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THE ROLE AND IMPORTANCE OF CIRCULAR BUSINESS MODELS IN SUSTAINABLE SUPPLY CHAIN MANAGEMENT

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Abstract
The study emphasizes the role of circular business models in promoting sustainable supply chain management. The paper first relates traditional and green supply chain management to environmental and social criteria that are increasingly becoming material issues on a global scale. The paper addresses some important circular business models, including closed-loop supply chains, recycling and re-use, design-driven circularity, sharing economy models, waste management, reverse logistics, bio-based technologies, responsible supply chains, and industrial symbiosis. Together, these business models offer resource efficiency, waste reduction, and life expansion through ecological and economic benefits. More a circular way of thinking is adopted into business processes, the more price-competitive those businesses become and thus comply with regulations and increase the confidence of their customers. In spreading the principles of circular business models, supply chain management becomes vital to the realization of the United Nations Sustainable Development Goals, which include combating climate change impacts, conserving natural resources, and maintaining social responsibility. Despite a certain degree of risk factor-the large upfront cost and the coordination of multiple stakeholders-circular business models offer a real transition to a more resilient, adaptable, and future-ready supply chain.

1 Introduction

Traditional supply chain management is a coordinated management approach that examines the flow of products, information, and funds among suppliers, manufacturers, distributors, retailers, and customers that constitute the supply chain. Supply chain management aims to deliver the right product to the customer at the right time, in the right place, and at the right price with minimized costs across the entire supply chain. In so doing, it aligns the materials, funds, and information flow together in an integrated manner. That is, it aims to create business models and strategies that will create customer satisfaction by coordinating fundamental business processes across the chain. Supply chain management is a system of management that aligns internal capabilities effectively while aligning the procured processes outsourced by the firm (Chopra, 2022). Supply chain management involves the planning and control of all supply chain operations. Coordination and cooperation with channel partners such as suppliers, intermediaries, third-party service firms, and

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customers are also part of it. Thus, supply chain management integrates internal as well as inter-company supply and demand management

Sustainable supply chain management is an approach that tries to optimize the profitability of the supply chain with the least possible environmental impact and with the improvement of social welfare. In this sense, it manages the operations, resources, information, and funds within the supply chain (Ivanov, 2022). It is, therefore, a generalized approach meant to guarantee the management and collaboration of material, information, and capital flows within different businesses of the chain concerning economic, environmental, and social aspects of sustainable development goals based on customer and stakeholder demands. In these sustainable supply chains, the members must comply with some environmental and social criteria to stay in the chain, thus maintaining their competitive advantage by satisfying their customers' requirements and corresponding economic criteria (Sarkis, 2021).

Several reasons exist to act for improving the environmental and social impacts throughout the supply chain. Many companies practice according to their corporate values and culture of addressing sustainability issues. For such companies, supply chain sustainability is an ethical obligation to be fulfilled and a component of social development and environmental protection. This approach supports the creation of internal alignment and commitments within the organization. Furthermore, many companies also carve out business cases for supply chain sustainability. For a company, the term business cases depends on numerous factors such as sector of industrial activity, carbon footprint of the supply chain, expectations of the stakeholders, business strategies considered, and corporate culture. Supply chain sustainability practices that respond to the different business cases can increase the value that a company can capture. The main business cases put forth for supply chain sustainability that research today supports (Beske & Janssen, 2021) include:

Managing Corporate Risk: Reducing business disruptions caused by environmental, social, and economic impacts, and protecting the company's reputation and brand value.

Ensuring Efficiency: Lowering input material, energy, and transportation costs; increasing labor productivity; and creating efficiency within the supply chain.

Creating Sustainable Products: Innovating to meet the growing demands of customers and corporate stakeholders and to transform markets.

Businesses that implement sustainable supply chain management achieve enduring success through their improved environmental and social performance and economic results. The implementation of sustainable supply chain management brings dual benefits to companies through market competitiveness and social advantages (Gölgeci & Kuivalainen, 2020). The wide-ranging characteristics of sustainable supply chain management require assessment through a comprehensive evaluation method.

The implementation of sustainable supply chain management enables organizations to decrease their environmental footprint. Companies that adopt environmentally friendly practices and optimize resource usage can decrease their operational expenses through reduced energy usage and waste output and carbon footprint (Khan et al., 2021). The combination of cost reduction and improved environmental standing and regulatory compliance emerges from these sustainable practices.

The implementation of sustainable supply chain management generates positive social effects for organizations. Organizations that implement fair labor practices and protect worker rights and maintain safe workplaces and support local communities achieve higher employee satisfaction and public approval (Silva et al., 2020). Businesses that demonstrate social responsibility build better stakeholder relationships and achieve substantial social sustainability outcomes.

