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Circular Economy in Supply Chain Management: Opportunities for Reducing Waste and Promoting Sustainability

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Abstract

This report explores circular economy strategies for supply chain management as a solution for reducing global waste and resource degradation. Sector, initiatives, and policy frameworks are reviewed in order to assess opportunities for sustainable development, and challenges of circular practice are discussed with emphasis on integrated policy, technological innovation, and collaborative stakeholder engagement. Findings indicate that the world is shifting towards a resilient, sustainable circular economy that supports environmental stewardship and economic prosperity. The Council of Supply Chain Management Professionals defines supply chain management as "the planning and management of all activities in sourcing, procurement, conversion, and logistics, including coordination with channel partners (e.g. suppliers, intermediaries, third-party service providers, and customers) and integration of supply and demand management within and across companies. A linear take-make-dispose model has depleted natural resources and generated record-breaking waste at an unsustainable level. A transition to a circular economy must be made in order to reverse this unsustainable tendency. This research examines circular economy concepts implemented in supply chain management in order to minimize waste, increase resource efficiency, and increase sustainability.

Key words: Supply chain management, zero waste, sustainability, circular economy, resource optimization, circularity design, cooperation, integration, stakeholders, Frameworks for policies

Review of Literature

The historical linear model of production and consumption with a 'take-make-dispose' attitude leads to resource overuse, damage to the environment, and generation of waste. With increasing global consumption, its sustainability is being doubted more than ever. The circular economy is an attractive alternative that focuses on reducing waste, using resources efficiently, and regenerating them by reuse, remanufacturing, and recycling. Supply chains are an essential part of global trade. They have focused on cost-effectiveness with linear material flows. Yet, the incorporation of circular economy principles

in supply chain management can make sustainability greater, decrease waste, and stimulate innovation, making the economic system more resilient and regenerative.

Circular Economy Strategies in Supply Chain Management: Towards Zero Waste. Dr. Elma Sibonghanoy Groenewald & Dr. Coenrad Adolph Groenewald. - 2024

Embedding sustainability in CE involves value creation, forward-looking stakeholder management, and long-term focus. Research indicates circular business models have the ability to create value from waste, improving sustainability. Resilient CSCM relies on customer behavior data, sustainable suppliers, and IT solutions. Balancing social responsibility with CE advantages enterprises, society, and the environment. Industry 4.0 enhances CSCM through optimized operations, reduced waste, and efficient decision-making.

Modeling circular supply chains as a method for waste management: A systematic review and conceptual framework- Haitham A. Mahmoud, Sarah Essam, Mohammed H. Hassan, Arafa S. Sobh - 2024

Shifting towards a circular supply chain is hindered by technology, market acceptance, and stakeholder engagement. It needs new technologies for tracking, disassembly, and product lifecycles extended, which necessitates huge investment and long payback periods. Market acceptance is also low since consumers tend to have a desire for new products rather than recovered ones.

Performance measurement system for circular supply chain management - Dennis Vegter, Jos van Hillegersberg, Matthias Olthaar 2023

In developing nations such as India, with a lot of people living there, there is a lot of garbage. However, not many of these pieces of garbage are treated by experts, so the country cannot utilize all its potential [Goyal et al. (2018)]. Though in Indian households there has always been a culture of recycling and reuse, the digital era struggles to nurture.

Circular practices in India - U. Amaleshwari and R. Jeevitha 2023

Linear 'take-make-waste' supply chains need to be redesigned to facilitate circular economy principles. This entails a reorientation of network design, purchasing, and processing to retain materials in use and prevent them from landing in landfill sites. Synergy with the circular economy Butterfly Diagram helps to reduce waste, recycle products, and sustainably regenerate the environment.- Abe Eshkenazi, Deborah Dull 2023

CSCM extends SSCM and GSCM with a regenerative strategy, methodically implementing circular economy practices in all stages and functions of the supply chain. Consistent with the CE philosophy, CSCM applies to manufactured as well as service products. CSCM promotes collaboration within and outside industries to optimize resource utilization, allowing supply chain managers to substantially enhance efficiency and profitability. It also lessens environmental, social, and economic effects, making it a sustainable and future-oriented approach.

Circular Supply Chain Management - Farooque, M., Zhang, A., Thürer, M., Qu, T., Huisingh, D., 2019

The circular economy (CE) is an environmentally friendly method of reducing the use of resources, waste, and energy loss through decelerating, closing, and minimizing material loops. Though not a new concept, CE has attracted widespread attention as a primary strategy for managing environmental issues and bringing together economic, political, and social actors. - Pearce and Turner 2013

Today's business management has moved away from one-to-one competition to supply chain versus supply chain competition. Success now hinges on integrating intricate business relations. Supply Chain Management (SCM) is the management of these networks, creating synergy with intra- and intercompany integration, promoting business excellence and cooperation.

