, MICMAC analysis
11	Gupta *et al.* (2020)	India	Resources, Conservation & Recycling	Supply chain sustainability, Innovation management, Barriers, Overcoming strategies, Best-worst method
12	Nazam *et al.* (2020)	Pakistan	Cogent Business & Management	Supply chain initiatives, Barriers, Fuzzy, AHP
13	Singh *et al.* (2020)	India	Journal of Manufacturing Technology Management	Green manufacturing, Lean manufacturing, Barriers, DEMATEL, Green Lean practices
14	Bag *et al.* (2021)	India	Journal of global operations and strategic sourcing	Barriers, Blockchain technology, Green supply chain management, Multi criteria decision making, Integrated Fuzzy-DEMATEL
15	Khan *et al.* (2021)	Pakistan	International journal of sustainable engineering	Sustainable supply chain, Multi-tier supplier management, Barriers, Explorative study, Emerging economy, Textile industry
16	Shisara *et al.* (2021)	Sri Lanka	Asian Journal of Science and Applied Technology	Supply Chain Management, Green Supply Chain Management, Barriers, Drivers, Sustainability
17	Chen *et al.* (2022)	Vietnam	Sustainability	Green initiatives, Supply chain management, Challenges, Vietnamese manufacturing industries, the ISM approach
18	Al Amin and Baldacci (2024)	Bangladesh	Journal of Cleaner Production	Quality function deployment, Optimization model, Sustainable supply chain management, Sustainability performance

the definitional trajectory and capability gaps shaping SSCM in the

manufacturing sector. Figure 2 summarizes the review and analysis procedure adopted in this study.

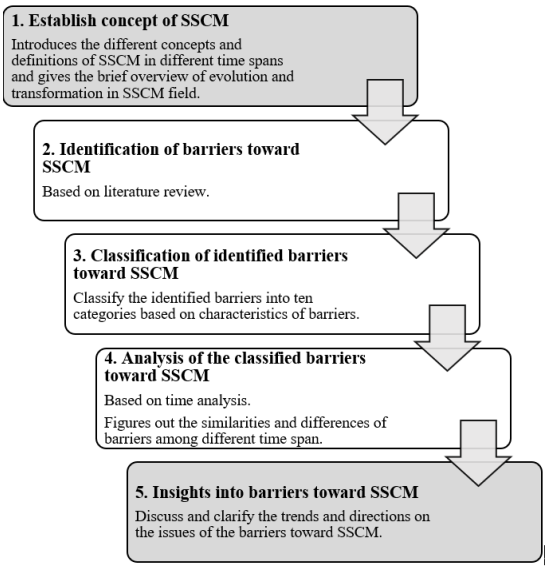

Figure 2
The procedure of review and analysis

3.2.1 Definitions of SSCM

The evolution of SSCM concepts and definitions across time periods

Before analyzing barriers that may hinder SSCM adoption, implementation and upscaling, it is important to establish a clear concept of SSCM. From this perspective, this section introduces the different concepts and definitions of SSCM in different time spans and gives the brief overview of evolution and transformation in SSCM field.

The following are the concepts and definitions of SSCM in each time period:

(1) Late 1980s and early 1990s

From the late 1980s to the early 1990s, researchers, practitioners, and governments initiated the integration of environmental concerns into supply

chain management and operations (Fahimnia *et al*., 2015). Subsequently, there has been a growing emphasis on incorporating sustainability into supply chain operations to enhance socio-environmental sustainability, recognized as a strategic decision (Khan *et al*., 2020). Stakeholders involved in this domain have been diligently exploring various facets of pertinent issues, resulting in the elevation of sustainability as a predominant research focus within the supply chain field (Kumar and Goswami, 2019).

Table 2
Definitions of SSCM in Late 1980s and early 1990s

Definitions of SSCM	Reference
Implementing sustainable strategies within the supply chain offers a viable route to reduce environmental harm linked to resource depletion, energy cost fluctuations, product liabilities, as well as pollution and waste management.	Shrivastava (1995)
The Triple Bottom Line (TBL) concept was introduced by British scholar John Elkington in 1997. This concept highlights that, beyond the traditional objective of maximizing profits, both nations and businesses should consider the economic, environmental, and social aspects in their operational strategies.	Elkington (1999)
Sustainable development gained consistent momentum starting in 2004. From that point onward, sustainability-related concerns within the conventional supply chain have significantly garnered attention in academic and industrial circles.	Khan *et al.* (2020)

The brief concept and definitions of SSCM in late 1980s and early 1990s summarize as follows:

- The strategic approach of aligning supply chain management with environmental concerns has been increasingly recognized, particularly from the late 1980s and early 1990s.
- Put forward the concept of TBL (economic, environmental and social facets) and integrate it into business's operations.
- The core tenet of sustainability can be summarized as addressing resource depletion, energy cost fluctuations, product liabilities, pollution, and waste management through implementation.
- Since 2004 onwards, academics and industries have focused on and put the efforts to the relevant issues of sustainability in traditional supply chain.

Overall, during the late 1980s and early 1990s, SSCM emerged as a concept emphasizing the integration of environmental considerations into supply chain strategies, with early efforts aimed at reducing resource depletion, pollution, and other environmental impacts. Although still fragmented, these discussions laid the groundwork for integrating sustainability into supply chain management. The introduction of the TBL expanded SSCM beyond environmental concerns to also encompass social and economic dimensions, representing a conceptual breakthrough. Over time, sustainable development gained broader attention, gradually shaping both academic research and industrial practices, laying the foundation for more comprehensive and multidimensional SSCM frameworks in subsequent decades.

(2) 2004-2010

Table 3
Definitions of SSCM in 2004-2010

Definitions of SSCM	**Reference**
Seuring and Müller were the first to propose SSCM. It encompasses the management of information, capital flows, materials, and the collaboration among firms across the supply chain.	Seuring and Müller (2008)
SSCM can be defined as the approach aimed at attaining enduring economic advantages by considering the triple bottom line dimensions—economic, social, and environmental—sourced from stakeholder and customer demands.	Carter and Rogers (2008); Seuring and Müller (2008)
SSCM involves practitioners engaging in systematic coordination among crucial inter-organizational business aspects. This collaborative effort manages both inter- and intra-firm processes, aimed at enhancing the long-term economic performance of individual businesses and their respective supply chains.	Halldórsson *et al.* (2010)
SSCM is regarded as an innovative concept enabling businesses to pursue long-term economic, environmental, and social objectives by mitigating environmental risks and impacts while enhancing ecological efficiency. The notion of sustainability in the supply chain has garnered substantial attention from both academia and industry.	Sarkis *et al.* (2010); Zhu *et al.* (2005)
SSCM involves the integration of environmental considerations into supply chain management. This encompasses various stages such as product design, material sourcing and selection, manufacturing processes, product delivery to consumers, and managing the product at the end of its useful life cycle.	Lee and Klassen (2008); Srivastava (2007)

The brief concept and definitions of SSCM in 2004-2010 summarize as follows:

- The notion of sustainability within the supply chain has consistently garnered attention and been implemented in both academic research and industry practices.
- The concept of TBL (economic, environmental and social facets) continued to be broadly adopted in the SSCM field. It has been regarded as the aspiration to achieve and the formulating mechanism for effective implementation.
- SSCM is defined as the coordination of information, capital flows, and materials, alongside fostering collaboration among various firms within the supply chain. It places significant emphasis on the value of cooperation and communication among key members within firms and the supply chain network.
- The requirements of stakeholder and consumer were taken into accounts during making the strategic decision in the implementation of SSCM.

During 2004–2010, SSCM emerged as a well-defined and increasingly recognized concept that moved beyond fragmented environmental initiatives toward a more comprehensive integration of TBL objectives across supply chains. During this period, SSCM definitions became more explicit, reflecting a shift from managing material and information flows to embedding sustainability across all stages of the supply chain, including product design, production, distribution, and end-of-life management. A defining characteristic of this evolution was the growing emphasis on stakeholder engagement and inter- and intra-organizational coordination, transforming SSCM from an operational concern into a strategic approach. Consequently, both academia and industry began to view SSCM as an innovative framework capable of balancing long-term economic performance with ecological efficiency and social responsibility.