Sustainable supply chains improve the long-term financial well-being of companies. Operational efficiency can be improved, and risks diminished, thus translating into higher profits due to lower costs (Vishwakarma et al., 2022). Nevertheless, nowadays, there has come to be an increasing emerging demand for sustainability-related companies by consumers and investors, who exercise a consciousness of their own. Hence, sustainable supply chain management becomes an important tool to families for sustaining financial success.

Sustainable supply chain management (SSCM) is a multilayered process through which organizations integrate environmental, social, and economic concerns to create long-term value for all stakeholders, consumers, and society. SSCM, in full ambit, from raw material extraction to processing, use, and final disposal, emphasizes the adoption of sustainable practices (Koberg & Longoni, 2019). Hence, by its nature, sustainable supply chain management is terribly complex and challenging.

The difficulties emerging from SSCM are caused by different structural, operational, and external factors. First of all, the implementation requires the coordination of a highly complex and large network of stakeholders, which encompasses suppliers, customers, regulatory agencies, non-governmental organizations,

A major barrier is that SSCM often increases short-term costs. Sustainable practices- sourcing materials to be environmentally friendly, maintaining ethical labor conditions, and reducing carbon emissions, among others- usually come with substantial initial costs. Hence, many firms simply cannot afford to absorb these costs in highly competitive markets, which trashes full-scale implementation of sustainability initiatives (De Giovanni, 2020). The other facet is that efficient SSCM demands solid data collection and reporting mechanisms, whereas keeping tabs on environmental and social performance through an entire supply chain is indeed a Herculean task, an opacity that most of the time causes major traceability bottlenecks-an actual barrier to evaluate true sustainability performance (Kouhizadeh et al., 2021).

Even with all the challenges, SSCM is of incredible value to both companies and society. Supply chains can address issues such as climate change, resource depletion, and social inequity. Conversely, sustainable practices assist firms in maintaining long-term reputational advantage, demonstrating compliance with the law, and meeting the increasing societal and environmental expectations of consumers and investors (Fathi et al., 2021). Therefore, SSCM is part of the journey to organizing a firm for the purposes of society while realizing a sustainable competitive advantage.

The core advantages and challenges, as synthesized from contemporary literature (Rajeev et al., 2022), can be summarised as follows:

Advantages:

Minimizing and Preventing Risk: Enhancing resilience to environmental, social, and economic disruptions.

Designing Efficient Processes and Strengthening Innovation: Improving resource productivity and fostering innovation through new, sustainable practices.

Enhancing Transparency and Ensuring Higher Standards: Building trust through greater visibility and adherence to elevated social and environmental standards.

Creating Value Collectively: Generating shared value for the company, its stakeholders, and society.

Challenges:

SSCM is a long-term strategic commitment, not a short-term project.

Identifying and assessing sustainability impacts and risks throughout the supply chain is difficult and requires focused effort.

Promoting sustainability with suppliers involves overcoming significant barriers and resistance to change.

Effective integration requires embedding sustainability into existing internal processes and systems.

Management must extend beyond direct (Tier 1) suppliers to include sub-suppliers (Tier 2 and beyond).

There are stringent data management and verification requirements for accurate reporting.

Sustainable or green SCM is a discipline that has emerged as companies pursue environmental conservation and sustainability. Research indicates that sustainable supply chain is

a significant developmental stage player moving from purely environmental-concerned systems to models having economic, social, and environmental considerations (Badr, 2024: 332). The primary ways of integrating sustainability have included implementing green logistics: such as transport-route optimization and so forth, as well as the use of environmentally friendly vehicles, etc., all of which minimize carbon footprint while promoting operational efficiency (King, 2024: 31).

Supply chain management for sustainability introduces a new operating environment where supply chain activities consider economic, environmental, and social issues, with the objective of minimizing any negative consequence on actors that derive value interactions with others. Therefore, globalization has built increasingly complex supply chains that must now meet higher regulatory requirements for environmental and labor protection (Blanka et al., 2024: 25). In advancing innovation and practice sustainability, collaboration is one, while the implementation of new technology is another. This collaboration to create synergy above the forefront sustainable option fosters value to the environment, specifically in the manufacturing environment where branding, customer loyalty, and market competitiveness can be established (Kittinun, 2024: 85).

Despite challenges such as high initial investments and regulatory complexities, a continued commitment to sustainable practices has become imperative for long-term success in supply chain management.