Issues in Supply Chain Management - Douglas M Lambert, Martha C Cooper 2000

3. Research Methodology

This study investigates the role of the circular economy in supply chain management and its potential for waste reduction and sustainability. A quantitative research approach is employed, utilizing primary data collected via Google Forms.

Data Collection

A structured questionnaire was designed to gather insights from supply chain professionals, business managers, and sustainability experts.

The survey consists of closed-ended and Likert scale-based questions to assess awareness, adoption, challenges, and impacts of circular supply chains.

The target respondents include professionals from logistics, procurement, manufacturing, and sustainability fields across various industries.

Data Analysis Tools

The collected data will be analyzed using statistical methods to derive meaningful insights:

t-test: To compare means and determine significant differences in circular economy adoption across different groups.

One-Way ANOVA: To analyze variations in circular economy practices among different industries or business sizes.

Regression Analysis: To identify the relationship between circular supply chain practices and key business outcomes such as cost efficiency and waste reduction.

Research Objectives

- To assess the awareness and adoption of circular economy principles in supply chain management.
- To identify key opportunities for reducing waste and promoting sustainability in supply chains.
- To explore industry-specific challenges in transitioning from linear to circular supply chains.
- To analyze the impact of circular economy practices on operational efficiency and cost reduction.
- To examine statistical relationships between circular supply chain adoption and business performance using regression analysis.

Introduction

The circular economy, with its focus on reuse, repair, recycling, and remanufacturing, provides a means to break the link between economic growth and resource consumption. Amidst the uneven waste management infrastructure in the world and increasing resource scarcity, adopting circular ways of working becomes imperative. The purpose of this research is to study the state of supply chain circular economy initiatives presently, determine the most important opportunities for implementation, and assess the challenges faced in advancing progress. Additionally, it aims to supply actionable advice for the stakeholders to support the transition to a more sustainable and circular economic model.

The marketplace in the world today is characterized by stiff competition. The emergence of products with shorter lifecycles and increased customer expectations have compelled business firms to spend money on, and direct attention towards, their supply chains. This, combined with ongoing developments in communications and transport technologies (e.g., mobile telecommunication, internet, and overnight delivery), has driven the ongoing development of the supply chain and of the methods to control it efficiently. Most recently, competitive market pressure and new information technologies have impacted the production system structures, requiring:

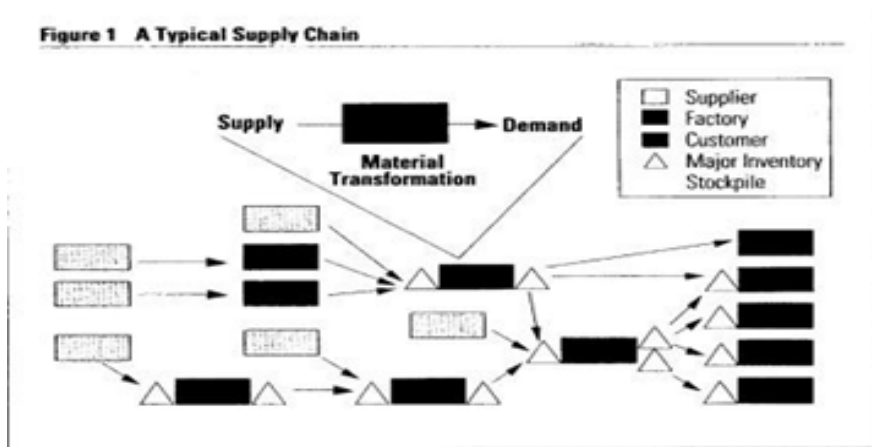
- Decrease in time to market
- Tighter flexibility of the systems
- Extreme reduction in cost
- Extended quality concept

The aim of this paper is to examine how technology can be used to support the practice of a circular economy in supply chains. As companies increasingly seek to move away from linear strategies towards a circular way of doing business, technological change offers great possibilities to improve resource use, optimize recycling procedures, and improve supply chain efficiency. This essay will seek to explore several technologies, including the Internet of Things (IoT), blockchain, and artificial intelligence (AI), which can enable the application of circular economy concepts in supply chains. Through an examination of the contribution of these technologies to enhancing supply chain transparency, efficiency, and collaboration, the paper seeks to highlight best practices and strategies that organizations can adopt to embrace the circular economy. Ultimately, this study aims to provide a comprehensive understanding of the intersection between technology and circular economy principles in supply chain management, offering insights for policymakers, businesses, and researchers to foster sustainable practices that benefit both the economy and the environment.