(3) 2011-2015

Table 4
Definitions of SSCM in 2011-2015

Definitions of SSCM	Reference
There remains no unanimous agreement on the precise definition and methods of measuring SSCM.	Tajbakhsh and Hassini (2015); Taticchi *et al.* (2013)
SSCM is acknowledged as the application of traditional supply chain operations in a sustainable manner. It is distinguished by the deliberate inclusion of economic, social, and environmental dimensions throughout the adoption, implementation, and expansion of supply chain management practices.	Brandenburg *et al.* (2014); Hassini *et al.* (2012); Sarkis and Dhavale (2015); Turker and Altuntas (2014); Wittstruck and Teuteberg (2012)
The primary objective of SSCM is to reduce, and ideally eradicate, the significant adverse impacts of the supply chain on the environment.	Andiç *et al.* (2012); Gavronski *et al*. (2011); Zhu and Geng (2013)
The breadth of SSCM encompasses product development, channel selection, market strategies, sourcing, intricate manufacturing processes, transportation logistics, governmental and industry regulations, resource availability, talent management, alternative energy initiatives, and security measures.	Closs *et al.* (2011)
Apart from considering environmental, social, and economic aspects, the supply chain also needs to factor in education when embracing SSCM. Here, education pertains to developing and securing managerial talent and the labor workforce to replace current employees.	Closs *et al.* (2011)
SSCM practices encompass various facets such as green design, remanufacturing-focused production planning and control, reverse logistics, energy efficiency, inventory management, product recovery, waste handling, and minimizing emissions.	Zailani *et al.* (2012)
For attaining the sustainability objectives of supply chains, collaboration among members within the supply chain is crucial. This collaboration is vital not only for effective communication but also for facilitating the seamless implementation of programs such as environmental management systems and the design of eco-friendly products.	Eltayeb *et al.* (2011); Zailani *et al.* (2012)

The brief concept and definitions of SSCM in 2011-2015 summarize as follows:

- There is no unanimous agreement on defining SSCM and establishing standardized measurement criteria.
- The concept of TBL is continuously adopted and broadly practiced in

SSCM field. Notably, the educational aspect is also considered important during SSCM implementation.

- Establishing strong relationships with stakeholders within firms and across the supply chain is a pivotal factor for the effective implementation of SSCM.
- SSCM practices encompass a range of activities such as green design, production planning and control aimed at remanufacturing, reverse logistics, energy conservation, inventory management, product recovery, waste handling, and emission reduction.

During 2011–2015, SSCM research entered a more mature and application-oriented phase, emphasizing the systematic integration of sustainability into traditional supply chain operations. Although a universally accepted definition or measurement method had not yet emerged, scholars converged on embedding economic, environmental, and social dimensions across all supply chain activities, including product development, logistics, and workforce management. The focus shifted from conceptual discussions to holistic operationalization, with inter-firm collaboration playing a critical role in enabling the effective implementation of green practices. This period thus marked a transition from SSCM as an emerging strategic framework to a practical, process-oriented approach, underscoring its growing managerial relevance.

(4) 2016-2020

- SSCM is perceived as or defined by the incorporation of corporate social responsibility (CSR) into business operations and supply chains, transcending both organizational and geographical boundaries.
- The progression towards and attainment of SSCM can be accomplished by effectively managing raw materials, minimizing waste from upstream to downstream, and reintegrating materials back to the upstream after their shelf life. This process aims to reduce environmental harm and enhance social impact.

Table 5
Definitions of SSCM in 2016-2020

Definitions of SSCM	Reference
SSCM is perceived as or defined by the incorporation of corporate social responsibility (CSR) into business operations and supply chains, transcending both organizational and geographical boundaries.	Giannakis and Papadopoulos (2016)
The progression towards and attainment of SSCM can be accomplished by effectively managing raw materials, minimizing waste from upstream to downstream, and reintegrating materials back to the upstream after their shelf life. This process aims to reduce environmental harm and enhance social impact.	Khan and Qianli (2017)
SSCM also involves attaining agreement on effectively implementing recycling, refurbishment, and disposal methodologies to ensure the sustainable treatment of products.	Raut *et al.* (2019)
SSCM is regarded as the process of strategizing and decision-making within operations and supply chains by integrating and fulfilling economic, environmental, and social aspects and requirements.	Esfahbodi *et al.* (2016); Kusi-Sarpong *et al*. (2019); Majumdar and Sinha (2018)
To ensure the seamless implementation of SSCM, it is imperative for key stakeholders to establish effective communication and jointly practice sustainability in both operations and supply chains.	Kusi-Sarpong *et al.* (2019)

- SSCM also involves attaining agreement on effectively implementing recycling, refurbishment, and disposal methodologies to ensure the sustainable treatment of products.
- SSCM is regarded as the process of strategizing and decision-making within operations and supply chains by integrating and fulfilling economic, environmental, and social aspects and requirements.
- To ensure the seamless implementation of SSCM, it is imperative for key stakeholders to establish effective communication and jointly practice sustainability in both operations and supply chains.

During 2016–2020, SSCM definitions increasingly emphasized the integration of CSR and sustainability practices across both organizational and geographical boundaries. CSR was no longer viewed as an external pressure but became a core component of SSCM, broadening its focus from environmental

and economic efficiency to include social considerations. Key practices encompassed the effective management of raw materials, waste minimization, recycling, refurbishment, and sustainable product treatment. Scholars also highlighted the critical role of stakeholder collaboration and communication in operational decision-making and strategy implementation. This period thus represents a qualitative evolution from a primarily environment-driven to a socially responsible SSCM paradigm that balances performance outcomes with normative and social responsibilities.

(5) 2021-2025

Table 6
Definitions of SSCM in 2021-2025

Definitions of SSCM	Reference
SSCM refers to managing the flow of materials, information, and finances within the supply chain, as well as collaboration among companies, while taking into account the sustainability objectives derived from customer and stakeholder demands across the three dimensions of economic, environmental, and social aspects. Blockchain in SSCM enhances competitiveness, mitigates risks, lowers costs, and reduces the supply chain's carbon footprint, while fostering trust, security, and faster transactions.	Bag *et al.* (2021)
SSCM refers to integrating environmental, social, and economic objectives within the supply chain to enhance long-term performance.	Khan *et al.* (2021)
SSCM is defined as a series of activities that mitigate the adverse impacts on the environment throughout the green manufacturing process, including conserving resource use, reducing the release of harmful substances into the environment, and promoting product recycling and reuse.	Shisara *et al.* (2021)
SSCM integrates eco-friendly practices into the supply chain to enhance sustainability, strengthen business performance, and requires coordinated stakeholder involvement to prevent environmental and community impacts.	Chen *et al.* (2022)
SSCM encompasses environmental initiatives, sustainability practices, waste reduction, greenhouse gas emissions, energy consumption, and other environmental impacts, as well as environmental and social responsibility.	Al Amin and Baldacci (2024)

- SSCM is considered a way to manage the flow of materials, information, and finances within the supply chain, as well as collaboration among

companies, while taking into account sustainability goals derived from customer and stakeholder demands across the economic, environmental, and social dimensions.

- Blockchain in SSCM enhances competitiveness, mitigates risks, lowers costs, reduces carbon footprint, and fosters trust, security, and faster transactions.
- It emphasizes integrating environmental, social, and economic objectives within the supply chain to enhance long-term performance.
- SSCM can be defined as a series of activities that mitigate adverse environmental impacts, including conserving resources, reducing the release of harmful substances, and promoting product recycling and reuse.
- It also integrates eco-friendly practices into the supply chain to enhance sustainability and business performance, emphasizing coordinated stakeholder involvement to prevent negative impacts on the environment and local communities.
- Moreover, SSCM encompasses environmental initiatives, sustainability practices, waste reduction, greenhouse gas emissions, energy consumption, and other environmental impacts, while also considering environmental and social responsibility.

From 2021 to 2025, definitions of SSCM increasingly converged on a multidimensional, technology-enabled framework that integrates economic, environmental, and social objectives to achieve long-term performance, competitiveness, and sustainability. While early emphases focused on efficiency, environmental protection, and resource management, later studies highlighted stakeholder collaboration, corporate social responsibility, and eco-friendly practices. A defining feature of this period is the adoption of digital technologies such as blockchain, IoT, and AI to enhance transparency, mitigate risks, and reduce carbon footprints. This represents a structural evolution in SSCM from a primarily normative and managerial framework to a digitally supported, strategically competitive model, where sustainability serves both as an ethical imperative and a source of strategic advantage.

Comparative analysis of SSCM definitions over time

Similarities: As shown in Table 7, since the late 1980s, SSCM has consistently emphasized the TBL orientation, integrating economic, environmental, and social objectives in line with the TBL framework. From 2004 onwards, SSCM definitions have highlighted stakeholder engagement and inter-organizational collaboration, emphasizing both inter- and intra-firm coordination and stakeholder participation; in later periods, this focus expanded to cross-organizational and cross-regional implementation. Furthermore, each period has stressed the integration of sustainability across supply chain stages, encompassing product design, logistics, raw material management, and end-of-life management. Collectively, these recurring themes illustrate the core principles that have guided SSCM practices over time.

Differences: Across periods, SSCM definitions gradually expanded in both scope and orientation. The scope of implementation has shifted from a firm-level focus toward cross-firm, cross-regional, and global supply chain networks, underscoring the growing importance of collaboration and shared responsibility beyond organizational boundaries. In terms of theoretical to practical orientation, SSCM has moved from conceptual and environmentally driven frameworks, to operationalized practices, and finally toward strategy-driven and technology-enabled approaches that directly enhance competitiveness and sustainability outcomes. A notable turning point emerged in 2021–2025, when digital technologies such as blockchain, AI, and big data shifted from supportive tools to core enablers of SSCM. These technologies enable higher transparency, risk mitigation, carbon reduction, and long-term performance, solidifying SSCM's role as a strategic driver of sustainable value creation.