2 Definition and Importance of Circular Models

Circular business models are operational models focused on achieving a sustainable economy by maximizing the utilization of resources and minimizing waste production and environmental impacts (Kirchherr et al., 2023). Grounded in principles of the circular economy, these models develop a high level of product lifecycle value generation which is emphasized by reusing and prolonging product cycle life. While supporting sustainable economic growth by minimizing resource use, maintaining natural capital, and minimizing waste production (Pieroni et al., 2021), Circular business models provide a key component for achieving potential recommendations and collaborative sustainable practices throughout a supply chain.

Several strategies can be utilized to apply circular business models. The first is primarily related to first design, whereby products are modularly designed as durable with the purpose of allowing repair, upgrading or re-use (Bocken et al., 2021). The second strategy is recovering materials at the end of the product in order to reuse resources. The recovery model is an essential circular business model, particularly in the recycling and waste management sector, to minimize environmental impact. Circular business models such as the "product-service system" or "sharing economy", seek to improve engagement-based work systems such as leasing and sharing over pure ownership to maximize time utility while minimizing consumption (Lüdeke-Freund et al., 2023).

Circular business models offer companies a competitive edge over one that is not. In this respect, circular business systems are capable of helping companies reduce the cost of resources, uphold their environmental responsibilities, and create environmentally conscious products that align with consumer choices (Morseletto, 2022). Hence, the conversion to a circular economy shows an increase in the innovative potential of companies while simultaneously creating business opportunities that sustain the creation and accumulation of long-term sustainable value.

Circular business models thus introduce a new paradigm for sustainable production and consumption. They put an emphasis on resource efficiency, waste prevention through some strategies, keeping products and materials in use for as long as possible, and collectively attacking global environmental issues. In the larger scheme of things, there is a genuine call for the establishment of circular business models if one hopes to develop the sustainability agenda and offset the adverse effects brought about through traditional consumptive behaviors.

The main circular business models highlighted in the literature can be listed as follows:

Product Design and Modularity: Durable, modular, and reusable products are the basic building blocks of any circular-dotted business model. To enable easy repairs, upgrades, reuse of components, or dismantling of products, such product designs are imperative. Modular design techniques actually make better use of resources by extending product cycles (Bocken et al., 2021).

Resource Reuse and Recycling: A fundamental principle of the circular economy, this model reduces negative environmental impacts by recycling or reusing products at the end of their life.

Thus, raw material consumption is reduced, and waste management processes are improved (Morseletto, 2022).

Product-Service System (PSS): The manufacturers in this model adopt a service-centered approach instead of focusing on ownership of their products. The product's usage time is extended through services such as leasing, sharing, and subscriptions while production of new products is discouraged (Lüdeke-Freund et al., 2023).

Recovery and Resource Recycling: This model is based on recovery of by-products and wastes from production processes and their use as raw materials for other production. Recovery lessens the raw material cost and maximizes companies' operational efficiency (Ellen MacArthur Foundation, 2024).

Sharing Economy: Sharing economy has recently become more widely spoken in the circular business model. This system encourages people to use their own personal assets. It has positive effects on the environment and economy, particularly in the domains of car sharing, office space sharing, and accommodation sharing (Kirchherr et al., 2023).

These circular business models create a competitive advantage for businesses by conserving resources and promoting environmental sustainability. At the same time, the circular economy approach facilitates companies' compliance with environmental regulations and the fulfillment of their social responsibilities.

3 The Role of Circular Models in Sustainable Supply Chain Management

3.1 Closed-Loop Supply Chain

The closed-loop supply chain is founded on one of the oldest principles known to logistics and supply chain: products accepted back into the supply chain at the end of their useful life are reprocessed and reintroduced into the supply chain (Atasu et al., 2021). In this model, waste and used products form the raw materials for making new products thereby reducing the consumption of natural resources and thus minimizing environmental effects. Closed-loop supply chain aims to have products reintroduced into the supply chain once their life-cycle is over instead of downright discarding them as waste. This strides toward collecting, repairing, remanufacturing, or recycling the products or components after their useful life has ended and reintegrating them into the supply chain (Atasu et al., 2021). Additionally, the consumption of natural resources is curtailed, while environmental impacts are concurrently limited.

The closed-loop supply chain model in turn envisages reverse logistics activities apart from the traditional forward logistics processes. Reverse logistics entails the set of processes involved in taking back the unwanted products from the customers, reprocessing them, dismantling their components, and fueling them back into the supply chain (Ülkü, 2022). This process not only ensures economic efficiency but also contributes to environmental sustainability.