Supply Chain Management (SCM)

Supply Chain Management (SCM) refers to the strategic planning of all operations pertaining to the production and distribution of goods and services, from raw material procurement to final product delivery to consumers. The international supply chain is a convoluted and dynamic system involving suppliers, manufacturers, distributors, retailers, wholesalers, and end users.

Effective SCM's prime objective is to maximize this interconnected network so that materials, information, and finances move in a smooth manner in the supply chain. It entails procurement, production, storage, transport, and ultimate distribution. Moreover, SCM necessitates synchronization of internal operations as well as external partners to maximize efficiency, minimize costs, and increase customer satisfaction. SCM, by definition of the Council of Supply Chain Management Professionals (CSCMP), unifies demand and supply management within and across organizations to maximize operating performance.



Effective Supply Chain Management-Tom Davis 1993

Importance of Supply Chain Management

An efficiently structured supply chain greatly improves the operational efficiency through lower costs, less wastage, and better cycle times. Companies with superior SCM capabilities are found to be 23% more profitable compared to the competition, indicating the quantitative influence of SCM on business success.

In addition, successful SCM allows businesses to anticipate and avoid risks like supply chain interruptions, thereby ensuring business continuity as well as conformity to regulatory requirements. Through timely and quality product delivery, SCM helps improve customer satisfaction and loyalty.

In the dynamic world of business today, the function of SCM goes beyond efficiency in operations to encompass sustainable living. Sustainable supply chain management seeks to minimize carbon footprints, streamline logistics and energy consumption, and reduce waste, connecting business goals with global sustainability agendas.

Key Elements of Supply Chain Management

a) Planning

Planning involves demand forecasting, production scheduling, and inventory management to ensure that the right products are available to meet consumer demand. It also includes setting strategic goals, defining key performance metrics, and adapting supply chain strategies to accommodate new product developments and market dynamics.

b) Sourcing

Sourcing entails selecting and managing suppliers, negotiating contracts, and ensuring a reliable supply of raw materials and components. This process also includes procurement, inventory control, and supplier relationship management to maintain operational consistency and cost efficiency.

c) Manufacturing

Manufacturing encompasses the organization of production activities, including the acceptance of raw materials, product design, assembly, and quality control. Effective manufacturing practices ensure product consistency, minimize defects, and optimize resource utilization.

d) Delivery

Delivery involves the transportation and distribution of finished goods, ensuring timely fulfillment of customer orders. This stage includes managing logistics operations, warehousing, distribution centers, and order fulfillment processes.

e) Returns

Handling returns requires an efficient reverse logistics network to manage defective, excess, or end-of-life products. This process includes returns processing, recycling, disposal, and customer service strategies to enhance overall supply chain performance and sustainability.

Circular Supply Chain Management

Applying circular thinking to the management of the supply chain and its industrial and natural ecosystems is known as circular supply chain management. Through system-level innovation in business models and supply chain functions, from product/service design through end-of-life and waste management, it technologically restores and renews biological materials in a zero-waste vision. Sustainability in supply chain management, where all parties involved in a product or service lifecycle—including manufacturers of parts and products, service providers, customers, and users—are involved.

By including a regenerative component, CSCM significantly enhances SSCM and GSCM. By methodically implementing CE's circular thinking in all supply chain activities and phases, it elevates the concept of sustainability. Similar to the CE philosophy, CSCM is applicable to both service and industrial products. With CSCM, organizations partner with others within or outside the industry in order to optimize the use of goods/materials. It presents a hopeful prospect to lead the supply chain managers to a breakthrough in resource effectiveness, and thus, profitability. At the same time, it reduces negative environmental, social, and economic effects.

Circular economy is gaining momentum as an improved option over the prevailing linear (take, make, and dispose) economic model. Circular Supply Chain Management (CSCM), with its fusion of the circular economy philosophy into supply chain management, provides a fresh and engaging view to the field of supply chain sustainability. Following this, research interest is on the rise. Yet, a review of existing literature indicates that there remains no integrated view to date of CSCM in the existing literature. This prevents a sharp differentiation from other supply chain sustainability definitions and impedes the advancement of the field further. In reply, this study initially categorizes different supply chain sustainability terminologies and formulates a consolidating definition of CSCM.