Understanding the evolution of SSCM definitions across different periods is crucial for clarifying both its conceptual foundations and its practical implications. SSCM has developed from firm-level environmental practices to cross-firm and global supply chain strategies, reflecting the growing importance of collaboration, accountability, and technological integration. By systematically analyzing how definitions have shifted from theoretical frameworks to

strategy-driven and technology-enabled orientations, this study provides insights

Table 7
Evolution of SSCM definitions across time periods

Period	Core Focus	Key Characteristics
Late 1980s – Early 1990s	Environment-oriented	Initial focus on reducing resource depletion and pollution; TBL concept gradually introduced, social and economic dimensions began to emerge alongside environmental concerns.
2004–2010	Comprehensive integration	Explicit TBL integration; emphasis on supply chain coordination and stakeholder engagement; systematic embedding.
2011–2015	Systematic and practical	Systematic integration of sustainability into traditional operations, including product development, logistics, and workforce management; operationalization across all supply chain activities; inter-firm collaboration for green practices; holistic management focus.
2016–2020	CSR and cross-boundary	CSR embedded within SSCM definitions; cross-organizational and cross-regional implementation; evolution to socially responsible SSCM.
2021–2025	Technology-driven, strategic and holistic	Convergence on multidimensional frameworks for long-term performance; digital technologies (blockchain, IoT, AI) integrated for transparency, risk mitigation, and carbon reduction; SSCM as a strategic and competitive framework.

into the dynamic nature of SSCM as both an academic construct and a managerial tool. Such analysis not only highlights how scholars and practitioners have progressively redefined the scope of SSCM to include social responsibility and digital transformation, but also identifies emerging trends and gaps that require further research. Therefore, tracing definitional evolution is not merely a historical exercise; it strengthens conceptual clarity, supports consistent operationalization, and offers a roadmap for future investigations and managerial practices in the field of SSCM.

3.2.2 Barriers to SSCM: Identification and classification

To ensure the conceptual clarity of our classification, the classification of barriers in this study followed a three-level framework (Category–Attribute–

Subitem) guided by the perspectives of RBV and dynamic capabilities. This structured approach provides a clear theoretical lineage for each classification term:

Category (origin of barriers): Barriers were categorized based on their origin, distinguishing between those stemming from internal resources under the firm's direct control and those arising from the external environment shaped by institutions and networks. The Internal category refers to firm-owned resources and capabilities such as managerial commitment, knowledge, technology, and financial resources, which constitute the essential building blocks of competitive advantage in line with the RBV perspective. The External category, by contrast, encompasses barriers embedded in the institutional and network environment, including suppliers, customers, competitors, government, and infrastructure. While this distinction reflects the RBV logic of firm-controlled versus environment-imposed resources, it also aligns with the dynamic capabilities perspective, which emphasizes that a firm's survival and renewal depend on its ability to reconfigure and align internal resources in response to exogenous shifts in the external environment.

Attribute (nature of resources): Within each Category, barriers were further classified as "hard" (tangible, physical, and financial resources such as infrastructure, technologies, and capital) or "soft" (intangible, relational, and cognitive resources such as knowledge, trust, culture, and commitment). This step ensures consistency with RBV's emphasis on resource types and highlights how dynamic capabilities are required to reconfigure both hard and soft resources over time.

Subitem (specific manifestation): Finally, the specific expressions of each barrier identified in the reviewed articles were coded as Subitems, which were systematically assigned to their respective Categories and Attributes based on a predefined coding protocol. Subitems capture the concrete manifestations of barriers extracted from the literature, and each is theoretically conceptualized as a precise deficit within a capability domain.

By applying this structured and tiered procedure, the framework ensures

that barriers are consistently mapped across periods, moving beyond a mere listing toward a theoretically grounded diagnostic tool. In theoretical terms, persistent barriers correspond to enduring RBV-related resource deficits, whereas emerging barriers indicate capability renewal gaps that require dynamic capabilities to reconfigure and realign resources under evolving institutional and technological pressures. This enables a deeper understanding of both the evolutionary trajectory of barriers and the fundamental capability challenges in SSCM adoption.

This section aims to provide a comprehensive summary and classification of the identified barriers from the selected articles in this study. The study segments the timeline into three intervals: 2004-2009; 2010-2015; 2016-2020. These barriers are categorized into two primary groups: Internal and External. Within the "Internal" category, there are four subcategories: Organization/Top executive/Subordinate/Internal Infrastructure. Additionally, the "External" category includes six subcategories: Competitors/Consumers/Government/Suppliers/Market/External Infrastructure (Figure 3). Detailed insights into the analysis and investigation of barriers affecting SSCM are presented in Table 8-11.

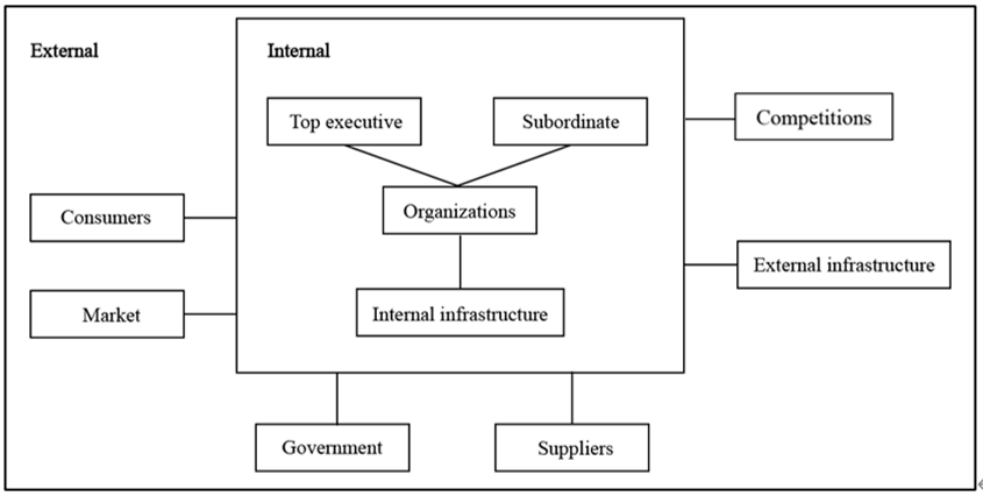

Figure 3
The framework of items in classification

Table 8
Barriers to SSCM in 2004-2009

Category	Attribute	Subitem	Description
Internal	Soft	Organization	· Implementation of SSCM proves to be economically unviable in industries, incurring higher costs.
			· Encountering substantial regulatory and market pressures with extensive experience.
			· Fear of exposing inadequate environmental performance.
			· Resistance towards adopting SSCM, manifesting as an unwillingness to share information.
			· Organizational structure limitations hinder innovation.
			· Inadequate adaptation to technological advancements.
			· Lack of internal technological resources.
			· Insufficient skilled human resources for SSCM implementation.
			· Distinct challenges prevailing across different industry sectors.
			· Competing objectives imposed by central government entities.
		Top executive	· Project stakeholders' inertia.
			· Lack of commitment from management.
			· Deficiency in mutual trust.
			· Resistance due to perceived time and resource expenses.
			· Limited knowledge and information concerning sustainability issues.
		Subordinate	· Inadequate training and education.
			· Absence of planning and strategies.
			· Lack of motivation among employees (incentives).
	Hard	Infrastructure	· Inadequate tecshnology infrastructure and processes.
			· Absence of technological advancements.
External	Soft	Competitions	· Pressure for lower prices amidst intense competition.
		Consumers	· Lack of awareness among customers about environmental benefits.
		Government	· Absence of tax benefits or other incentives.
			· Limited government support and environmental regulations.
		Suppliers	· Inadequate knowledge and experience among suppliers.
			· Communication and coordination challenges within the supply chain.
			· Poor commitment from suppliers.
			· Insufficient support within the supply chain.
		Market	· Lack of awareness about economic benefits.
			· Inadequate demand and public awareness.
			· Pressure to reduce costs at the expense of the environment.
			· Intense competition and uncertainty.
			· Language barriers and cultural disparities.
			· Limited involvement of the public in sustainability development.
	Hard	Infrastructure	· Difficulty in locating recycling centers.

Table 9
Barriers to SSCM in 2010-2015

Category	Attribute	Subitem	Description
Internal	Soft	Organization	· Reluctance or apprehension toward change. · No clear statement for responsibilities among different departments. · Financial constraints (Limited budget for SSCM implementation). · Deficiency in information and data availability. · Absence of robust planning systems (Lack of long-term strategic environmental objectives). · Difficulty in translating positive environmental attitudes into actionable steps. · Encountering various pressures to establish more environmentally conscious operations. · Inadequate collaboration between product designers and suppliers to mitigate product environmental impacts. · Communication inefficiencies. · Insignificant financial returns (No or minimal return on investment). · No significant benefit (especially short-term benefit). · Shortage of resources and capabilities. · Health and safety concerns. · Job security challenges. · A prevailing organizational culture averse to risk. · Gaps between planning and production processes (Absence of integrated systems in designing and executing sustainable development policies, programs, and strategies). · Insufficient skilled workforce for SSCM implementation. · Lack of corporate social responsibility integration. · Adherence to regulatory compliance. · Inconsistent and insufficient performance metrics / Lack of strategic planning. · Lack of collection and analysis for data of material/energy flow. · Lack of R&D capability. · Limited cooperation with research institutions. · High cost implications (Substantial initial implementation costs). · Too high cost (eco-design etc.). · Too high disposable cost for hazardous wastes. · High cost for using environmental packaging. · Lag in adopting technological advancements. · Absence of motivation to embrace SSCM. · Insufficient ethical standards and corporate social responsibility. · Lack of mutual understanding between governmental and non-governmental entities about the emerging challenges of SSCM.