The main benefits of the closed-loop supply chain consist of reductions in raw material expenditures, waste management costs, and adverse environmental effects. Moreover, increasing environmental awareness among consumers and rising demand for sustainability are inducing businesses to opt for circular models such as the closed-loop supply chain (Agrawal et al., 2022). Practices under the closed-loop supply chain also boost companies' capability to produce products that are environmentally friendly, hence granting them a competitive edge in the market (Han et al., 2023). Closed-loop aims at SDGs by making resources reusable and minimizing loss of materials.

In conclusion, the closed-loop supply chain is a potential model whose activities promote the environment and economic sustainability by assuring the recovery of products before, during, or after their life cycle. Implementation of this model also optimizes the use of natural resources, reduces environmental impacts, and develops business opportunities to augment economic activities.

3.2 Recycling and Reuse

Recycle and reuse are the two pillars of sustainable supply chains, clustering under the circular model. The process consumes fewer natural resources and mitigates environmental impact by turning wastes into reusable resources. Unlike the traditional linear model of production and consumption, circular supply chains try to put resource efficiency first by prolonging product life

cycles and to reintegrate waste into the production processes (Kirchherr et al., 2023). There are prominent economic and beneficial environmental effects that recycling and reuse promote.

Recycling and reuse in supply chains reduce dependence on newly acquired raw materials, thereby cutting costs. Recycling materials such as plastics, papers, metals, and glasses lessen raw material acquisition cost and ever so slightly support a secure supply chain (Ülkü, 2022). Recycling and reuse give producers access to materials that are less costly so that companies improve profit margins. Furthermore, businesses will earn a competitive edge in preparing environmentally friendly products and satisfying customer demands by putting these processes into use (Agrawal et al., 2022).

Recycling wastes from an environmental point of view until the waste is set to be discharged into nature, causing pollution in the environment and halting the depletion of natural resources. When these processes are integrated into the supply chain, they provide certain direct environmental benefits to the collecting, processing, and re-using phases (Han et al., 2023). Besides, recycling and reuse operations also reduce carbon emissions that help entities achieve their sustainability objectives.

From the social perspective, the recycling and reuse processes can bring about employment and help to society. These activities are in a position to bring jobs, especially in the under-developing regions, and assure local economy (Morseletto, 2022). Additionally, these practices offer companies opportunities to fulfill their social responsibilities, as environmentally and socially responsible business practices enhance public awareness and strengthen consumer trust.

In conclusion, recycling and reuse serve as critical circular models in supply chains, delivering resource efficiency, cost savings, environmental sustainability, and societal benefits. These processes assist companies in achieving sustainable development goals while reducing negative environmental impacts and enabling them to fulfill their social responsibilities.

3.3 Design-Driven Circularity

This model refers to the shaping of products according to circular economy principles at the design stage. Products are designed to be durable, reusable, and recyclable. Furthermore, design ensures that the products are of modular construction, repairable, and have separable components, which in turn would further extend product life cycles and prevent waste. The notion of design-driven circularity refers to the incorporation of circular economy principles at the product design stage. In this product design concept, products are engineered to be more durable and, therefore, reusable and recyclable. Circularity at the design stage is of paramount importance, along with lengthening the product life cycles and thereby minimizing the production of wastes. Design-driven circularity focuses on how design changes the nature of traditions to enhance product durability and functionality with minimal environmental impact during its production, use, and subsequent recycling (Bocken et al., 2021).

Using this circular model, one must consider material efficiency, energy efficiency, modularity, and recyclability in design. For example, if the product is designed in a modular way, then the users can exclude only the parts that are not working or no longer serviceable and still keep the majority of the product (Pieroni et al., 2021). This also supports manufacturing products to reuse or recycle effectively. Design-driven circularity uses fewer resources while the product is being used and efficiently recycles waste in consideration of supply chain sustainability.

Design-driven circularity in the supply chain entails wastage reduction with efficient use of raw materials and resources. It makes sure that there is hardly any material that gets lost in the various production steps and that the product life-cycle is extended; another side effect is that the supply chain becomes flexible since circular designs often mean easy repair or refurbishment of the products (Stahel, 2021). A design-driven circularity is an efficient material and waste management system in the supply chain, which in turn brings economic and environmental benefits. Such a circular economy approach in the supply chain aids organizations in meeting their sustainability objectives. Design-driven circularity stimulates the making of environmentally conscious products, thus allowing companies to better address the evolution of the market; this model also appears to characterize an excellent opportunity for companies in respect of social responsibility, environmental impact diminution, and economic efficiency (Bocken et al., 2021).

Design-driven circularity plays a critical role in ensuring sustainability in supply chains. Adopting circularity principles in product design ensures efficient resource use, reduces waste, and minimizes environmental impacts, thereby helping companies achieve their sustainable development goals.