The Ellen MacArthur Foundation (EMF) (2014) promoted CE as a restorative and regenerative industrial system. At every stage of biological and technical cycles, CE aims to keep materials, components, and products in their most valuable and useful states. This enhances natural capital and makes it possible to safely restore biological components or nutrients to the biosphere. Similar to this, geosphere-derived technical nutrients can be designed for recovery (recycling, renovating, and remanufacturing); as a result, they can be kept in the technosphere by circulating within and contributing to the economy with little waste.

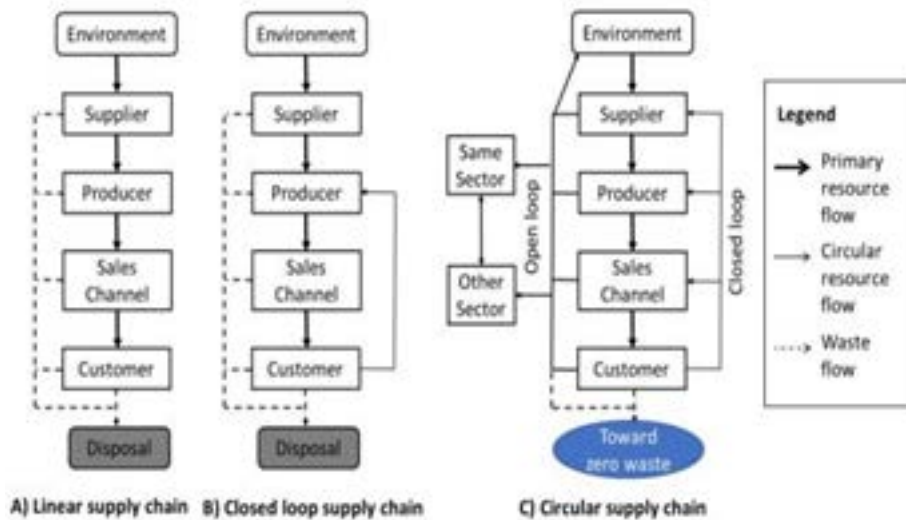


Fig 2 Linear, Closed and circular supply chains

Circular Supply Chain Management: A Definition and Structured Literature Review Farooque, M., Zhang, A., Thürer, M., Qu, T., Huisingh, D., 2019.

Because a circular supply chain is intended to systematically restore and regenerate resources in the industrial and natural ecosystem in which it is embedded, it should ideally produce zero waste. As seen in Figure 1c, there are two different kinds of resource flows in circular supply chains: primary resource flows and circular resource flows. In both linear and closed-loop supply chains, the forward flow of goods is considered to be the primary resource flow. Recycled, retained, reused, repaired, remanufactured, refurbished, recovered, and other “re-” type flows of goods, materials, and energy are represented by the circular resource flows.

Industry-Specific Challenges in Transitioning from Linear to Circular Supply Chains

The shift from a linear supply chain model (take-make-dispose) to a circular supply chain (reduce-reuse-recycle) presents industry-specific challenges that impact implementation and scalability. While circular supply chains offer environmental and economic benefits, industries face unique hurdles in adopting them effectively.

1. Manufacturing Industry

Manufacturers struggle with high initial investment costs for redesigning products and processes to enable recyclability and reusability. Additionally, integrating reverse logistics—the process of collecting and reintroducing materials into the supply chain—demands infrastructure and technology that many firms lack.

2. Retail and Consumer Goods

Retailers depend heavily on customer participation for circular models like product returns, refurbishing, and resale. However, consumer behavior is unpredictable, and many hesitate to buy recycled or refurbished goods due to quality concerns. The lack of standardized return policies and collection networks further complicates circular initiatives.

3. Logistics and Transportation

Circular supply chains require efficient reverse logistics, but existing infrastructure is designed for one-way distribution. Companies face challenges in optimizing transportation costs and reducing carbon footprints while handling returned products and materials.

4. Food and Agriculture

The food industry struggles with perishability and lack of proper waste management systems. Reducing food waste requires innovative solutions like composting, upcycling food by-products, and leveraging AI for demand forecasting, which many businesses have yet to implement effectively.