			・Inadequate balance among environmental, social, and economic benefits. ・Absence of policies and practices to retain skilled and experienced employees within organizations. ・Fear of failure. ・Adoption of safety standards.
		Top executive	・Absence of commitment from top management. ・Limited awareness of economic benefits. ・Managerial failure to act strategically.
		Subordinate	・Insufficient knowledge and training in SSCM. ・Inadequate data collection procedures. ・Low awareness of workers.
	Hard	Infrastructure	・Lack of infrastructure and processes for SSCM implementation.
External	Soft	Competitions	・Competitiveness and market uncertainty.
		Consumers	・Lack of customer awareness about environmental benefits. ・Customer-driven pressures. ・Fluctuating customer demands.
		Government	・Absence of tax benefits or incentives. ・Governmental environmental regulations and support. ・Inadequate policies and regulatory frameworks.
		Suppliers	・Absence of suppliers dedicated to sustainability. ・Insufficient commitment from suppliers. ・Challenges in certifying suppliers' environmental management systems. ・Difficulty in sustaining suppliers' environmental awareness. ・Complexity in measuring and monitoring suppliers' environmental practices. ・Limited mutual trust among supply chain members. ・Insufficient knowledge and experience among suppliers. ・Inflexibility in the design of supply chain networks.
		Market	・Insufficient environmental knowledge. ・Lack of initiative from individuals. ・Constraints due to location. ・Inadequate societal pressure. ・Economy focused on planning. ・Community pressures. ・Prioritizing cost reduction over environmental concerns. ・Lack of public awareness and demand.
	Hard	Infrastructure	・Challenges in locating recycling centers.

Table 10

Barriers to SSCM in 2016-2020

Category	Attribute	Subitem	Description
Internal	Soft	Organization	・Financial constraints.
			・Insufficiently robust planning systems.
			・Limited awareness of potential benefits.
			・Difficulty in translating positive environmental attitudes into actionable steps.
			・Absence of significant pressures or a lack of widespread adoption pressure.
			・Discrepancy between technological design and implementation.
			・Deficiency in Research and Development (R&D) and innovation capabilities.
			・High initial investment required for the latest technology.
			・Multifaceted, intricate, and evolving regulations.
			・Bureaucratic procedures and extensive documentation processes.
			・Deficiency in performance measurement and incentive structures.
			・Lack of functional integration and collaboration.
			・Limited ability to engage with external networks.
			・Lack of trust in information sharing and forming collaborative ventures.
			・Inadequate resources and expertise.
			・Insufficient involvement of stakeholders.
		Top executive	・Absence of commitment from top management.
			・Resistance or apprehension towards change (Concerns about increased workload and decreased flexibility).
			・Insufficient training and inadequate progress monitoring.
			・Uncertainty regarding return on investment.
			・Ambiguity in roles and challenges in decision-making.
			・Deficiency in entrepreneurial skills and innovative thinking.
		Subordinate	・Inadequate employee training.
			・Deficient communication practices.
			・Lack of empowerment at lower organizational levels.
	Hard	Infrastructure	・Insufficient technology infrastructure and procedural frameworks.
External	Soft	Competitions	・Lack of competitiveness.
		Consumers	・Limited awareness among customers regarding environmental benefits.
			・Lack of customer awareness about SSCM.
			・Perception that sustainable products lack quality.
			・Ambiguity in customer requirements.
		Government	・Inadequate governmental support and policies.
			・Absence of incentives.
		Suppliers	・Poor commitment from suppliers (Shortage of sustainable suppliers).
			・Lack of flexibility in designing supply chain networks.
			・Insufficient understanding among stakeholders in the supply chain.
		Market	・Limited environmental knowledge.
			・Inadequate market demand.
	Hard	Infrastructure	・Challenges in identifying recycling centers.
			・Lack of waste management and recycling facilities.

Table 11
Barriers to SSCM in 2021-2025

Category	Attribute	Subitem	Description
Internal	Soft	Organization	· Lack of concept of green procurement and green products.
			· Lack of information sharing.
			· Lack of expertise / lack of environmental knowledge and awareness.
			· Lack of stakeholder involvement.
			· Internal communication failures.
			· Lack of collaboration with research institutions.
			· Lack of corporate social responsibility.
		Top executive	· Lack of top management commitment.
			· Lack of awareness of the need for multi-tier sustainable supplier management (MT-SSM).
			· Lack of interest.
			· Fear to invest.
			· Fear of failure.
			· Lack of knowledge and experience.
			· Lack of involvement of top management in adopting.
			· Human factors and safety challenges.
		Subordinate	· Lack of expertise.
			· Lack of environmental awareness.
			· Lack of knowledge and experience.
			· Lack of training courses about implementing SSCM.
			· Lack of training related to reverse logistics.
			· Fear of failure.
	Hard	Infrastructure	· Lack of green technology.
			· Lack of new technology, materials and processes.
			· Lack of financial gains, resources, and capacity.
			· Lack of effective environmental measures.
			· Complexity in measuring/monitoring environmental practices.
			· Lack of IT infrastructure.
			· Challenges in integrating advanced technologies/processes.
			· Complexity of green process and system design.
			· High investments and less return-on-investments.
			· High cost of hazardous waste disposal.
			· Lack of reverse logistics.
External	Soft	Competitions	· Market competition and uncertainty.
		Consumers	· Lack of environmental knowledge and awareness.
			· Lack of customer awareness and pressure about SSCM.
			· Unaware of the environmental benefits.
		Government	· Lack of government policies and regulations.
			· Lack of award system.
			· Weak regulatory environment / lack of enforcement.
			· Political pressures.
			· Compliance with certifications and standards.
		Suppliers	· Lack of information sharing.
			· Poor supplier commitment.
			· Lack of an environmental partnership with suppliers.

		・Lack of interest. ・Lack of knowledge and experience. ・Lack of green professionals. ・Lack of green innovations. ・Lack of supply chain integration. ・Collaboration challenges.
	Market	・Lack of concept of green products. ・Restrictive company policies towards product/process stewardship. ・The media doesn't have anypolicy to cover green supply chain management practices. ・Lack of awareness about reverse logistics adoption. ・Lack of environmental knowledge. ・Lack of corporate social responsibility. ・Lack of eco designs. ・High cost in green packaging. ・Product cost and market situation are unbalanced.
Hard	Infrastructure	・High cost of production and maintenance of the products. ・The complex design of process and available technology. ・High cost of waste disposal.

Common barriers across periods: Persistent challenges

- **Internal commitment and capability gaps:** A lack of top management commitment, limited sustainability knowledge among managers and employees, insufficient training, and weak cross-functional collaboration and communication have persisted across all periods.
- **Cost and resource constraints:** High initial investment requirements, financial pressures, and low or uncertain short-term returns have consistently been central barriers.
- **Supplier-related challenges:** Weak supplier commitment, insufficient green capabilities and knowledge, and difficulties in information sharing and coordination constitute persistent external "soft" barriers.
- **Customer and market awareness gaps:** Limited customer awareness of environmental benefits and low demand for green products have undermined adoption incentives.
- **Infrastructural and institutional deficiencies:** Recycling facilities, waste management systems, and monitoring mechanisms have long lagged behind, reflecting persistent weaknesses in the supporting infrastructure.

Across different periods, several persistent barriers to SSCM can be

identified. A recurring challenge is the lack of internal commitment and capabilities, reflected in insufficient top management support, limited sustainability knowledge among managers and employees, inadequate training, and weak cross-functional collaboration. Cost and resource constraints have also remained central, as firms face high initial investment requirements, financial pressures, and uncertain or low short-term returns. Externally, supplier-related barriers such as weak commitment, limited green capabilities, and difficulties in information sharing and coordination have persisted. Customer-side limitations, including low awareness of environmental benefits and limited demand for sustainable products, have further weakened adoption incentives. Moreover, deficiencies in infrastructure and institutional support, including underdeveloped recycling facilities, waste management systems, and monitoring mechanisms, have long hindered effective implementation.

Temporal differences in SSCM barriers

(1) 2004–2009:

This period was dominated by concerns about disclosure risks, cost pressures, and organizational resistance. Prominent barriers included language and cultural differences, reluctance to disclose environmental performance, organizational rigidity, and technological resource shortages. Collectively, these reflect a perception of sustainability as an *additional, non-core burden* rather than a strategic priority.

(2) 2010–2015:

The period marked a bottleneck in the institutionalization process, including unclear responsibilities, lack of planning and metrics, weak cross-functional integration, and limited collaboration between designers and suppliers. Simultaneously, high costs of eco-design, green packaging, and hazardous waste treatment, along with insufficient data and measurement, emerged as significant obstacles.

(3) 2016–2020:

Deficiencies in systematic management and innovation capacity became evident. Key issues included insufficient R&D and innovation, a gap between

design and implementation, inadequate performance measurement and incentive mechanisms, and increasingly complex regulations and bureaucratic processes. Consumer skepticism about the quality of green products also surfaced more explicitly.

(4) 2021–2025:

Barriers shifted toward challenges in digitalization, advanced technologies, and multi-tier supply chain management. Organizations faced difficulties with information technology (IT) and data infrastructures, complex monitoring systems, integration of green technologies, new materials, and processes, as well as high investments with limited returns. Reverse logistics capabilities remained underdeveloped. At the supply chain level, limited awareness and engagement in multi-tier supplier management became salient, while externally, weak regulatory enforcement and pressures from compliance with standards and certifications intensified.

Evolution of barriers to SSCM in the manufacturing industry

A temporal analysis of barriers to SSCM reveals a clear evolutionary trajectory from early-stage cost and resistance concerns to more complex challenges involving institutionalization, innovation, and multi-tier governance (Table 12). During the initial period (2004–2009), organizational barriers were predominantly driven by cost pressures, disclosure risks, regulatory compliance anxieties, and resistance to change. Internally, firms struggled with insufficient managerial commitment, limited skilled human resources, technological constraints, organizational rigidity, and reluctance to share information. Externally, intense market competition, low customer awareness, and inadequate supplier capabilities reinforced these obstacles. Sustainability was largely perceived as an additional, non-core burden rather than a strategic imperative.

Between 2010 and 2015, the nature of barriers began shifting toward institutionalization and capability development. Firms faced fragmented responsibilities, unclear planning systems, weak integration of cross-functional and R&D efforts, and insufficient performance metrics and incentive mechanisms. Cost concerns persisted, particularly regarding eco-design, green

packaging, and hazardous waste management, but these were increasingly intertwined with systemic challenges, including limited data availability, inadequate collaboration with suppliers, and weak alignment of SSCM initiatives with strategic objectives.

From 2016 to 2020, the focus moved deeper into operational capabilities and innovation capacity. Organizations struggled with technological integration, gaps between design and implementation, performance monitoring, regulatory complexity, and multi-stakeholder engagement. Consumer skepticism toward green product quality further highlighted the importance of managing both internal and external perceptions.

In the most recent period (2021–2025), SSCM barriers are dominated by challenges related to digitalization, advanced technologies, and multi-tier governance. Firms now confront challenges in IT and data infrastructure, integration of green technologies and new materials, high investment costs with limited returns, underdeveloped reverse logistics, and limited engagement in multi-tier supplier management. Externally, weak regulatory enforcement and the need to comply with multiple standards exacerbate these systemic obstacles.

Overall, the trajectory in the manufacturing industry illustrates a shift from initial concerns centered on cost and resistance toward more complex and systemic challenges. In particular, institutionalization, data-driven decision-making, innovation capabilities, and multi-tier governance have emerged as critical factors for successful SSCM implementation in manufacturing firms.

Continuous vs. Emerging barrier matrix

This typology provides a clear reflection of the integration between the RBV and dynamic capabilities perspectives. Continuous barriers denote persistent deficiencies in critical, yet hard-to-develop resources, such as managerial commitment, limited financial resources, and supplier green capabilities. In contrast, emerging barriers represent the dynamic capabilities that firms must cultivate to maintain competitiveness in an evolving sustainability

Table 12
Evolution of SSCM barriers and strategic focus (2004–2025)

Time Period	Barrier Characteristics	Internal Challenges	External Challenges	Cost / Institutional / Innovation Focus
2004–2009	Surface-level resistance and cost concerns	Managerial resistance, low internal commitment, technological resource shortages, organizational rigidity	Limited supplier engagement, intense market competition, low customer awareness	High costs, sustainability perceived as a non-core burden
2010–2015	Institutionalization and capability gaps	Fragmented responsibilities, inadequate planning and performance metrics, weak cross-functional and R&D integration	Insufficient supplier collaboration, limited data collection and measurement systems	High costs for eco-design, green packaging, and hazardous waste management
2016–2020	Core operational and innovation challenges	Technological integration gaps, innovation deficiencies, underdeveloped performance measurement and incentive structures	Regulatory complexity, consumer skepticism regarding green product quality	Focus on decision-making frameworks, performance management, and alignment with strategic objectives
2021–2025	Digitalization and multi-tier governance	Advanced IT and data infrastructure requirements, complex monitoring and reporting, high investment costs with limited returns	Weak regulatory enforcement, multiple standards and certification requirements, limited multi-tier supplier engagement	Reverse logistics, green technology integration, innovation capabilities, multi-tier governance

landscape, including digital integration, multi-tier governance, and advanced innovation capacity.

To further advance theoretical and practical understanding, we propose a 2×2 matrix that categorizes barriers as *continuous* versus *emerging* across both *internal* and *external* domains.

- Continuous–Internal: persistent issues such as weak top management commitment, cost pressures and short-termism, insufficient training, and poor cross-functional communication.
- Continuous–External: recurring obstacles including supplier non-commitment or capability deficits, limited customer awareness and demand, and infrastructural constraints.
- Emerging–Internal: novel challenges such as R&D and data-driven

capability gaps, advanced technology integration, and governance of multi-tier supply chains.

- Emerging–External: recent pressures including gaps between standards and enforcement, political and policy uncertainty, and the development of reverse logistics systems.

By mapping barriers into this typology, this study contributes a dynamic lens for distinguishing "enduring bottlenecks" from "frontier challenges". This dual contribution enables both scholars and practitioners to recognize which issues require long-term systemic interventions versus those that demand anticipatory capability development to address emerging complexities in SSCM.

Summary

Taken together, these shifts reveal a clear evolutionary trend from concerns about *whether to adopt* SSCM to more complex questions of *how to implement it effectively and to what depth*. In the early stages, barriers were primarily shaped by compliance concerns, cost anxieties, and resistance to change. Over time, these were replaced by systematization challenges such as responsibility allocation, strategic planning, key performance indicator system (KPI) development, and cross-functional and inter-organizational coordination. Capability-building has also become increasingly central, with barriers evolving from basic awareness and training gaps toward deficiencies in R&D, innovation, performance incentives, data management, and process digitalization. Similarly, technological issues have shifted from the absence of basic infrastructure to difficulties in integrating advanced technologies, monitoring systems, reverse logistics, and eco-design solutions, alongside concerns about uncertain returns. The scope of supply chain barriers has expanded from single-tier supplier management to multi-tier and network-level collaboration, demanding more advanced governance and information-sharing mechanisms. Finally, the institutional environment has evolved from weak incentives and awareness to a paradoxical situation in which standards and certifications have become more complex, yet regulatory enforcement remains weak, creating pressing demands for consistency and enforceability.

Interpreted through the RBV, persistent barriers reflect the absence of valuable and rare resources, such as sustainability expertise, green technologies, or cross-functional integration mechanisms. These shortages constrain firms' ability to embed sustainability into their supply chains and thereby manifest as enduring obstacles. At the same time, drawing on the dynamic capabilities perspective, emerging barriers highlight the need for firms to continuously reconfigure and renew their resources to adapt to technological, regulatory, and market shifts. Challenges such as digitalization, advanced IT integration, and multi-tier supplier governance are not simply resource shortages but indicators of insufficient dynamic capability development.

Accordingly, this study reframes SSCM barriers not as static obstacles but as manifestations of underlying capability gaps (Table 13). We classify these into five core domains: (1) Governance and Commitment (e.g., top management support, clarity of responsibility, cross-functional integration), (2) Human Resources and Knowledge (e.g., training, R&D/innovation, sustainability literacy), (3) Technology and Data (e.g., IT systems, measurement and monitoring, digital integration), (4) Finance and Resources (e.g., initial investment, ROI calculations, incentive alignment), and (5) Ecosystem and Institutional Alignment (e.g., multi-tier supplier governance, customer demand formation, regulatory enforcement and certification). Viewed longitudinally, the salient barriers that dominate in each period can be interpreted as stage-specific reflections of these capability domains. This framework thus shifts the discourse from describing discrete obstacles to theorizing a dynamic capability-building trajectory, highlighting that firms must progressively construct complementary capabilities across governance, knowledge, technology, finance, and ecosystems to sustain SSCM maturity.