Key Concepts of The circular Supply Chain

a) Sustainable Sourcing

The circular supply chain begins with the responsible procurement of materials, prioritizing renewable resources or those derived from recycled waste. Companies are increasingly collaborating with suppliers that offer perpetually recyclable materials or implement environmentally conscious practices to minimize ecological impact.

b) Design for Longevity

Products are engineered for durability, ensuring an extended lifecycle with provisions for future reuse or recycling. This includes designing for easy disassembly to facilitate material recovery and selecting components that can be efficiently refurbished and reintegrated into the market.

c) Return Systems

Efficient return mechanisms are essential for reclaiming end-of-life products and reintegrating them into the supply chain rather than discarding them. Businesses may implement buy-back programs, leasing models, or customer incentives to encourage product returns and reduce waste.

d) Remanufacturing and Recycling

Upon return, products undergo remanufacturing or recycling processes. Remanufacturing restores items to like-new condition, extending their usability, while recycling involves breaking down products into raw materials for the creation of new goods, thus ensuring a closed-loop supply chain system.

8. Challenges and Barriers to Implementation

Organizations must overcome a number of obstacles and hurdles when switching to circular supply chains in order to successfully apply the concepts of the circular economy. Developing strategies to ease this transition requires an understanding of these challenges.

1. **Regulatory Obstacles:** The current regulatory environment, which frequently opposes circular economy initiatives, is one of the biggest obstacles. Companies attempting to adopt practices like recycling, remanufacturing, and resource recovery face challenges because many regulations were created with traditional linear models in mind. Regulations might, for example, impose stringent waste disposal requirements that deter material reuse or increase compliance costs for businesses looking to innovate in their waste management strategies (European Commission, 2020). Investment may be discouraged and the transition may be slowed by this mismatch between regulations and circular practices.
2. **Supply Chain Complexity:** Adoption of circular practices may be impeded by supply chain complexity. While circular supply chains necessitate close cooperation between numerous stakeholders, including suppliers, manufacturers, and end users, traditional linear supply chains are usually simpler and more straightforward. This intricacy may make it difficult to track materials, guarantee product quality, and handle returns. Businesses may find it difficult to form the alliances and lines of communication required to support successful circular supply chains, which could result in inefficiencies and higher expenses.
3. **Lack of Knowledge and Experience:** It's possible that many organizations are unaware of or do not comprehend the concepts and procedures of the circular economy. The creation of practical

plans for putting circular practices into practice may be hampered by this knowledge gap. Finding the right technologies and procedures for the shift to circular supplychains may also be challenging due to a lack of experience within companies. Employees must receive education and training in order to be prepared for this shift.

4. **Financial Restrictions:** Putting circular practices into practice frequently necessitates upfront expenditures for new infrastructure, technology, and procedures. Financial limitations may prevent many organizations, especially small and medium-sized businesses (SMEs), from making these investments. Organizations may be further discouraged from making the required adjustments if they are uncertain about the return on investment (ROI) for circular initiatives.

Data Analysis

1. T-Test (Comparing Satisfaction Scores Based on Familiarity with Circular Economy)
Hypotheses:
2. H_0 (Null Hypothesis): There is no significant difference in the satisfaction scores between those who are “Very Familiar” and “Not Familiar” with Circular Economy.
3. H_1 (Alternative Hypothesis): There is a significant difference in the satisfaction scores between the two groups.

Group	Mean Satisfaction Score	Variance	Sample Size
VeryFamiliar	2.29	2.10	17
Not Familiar	2.65	1.69	23
T-Statistic	-0.82	---	---
P-Value	0.417	---	---

Decision: Since $p\text{-value} (0.417) > 0.05$, H_0 is accepted.

Interpretation: Since the $p\text{-value} (0.417)$ is greater than 0.05 , there is no statistically significant difference in satisfaction scores between the two groups.

ANOVA (Comparing AI Adoption Scores across Roles in the Supply Chain) Hypothesis:

H_0 (Null Hypothesis): There is no significant difference in AI adoption scores among different roles in the supply chain industry.

H_1 (Alternative Hypothesis): At least one group has a significantly different AI adoption score.

Role in Supply Chain Industry	Mean AI Adoption Score	Variance
Procurement	3.73	2.21
Logistics	3.25	3.04
Manufacturing	3.19	2.30
Retail	2.69	1.98
Other	3.57	2.17
F-Statistic	1.50	---
P-Value	0.208	---

Decision: Since $p\text{-value} (0.208) > 0.05$, H_0 is accepted.

Interpretation: The $p\text{-value} (0.208)$ is greater than 0.05 , meaning there is no statistically significant difference in AI adoption scores among different roles in the supply chain.