The longitudinal comparison reveals a clear evolution in barriers to SSCM. In the early stage (2004–2009), barriers were predominantly characterized by cost concerns, managerial inertia, and resistance to change, with firms perceiving SSCM as economically unviable. Between 2010 and 2015, challenges shifted toward systematization gaps, including unclear responsibilities, insufficient data

Table 13

Temporal evolution of SSCM barriers across five capability domains

	2004-2009	2010-2015	2016-2020	2021-2025
Governance & Commitment	Lack of top management commitment, managerial inertia, unclear responsibilities, and resistance to change.	Lack of top management commitment, unclear responsibilities, weak planning, and an organizational culture resistant to risk.	Lack of top management commitment, resistance to change, ambiguous decision-making roles, and limited entrepreneurial orientation.	Lack of top management commitment, limited awareness of multi-tier supplier management, fear of investment and failure.
Human Resources & Knowledge	Employees and managers lacked sustainability literacy, training was insufficient, and motivation was low.	Poor CSR integration, insufficient knowledge and training, inadequate R&D, and limited collaboration with research institutions.	Inadequate employee training, poor communication, lack of empowerment, and insufficient R&D and innovation capacity.	Insufficient environmental knowledge, lack of training (especially in reverse logistics), and shortage of green professionals.
Technology & Data	Weak technological infrastructure, lack of internal technological resources, and inability to adapt to new technologies.	Inadequate data collection, lack of performance metrics and KPIs, and weak infrastructure.	Deficient performance measurement and incentive systems, weak IT and process frameworks, and lack of system integration.	Absence of green technologies and new materials, inadequate IT infrastructure, complexity in monitoring and measurement, and difficulties in system design.
Finance & Resources	High costs, economic infeasibility, and limited resources.	Financial constraints, high initial investment, and uncertain or minimal returns.	High investment costs, insufficient resources, and uncertainty of ROI.	High costs with low returns, expensive hazardous waste disposal, and absence of reverse logistics systems.
Ecosystem & Institutional Alignment	Limited government support, absence of tax incentives, weak supplier commitment, low consumer environmental awareness, and intense competition with market uncertainty.	Weak supplier commitment to sustainability, insufficient government policies, volatile consumer demand, lack of market knowledge, and competitive uncertainty.	Limited governmental support and incentives, lack of supplier flexibility, weak consumer environmental awareness, and low market demand.	Weak government policies and enforcement, poor supplier innovation and collaboration, insufficient societal and media engagement, low awareness of green products in the market, and persistent competition and uncertainty.
Keywords	High costs, lack of commitment, insufficient training, inadequate government support, competitive pressures.	Weak institutionalization, data gaps, lack of KPIs, high costs, insufficient supplier commitment.	Weak innovation capability, lack of system integration, IT and data deficiencies, uncertain ROI, insufficient policy support.	Reverse logistics gaps, multi-tier governance, weak green innovation, IT integration challenges, lack of policy and market support.

collection, lack of KPI frameworks, and limited R&D collaboration. From 2016 to 2020, barriers increasingly reflected capability-building deficits, such as

deficiencies in innovation capacity, IT infrastructure, and system integration, alongside persistent uncertainty regarding returns on investment. In the most recent period (2021–2025), the barriers have deepened into the "next frontier", centering on multi-tier governance, reverse logistics, digital integration, and green innovation, while still constrained by high costs and inadequate policy support. Taken together, this evolutionary trajectory illustrates how SSCM barriers have shifted from questions of whether to adopt sustainability toward more complex challenges of how to institutionalize, operationalize, and scale it across multi-tier supply networks.

4. Discussion

4.1 Seven core barriers to SSCM implementation

The seven issues discussed in this section emerged through a systematic process specifically focused on the manufacturing industry. They were derived from our temporal content analysis of 18 studies identified in the temporal literature review. Guided by a coding framework grounded in the RBV and dynamic capabilities perspectives, barriers were first categorized across internal and external domains and further mapped into capability-related dimensions (e.g., governance and commitment, knowledge resources, technology and data, financial constraints, and ecosystem alignment). Through iterative coding and cross-period comparison, recurrent and salient patterns were synthesized into seven core issues. These issues represent the most persistent and consequential barriers that have consistently impeded the implementation of SSCM within manufacturing firms over time, thus providing a structured foundation for the subsequent discussion of their theoretical and practical implications.

Issue1: Limited practitioner awareness of SSCM's benefits. Our temporal coding revealed that a recurring internal barrier across all periods: practitioners' limited recognition of SSCM's economic and strategic benefits. While prior studies highlight the potential gains in efficiency and financial performance, many managers continue to perceive uncertain or minimal returns,

which undermines their motivation and top management commitment.

Issue 2: Customer awareness gaps regarding SSCM's environmental benefits. The cross-period analysis indicated that customer-related barriers remain persistent, particularly the lack of widespread awareness of SSCM's environmental advantages. Although consumer concern for sustainability has grown, our review shows that limited customer pressure still constrains firms' incentives to adopt SSCM practices.

Issue 3: Insufficient governmental support and incentive mechanisms. From the external domain, a recurring theme identified in the literature is insufficient governmental support, including weak financial incentives and limited policy mechanisms. Our analysis confirms that inadequate institutional support consistently diminishes firms' willingness to implement SSCM.

Issue 4: Practitioners' cautious attitudes shaped by financial concerns. The coding framework further highlighted economic and financial considerations as persistent internal barriers shaping practitioners' attitudes. Despite SSCM's increasing prominence, recurring concerns about costs, time, and resource allocation continue to generate reluctance among firms to adopt these practices.

Issue 5: Double-edged impact of government legislation. Our review found that legislative factors represent a double-edged barrier across periods. While regulations often serve as drivers for SSCM adoption, increasingly stringent requirements were repeatedly identified as hindering smooth implementation, reflecting a recurring institutional misalignment.

Issue 6: Trust, communication, and collaboration deficits among supply chain members. Another consistent barrier concerns relational dynamics within supply chains. Across multiple periods, inadequate trust, weak communication, and limited collaboration among key members have been recognized as significant obstacles to SSCM implementation.

Issue 7: Supplier-related challenges and capability deficits. Finally, supplier dependence and capability gaps were frequently emphasized in the reviewed studies as persistent external barriers. Our analysis identified recurring challenges related to supplier commitment, limited knowledge, and insufficient

green expertise, which together constrain firms' flexibility in implementing SSCM.

4.2 Temporal evolution: From static obstacles to dynamic capability gaps

This study systematically maps the temporal evolution of SSCM barriers in the manufacturing sector over the past two decades. Whereas prior research has largely emphasized the categorization and enumeration of barriers, this study contributes by moving beyond descriptive classification to explain why some barriers persist across decades while others emerge in response to changing institutional and technological contexts. Specifically, this discussion addresses three dynamic dimensions: (1) why certain barriers have demonstrated long-term persistence, (2) why new barriers have emerged in recent years, and (3) how these dynamics can be captured within an integrative evolutionary model. To this end, we advance a multi-level discussion that interprets barriers as manifestations of structural resource deficits (persistent barriers) and capability renewal gaps (emerging barriers). Building on this foundation, we develop an evolutionary model of SSCM barriers that traces their developmental trajectories in the manufacturing sector and outlines the theoretical and practical implications of these dynamics.

4.2.1 Persistent barriers as structural resource deficits

The temporal analysis reveals that certain barriers exhibit remarkable persistence across time, defying the expectation that organizational learning, technological advancement, and institutional maturation would gradually resolve them. This study suggests that persistent barriers should not be understood as simple repetitions of the same problems but as deeply embedded structural deficits rooted in organizational, cognitive, and institutional architectures.

From an RBV perspective, persistent barriers reflect enduring deficiencies in valuable, rare, and inimitable resources that are difficult to build or reconfigure.

1. Managerial commitment and cross-functional governance: A lack of top management commitment and weak cross-departmental integration consistently appears across all periods. These barriers persist because they are rooted in organizational culture and governance structures, which evolve slowly and resist short-term interventions. Unlike technologies or processes, commitment and governance routines cannot simply be purchased or outsourced; they require long-term cultivation and embedding within the firm's strategic orientation.

2. Financial and resource constraints: High upfront costs and uncertain returns have remained central barriers for decades. This persistence reflects a structural short-termism in managerial decision-making, where capital allocation mechanisms prioritize immediate profitability over long-term sustainability benefits. Such financial logics are reinforced by investor pressures and volatile markets, making sustained green investment difficult to justify within existing business models.

3. Institutional and infrastructural deficiencies: Underdeveloped recycling facilities, insufficient waste management systems, and weak enforcement of regulations represent enduring bottlenecks external to the firm. These institutional voids limit the incentives and capacities of even willing firms to fully implement SSCM. Because they are shaped by broader policy and societal dynamics, such barriers cannot be resolved solely by individual corporate initiatives, thereby ensuring their continuity across time.

Integrating insights from institutional theory and the path dependence literature, this study identifies three structural mechanisms that explain their long-term persistence:

1. Cognitive lock-in effects: Managerial mindsets frequently frame sustainability as a cost center rather than a source of competitive advantage. This cognitive inertia generates self-reinforcing cycles: anticipated high costs justify limited investment, limited investment inhibits economies of scale or learning effects, and high costs are perpetuated. Such mental frames are further reinforced

by industry norms that privilege operational efficiency and short-term profitability, thereby entrenching resistance to strategic sustainability adoption (Arthur, 1989; Sydow *et al*., 2009).

2. Organizational capability path dependence: The historical emphasis of manufacturing firms on efficiency and cost minimization has produced specialized asset configurations and knowledge bases optimized for linear production models. These accumulated capabilities create switching costs that render sustainability-oriented transformations economically and organizationally prohibitive. As a result, firms remain locked into established routines and competencies, perpetuating critical resource shortages, including sustainability expertise, cross-functional integration, and innovation capacity, that hinder SSCM adoption (Sydow *et al*., 2009).