Regression Analysis (Predicting Satisfaction Score)

Hypothesis:

H_0 (Null Hypothesis): Investment Score and AI Adoption Score have no significant effect on Satisfaction Score.

H_1 (Alternative Hypothesis): Atleast one predictor variable (Investment Score or AI Adoption Score) significantly affects Satisfaction Score.

Predictor Variable	Co-Efficient	P-Value	Interception
Intercept	2.15	0.000018	Baseline Satisfaction Score
Investment Score	0.05	0.610	No significant impact of investment on satisfaction
AI Adoption Score	0.14	0.140	No significant impact on AI adoption on satisfaction

Decision: Since both p-values >0.05, H_0 is accepted.

Conclusion: Neither Investment Score nor AI Adoption Score significantly predict Satisfaction Score.

Interpretation: Since both predictor variables have p-values greater than 0.05, neither Investment Score nor AI Adoption Score significantly predict Satisfaction Score.

Recommendations

A. T-Test (Satisfaction Scores & Familiarity with Circular Economy)

Insight: The lack of a statistically significant difference in satisfaction scores between those “Very Familiar” and “Not Familiar” with the Circular Economy suggests that knowledge of circular economy principles does not influence satisfaction levels. This could mean that satisfaction is driven by other factors, such as business performance, cost savings, or operational efficiency rather than awareness.

Recommendation

Instead of focusing only on education about the circular economy, organizations should explore what truly drives satisfaction—perhaps factors like financial benefits, ease of implementation, or regulatory incentives.

Conduct qualitative studies (interviews or surveys) to identify what aspects of sustainability or circular economy matter most to different stakeholders.

B. ANOVA (AI Adoption Across SupplyChain Roles)

Insight: The results indicate that AI adoption scores do not significantly vary across different roles in the supply chain. This suggests that AI adoption is fairly uniform or that barriers and drivers of AI adoption are consistent across the supply chain.

Recommendation

Conduct further analysis to identify the key challenges preventing significant variation in AI adoption (e.g., cost, lack of skills, infrastructure).

Implement targeted AI training programs for different roles to maximize AI utilization based on

job-specific requirements.

Explore whether company size, industry type, or geographical location influences AI adoption more than job roles.

3. Regression Analysis (Predicting Satisfaction Score)

Insight: Neither Investment Score nor AI Adoption Score significantly predict Satisfaction Score, indicating that financial investments or AI usage alone do not directly impact satisfaction. Satisfaction could be influenced by unmeasured factors such as efficiency improvements, profitability, or regulatory compliance.

Recommendation

Identify and incorporate other potential factors into the analysis, such as operational efficiency, cost savings, ease of implementation, and environmental impact.

Use qualitative data (surveys, interviews) to understand what aspects of AI adoption or investment contribute to satisfaction—it may not be the adoption itself but rather the benefits derived from it.

Conduct a moderation or mediation analysis to see if AI adoption and investment influence satisfaction indirectly through other variables like productivity or cost reduction.

Conclusion

In order to achieve zero waste, the paper has examined how supply chain management can incorporate circular economy strategies. Several important insights have been revealed by examining case studies, talking about difficulties and obstacles, and describing the advantages of implementing circular economy principles. First, by implementing circular economy practices in their supply chains, businesses can reap substantial benefits. Cost cutting, resource efficiency, risk reduction, innovation, and environmental preservation are a few of these. Businesses can increase their competitiveness and support sustainability goals by implementing strategies like redesigning products for circularity, investing in recycling infrastructure, and working with stakeholders.

Second, although there are obstacles and challenges associated with the shift to a circular economy, including regulatory restrictions, technological limitations, and consumer behavior, these can be overcome with strategic planning, teamwork, and innovation. Companies can unlock opportunities for growth, resilience, and long-term viability by proactively addressing these challenges. In summary, supply chain management's shift to a circular economy offers companies a revolutionary chance to add value, cut waste, and advance sustainability. Businesses can help create a more resilient and sustainable future for everybody by implementing holistic approaches to supply chain management and embracing circularity as a guiding principle.

It is becoming more widely acknowledged that the changing perspectives and practices in the planning and execution of CEs are superior to the widely used linear (take, make, dispose) economic model. It has a lot of potential to assist businesses in making significant progress in their sustainability performance. As a result, there is increasing interest in researching the integration of CE into SCM. Nonetheless, there are still a lot of misunderstandings regarding supply chain sustainability terminology. This study made the case that a lack of knowledge about what CSCM actually entails and which research directions are strategically important is impeding the field's progress. We responded by offering a definition of CSCM based on the larger body of literature.

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