3. Institutional contradictions: Policy environments often reveal gaps between aspirational regulations and enforcement capacity. These institutional contradictions produce ambiguous or uncertain incentives, discouraging long-term investment in sustainability. Institutional voids manifest not only in weak recycling infrastructures and insufficient monitoring systems but also in fragmented regulatory frameworks that undermine credibility and consistency (DiMaggio and Powell, 1983; Scott, 1995).

Beyond firm-level dynamics, persistent external barriers also reflect structural asymmetries in stakeholder networks. Supplier commitment deficits arise not from individual decisions but from power imbalances, where sustainability demands are perceived as unilateral cost transfers imposed by dominant buyers. Similarly, limited customer awareness and demand for green products persist due to systematic information asymmetries and the absence of clear value premiums for sustainable alternatives.

Taken together, these dynamics suggest that persistent barriers are better understood as structural bottlenecks embedded in organizational and institutional architectures, rather than as temporary obstacles awaiting resolution.

4.2.2 Emerging barriers as capability renewal gaps

Persistent barriers underscore enduring structural constraints that are difficult to overcome through incremental organizational learning, whereas emerging barriers reflect capability renewal gaps arising from shifts in the technological, organizational, and institutional landscape. Viewed through the dynamic capabilities lens, these barriers point to firms' limited ability to reconfigure, integrate, and renew resources in response to evolving sustainability demands, thereby reinforcing the critical role of continuous capability renewal in sustaining competitive advantage.

1. Digitalization and data-driven ecosystems: The integration of blockchain, IoT, and AI has shifted supply chains from linear efficiency-driven systems to complex, networked ecosystems. These challenges differ qualitatively from earlier technological gaps: firms are no longer struggling with the absence of basic IT systems, but with the inability to develop advanced data infrastructures, analytics, and cross-firm data-sharing mechanisms. This signals a higher-order capability deficit in enabling transparency, traceability, and predictive decision-making across multi-tier supply chains.

2. Multi-tier supply chain governance: Sustainability responsibilities have expanded beyond dyadic buyer–supplier relationships to encompass second- and third-tier suppliers. This multi-tier supply chain management generates exponentially greater coordination costs, monitoring requirements, and accountability demands. Traditional governance mechanisms, optimized for bilateral exchanges, are insufficient for managing geographically dispersed and multi-layered supplier networks. Globalization and stakeholder activism have thus created new governance challenges that require novel, systemic approaches.

3. Institutional fragmentation and regulatory gaps: Instead of converging toward uniform standards, institutional environments are characterized by a "standards forest" of competing certifications and frameworks. This proliferation increases compliance burdens while offering limited improvements in sustainability outcomes. Moreover, the widening gap between

ambitious regulatory aspirations and limited enforcement capacity exacerbates uncertainty and investment risks. Paradoxically, institutional maturation has generated new layers of complexity rather than eliminating earlier voids.

4. Innovation and business model transformation: Emerging pressures from circular economy principles, carbon neutrality goals, and shifting consumer expectations reveal firms' struggles to redesign products, processes, and business models. Unlike earlier cost-driven challenges, these barriers reflect the absence of transformational dynamic capabilities that enable continuous innovation, ecosystem collaboration, and business model reconfiguration. Firms that fail to cultivate such capabilities risk being locked into outdated sustainability logics.

These observations suggest that emerging barriers are not merely operational obstacles but manifestations of delayed or incomplete capability renewal. They indicate firms' limited ability to reconfigure, integrate, and renew resources in alignment with rapidly evolving technological, regulatory, and societal demands, thereby underscoring the centrality of dynamic capabilities in sustaining long-term competitiveness.

4.3 A model for the evolution of SSCM barriers in the manufacturing industry

To better capture the dynamics of SSCM barriers in the manufacturing industry, we adopt a temporal perspective that categorizes these barriers into distinct evolutionary phases. Prior research has largely relied on static classifications, often mixing barriers across periods without adequately addressing their temporal progression. In contrast, this study explicitly examines the longitudinal evolution of barriers, thereby uncovering how persistent capability deficits manifest in different forms over time. The periodization is based on observable developments in four complementary dimensions: (1) policy and regulatory evolution, such as the introduction of corporate social responsibility guidelines, sustainability reporting mandates, and net-zero commitments; (2) technological progress, including the adoption of digitalization, blockchain, IoT, and Industry 4.0 technologies; (3) institutional and

organizational maturity, reflecting the gradual formalization of SSCM practices, KPI systems, and supplier collaboration mechanisms; and (4) industry and market trends, such as the increasing emphasis on circular economy, carbon neutrality, and ecosystem-level coordination.

Guided by these considerations, we define four phases that capture the evolution of SSCM barriers over time. Phase I (2004–2009) reflects early adoption challenges driven by cost pressures and managerial resistance. Phase II (2010–2015) highlights the institutionalization of SSCM alongside persistent capability gaps. Phase III (2016–2020) underscores innovation deficits and growing governance complexity. Phase IV (2021–2025) addresses digital transformation and multi-tier ecosystem coordination. This periodization offers a structured lens for distinguishing persistent barriers as structural resource deficits from emerging barriers as capability renewal gaps (Figure 4).

Phase I: Adoption and Cost-Resistance (2004–2009). Early barriers were dominated by concerns over costs, disclosure risks, and managerial inertia. Firms largely perceived sustainability as an external burden rather than a strategic imperative. A reinforcing cycle emerged: high perceived costs → resistance to adoption → limited investment → persistently high costs.

Phase II: Institutionalization and Capability Gap (2010–2015). With rising institutional pressures, firms faced challenges in embedding SSCM into organizational structures and processes. Fragmented responsibilities, weak KPI systems, and limited supplier collaboration highlighted the gap between institutional demands and organizational readiness. The inability to systematize practices reinforced capability deficits and slowed diffusion.

Phase III: Innovation and Governance Complexity (2016–2020). As SSCM expanded, innovation demands—such as eco-design, reverse logistics, and carbon management—outpaced firms' governance mechanisms. The resulting increase in coordination costs and regulatory complexity dampened managerial incentives, creating a spiral where governance limitations constrained

innovation, and stalled innovation reinforced governance complexity.

Phase IV: Digital–Ecosystem Coordination (2021–2025). The most recent phase reflects barriers at the ecosystem level, where digital integration, multi-tier governance, and institutional fragmentation intersect. While blockchain, IoT, and AI promise transparency and traceability, inadequate data infrastructures, interoperability challenges, and uncertain returns create hesitation. Barriers are no longer limited to adoption or institutionalization but extend to orchestrating digital–ecosystem coordination under fragmented and evolving regulatory environments.

Throughout these phases, certain structural deficits, including managerial commitment, financial short-termism, and institutional voids, remain unresolved, constraining progress at every phase. This model underscores that SSCM barriers evolve from adoption concerns ("whether to adopt") to institutionalization challenges ("how to embed"), and finally to scaling complexities ("how to deepen and extend").

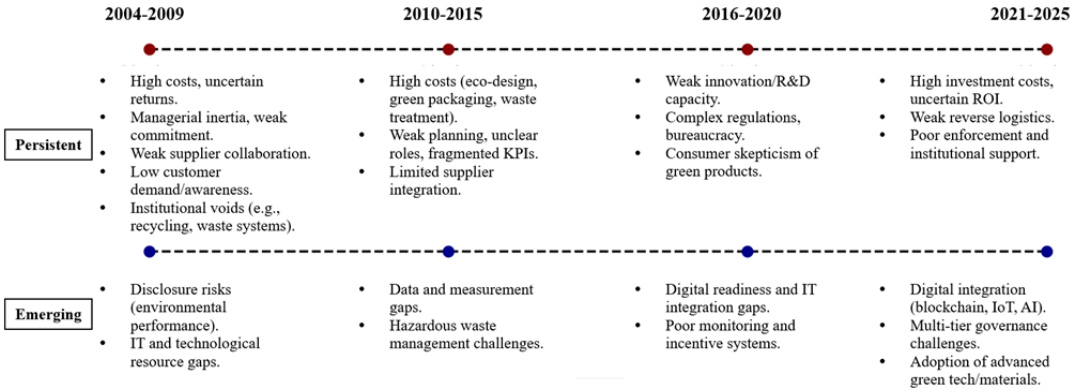

Figure 4

Temporal evolution of SSCM Barriers in manufacturing (2004-2025)

4.4 Barrier-capability framework

Building on our temporal analysis of barriers to SSCM in the manufacturing

industry, we propose a Barrier–Capability Framework that interprets these barriers as evolving manifestations of underlying capability gaps. These gaps can be classified into five domains: (1) Governance and Commitment, (2) Human Resources and Knowledge, (3) Technology and Data, (4) Finance and Resources, and (5) Ecosystem and Institutional Alignment. Each domain evolves over time, with the same capability deficiency taking on different forms depending on the maturity stage of SSCM.

Each domain evolves over time, with the same underlying capability deficiency manifesting differently depending on the maturity stage of SSCM. This dynamic perspective reframes barriers not as static obstacles but as stage-specific reflections of capability deficits, helping to explain both their persistence and emergence over different periods.

In Governance and Commitment, early-stage barriers (2004–2009) were characterized by a lack of top management commitment and managerial inertia. In 2010–2015, these barriers evolved into unclear responsibilities and weak planning mechanisms, reflecting firms' struggles to institutionalize sustainability practices. In the digital era (2021–2025), governance barriers manifest as hesitation to invest in multi-tier supplier management and risk aversion toward large-scale digital and innovation-driven transformations.

In Human and Knowledge Resources, early barriers included insufficient sustainability literacy and low motivation among employees, progressing to inadequate training, poor communication, and weak R&D capabilities in later stages. In the most recent period, firms face shortages of green professionals and gaps in advanced environmental knowledge, particularly related to reverse logistics and sustainable innovation.

Technology and Data Infrastructure initially posed challenges in terms of basic IT resources and technological adaptability. Between 2010–2015, barriers shifted to data collection deficiencies, lack of KPIs, and weak performance monitoring. In the 2021–2025 period, firms encounter complex IT integration issues, difficulties in monitoring multi-tier supply chains, and challenges in adopting green technologies and advanced system design.

Financial and Business Model Design barriers evolved from high costs and limited resources in early stages to challenges with ROI uncertainty and expensive implementation of green initiatives in later periods.

Finally, Ecosystem and Institutional Alignment reflects firms' interaction with external pressures. Early-stage barriers included limited government support, weak supplier engagement, and low consumer environmental awareness. Over time, these evolved into gaps in supplier collaboration, insufficient policy incentives, and difficulties managing societal and market expectations in a digitally connected, sustainability-driven environment.

This Barrier-capability framework provides a comprehensive lens for understanding SSCM evolution in manufacturing firms. By linking barriers to underlying capability gaps and stage-specific manifestations, it offers a practical roadmap for managers and policymakers to strengthen dynamic capabilities and strategically address both persistent and emerging challenges. It also establishes a foundation for future research on how firms can progressively build capabilities to advance SSCM maturity, optimize multi-tier governance, and implement innovation-driven sustainable practices.

4.5 Cross-period analysis: Alignment and misalignment between definitions and barriers

A cross-period comparison of SSCM reveals both alignment and misalignment between evolving definitions and encountered barriers.

Alignment: When new SSCM principles were introduced, barriers often mirrored the practical demands of implementation. For example, in 2010–2015, definitions stressed systematic integration, while barriers reflected unclear responsibilities, lack of metrics, and weak supplier collaboration. In 2016–2020, the emphasis on CSR and stakeholder engagement corresponded with barriers such as insufficient R&D, regulatory complexity, and consumer skepticism.

Misalignment: Gaps between theory and practice emerge when conceptual advances outpace organizational capabilities. In 2004–2009, the TBL was widely promoted, yet barriers remained cost concerns and managerial inertia. Similarly,

in 2021–2025, visions of technology-enabled, multi-tier governance contrast with barriers like poor IT infrastructure, weak reverse logistics, and limited supplier engagement.

Overall, SSCM's evolution reflects a dual dynamic: alignment when definitions are operationalized, and misalignment when visionary frameworks exceed firms' adaptive capacity. This underscores that SSCM develops through recurring tensions between strategic aspiration and implementation reality.

4.6 Theoretical and practical implications

4.6.1 Theoretical implications

This study advances SSCM research in the manufacturing industry by framing barriers not as static obstacles but as evolving manifestations of dynamic capability deficits. Drawing on dynamic capabilities theory, different periods of SSCM maturity in manufacturing firms can be interpreted as requiring distinct bundles of governance, knowledge, technological, financial, and ecosystem capabilities. When these capabilities remain underdeveloped, barriers emerge in forms specific to the stage of maturity, such as early-stage cost fears and managerial inertia, mid-stage deficiencies in planning and performance metrics, and later-stage difficulties with digital integration and multi-tier supplier governance. This perspective highlights that SSCM evolution in manufacturing follows a capability-building trajectory in which firms must progressively reconfigure and upgrade resources to sustain maturity.

- **Dynamic reconceptualization of barriers**: This study reframes SSCM barriers not as static categories but as evolving manifestations of resource and capability gaps. By interpreting barriers as signals of organizational capabilities, we shift the analytical focus from descriptive lists to dynamic trajectories, linking SSCM research with strategic management theory.
- **Advancing understanding of capability evolution**: Through temporal analysis, the study reveals both the path dependence of persistent

barriers and the path-breaking nature of emerging barriers. This approach advances theorization on how firms develop, reconfigure, and renew capabilities in response to sustainability challenges.

- **Barriers evolution model in the manufacturing industry:** We propose a model of recursive deepening and threshold-based transitions to explain how persistent and emerging barriers interact over time specifically within the manufacturing industry. Drawing on insights from the RBV and dynamic capabilities perspectives, this model provides a robust framework for understanding the longitudinal evolution of SSCM barriers in manufacturing contexts.

4.6.2 Practical implications

For practitioners in the manufacturing industry, our findings underscore the path dependence inherent in SSCM implementation. Firms that fail to address foundational barriers, such as financial feasibility, managerial commitment, and supplier engagement, are likely to encounter greater difficulty in advancing toward innovation-driven or digitally enabled SSCM. Conversely, manufacturing organizations that invest early in governance structures, training, and cross-functional coordination create the conditions for more effective digital transformation and multi-tier supply chain management. Thus, managers should adopt a sequenced approach: addressing persistent cost and commitment issues while simultaneously anticipating future requirements in data infrastructures, green innovation, and collaborative governance. For policymakers, the findings highlight the need to strengthen regulatory enforcement and provide infrastructural and financial support that help manufacturing firms overcome both enduring and emerging challenges.

1. Addressing Persistent Barriers: Managers should recognize that persistent barriers are structural in nature and require systemic interventions rather than incremental fixes. Examples include governance reforms, incentive realignment, and infrastructure investments to build foundational capabilities.

2. Overcoming Emerging Barriers: Emerging barriers call for anticipatory

capability building and proactive strategies. Firms should invest in digital infrastructures, multi-tier governance mechanisms, and experiment with circular business models to stay ahead of evolving technological, regulatory, and market demands.

In sum, this study reconceptualizes SSCM barriers in the manufacturing industry as evolving manifestations of structural resource deficits and capability gaps. Integrating temporal analysis with RBV and dynamic capabilities perspectives, it shows that barriers are dynamic signals of firms' capability trajectories rather than static obstacles. This perspective advances theoretical understanding of sustainability challenges in manufacturing and offers managers and policymakers practical guidance for addressing both persistent and emerging barriers. By linking barrier persistence to structural and institutional path dependencies and emphasizing continuous capability renewal, the study provides a foundation for future research on how manufacturing firms can strategically overcome obstacles and accelerate the transition to sustainable supply chains.

5. Conclusions

This study systematically investigates the temporal evolution of barriers to SSCM in the manufacturing sector from 2004 to 2025. By integrating the RBV and the dynamic capabilities perspectives, we conceptualized barriers not as static impediments but as evolving manifestations of capability deficits. Our findings reveal a clear trajectory in barrier evolution: from early concerns over cost and resistance, through institutionalization and capability gaps, to complex challenges involving digitalization, multi-tier governance, and innovation capacity. This longitudinal perspective highlights that SSCM adoption is not a discrete effort but an ongoing process shaped by both persistent structural bottlenecks and emerging challenges.

Despite progress in embedding sustainability into supply chains, manufacturing firms continue to face persistent capability deficits, including weak managerial commitment, a short-term financial orientation, and inadequate institutional support. Concurrently, emerging challenges from digital

transformation, regulatory fragmentation, and multi-tier supplier networks demand continuous reconfiguration of resources and capabilities. These findings emphasize the need for a dual strategy: addressing foundational structural deficits through systemic reforms and long-term investment, while developing anticipatory capabilities to respond to rapidly evolving technological and institutional environments.

Theoretically, this study frames SSCM barriers as dynamic indicators of firms' capability trajectories, advancing scholarly debates on the RBV and dynamic capabilities. Methodologically, it introduces a temporal literature review that links the definitional evolution of SSCM with barrier trajectories, offering a replicable framework for future research. Practically, it provides managers with a roadmap to sequence interventions across SSCM maturity stages, differentiating systemic solutions to foundational barriers from anticipatory strategies for emerging frontier challenges, while highlighting institutional voids and regulatory inconsistencies that policymakers must address to enable sustainable supply chains.

Several limitations should be acknowledged. First, the study relied on 18 systematically selected articles, which may limit the breadth of perspectives. Future research could expand the scope by incorporating grey literature, industry reports, and cross-sectoral comparative analyses. Second, the temporal mapping was conducted at the industry level; longitudinal case studies at the firm or supply chain level could yield deeper insights into how specific organizations navigate the evolving barriers. Third, while this study focused on the manufacturing sector, cross-sectoral research could clarify whether the identified capability gaps are industry-specific or more broadly applicable. Finally, empirical studies integrating firm-level data with temporal analysis could validate and extend the robustness of these findings, thereby advancing the dynamic theorization of SSCM barriers.

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