3.4 Sharing Economy

The sharing economy is a model that revolves around renting or sharing products/services, as opposed to purchasing them. This model is primarily used in transportation and consumer goods, as the products have more use by more people through sharing, which decreases the gross volume of both production and consumption. The sharing economy is an economic model that emphasizes the temporary use of products/services instead of ownership. Through the model of sharing, individuals or businesses can use resources and materials more efficiency and sustainably. The sharing economy is also largely influenced by a variety of digital platforms that use a 'usage' approach that improves supply chain efficiency while also reducing the environmental impact. The sharing economy changes the paradigm of ownership, allowing products to be accessed in a broader capacity and used more efficiently (Curtis and Mont, 2020). The sharing economy improves resource utilization in the supply chain. For example, in the transportation space, car-share allows consumers or businesses to rent vehicles instead of owning them. This improves utilization in transport capacity while also reducing the number of vehicles, thus, improving resource consumption and the environmental impact (Schor, 2020). Additionally, sharing or renting products lowers production volumes, reducing the amount of raw materials and energy used in production processes and minimizing environmental impacts in the supply chain.

The sharing economy also disrupts consumer behavior and transforms demand for companies' production and distribution processes. In the sharing economy, people can legally own fewer items, while also extending the life cycle of the product. This encourages manufacturers to make better products that are durable and last longer because they are more attractive to re-use or rent. This contributes to the circle of supply chains and also promotes efficient usage of resources (Sundararajan, 2021). The sharing economy establishes a means to eliminate economic inequalities and achieve more equitable resource distribution. Sharing products complements the burdens of ownership and increases the likelihood of products being utilized by a broader base of users. This adds to the social good while enhancing the sustainability of our ecosystem (Acquier et al., 2021).

3.5 Waste Management and Reverse Logistics

Being a core principle of the circular economy, waste management pertains to collecting, processing, recycling, or reusing the waste which is generated during production and consumption. Basically, waste management in circular supply chains is converting waste into resources. The objective is to adversely affect waste to the smallest degree while creating an environment to reuse valuable materials. Waste management systems promote sustainability in the supply chain and can also economically benefit it since recycled materials can be used for manufacturing new products, thereby reducing production costs. Proper waste management in supply chains implies proper waste segregation, reuse, recycling, and composting techniques. Electronic, plastic, and other industrial wastes, when properly managed, become potentially useful raw materials. Waste recycling is considered the conservation of natural resources, saving energy, and reducing greenhouse gas emissions (Dora et al., 2022). Waste management in the circular model is thus of paramount importance since it prevents environmental degradation and promotes economic efficiency so as to boost the competitiveness of an enterprise.

Reverse logistics consists of the process of collecting, reprocessing, repairing, or recycling of products that are subsequently placed in the possession of a consumer (Ülkü, 2022). A reverse logistics model entrusts that products will be involved in some form of recycling or reuse after the sale. Reverse logistics is, then, a very crucial component of a circular supply chain model and recognizes that used products are available to be reintroduced to the supply chain of materials. This provides environmental benefits and enhances efficiency in a supply chain. Reverse logistics encourages companies to recycle and reuse their products thereby lowering costs in the supply chain and improving resource efficiency. Waste management as a driver or lever should be a method

of sustainable supply chain practices that serves as a basis of, or for, the circular economy (Agrawal et al., 2022). Products stay viable longer through reverse logistics, consuming fewer resources in new production, while causing less waste. Also, reverse logistics can develop customer loyalty, for when customers know that products are designed to come back to go through the reverse flow process, customers may change how they consume more responsibly (Han et al., 2023).

Both takeaways are vital to waste management and reverse logistics applying the circular model in general supply chains. These processes pursue the minimization of waste with efficiency in resource use and reduction in adverse environmental impacts. In addition to the cost savings that these processes bring to companies, with the environment sustainability processes in place, the entire operation of supply chains becomes leaner and more competitive. Waste management and reverse logistics in circular supply chains therefore help create a fair and sustainable economic framework.

3.6 Bio-based and Clean Technologies

When it comes to green and bio-based technologies, we refer to technological applications that use biodegradable material that have reduced adverse interactions with environmental systems, and sustainability objectives. As a result, bio-based and clean technologies, use resources efficiently, without damaging systems found in nature, and prevent waste from being produced that cannot recycle it back to biological systems (Stevenson et al., 2021). Thus, bio-based technologies are vital to waste management, recycling and reusability, and play an essential role in implementing circular models of supply chains. Bio-based technologies contribute to circular supply chains and green sustainability through processes that contribute to longer lifespans of products, or returns the end of life products into nature without harming it, therefore reducing their negative environmental impact by replacing synthetic and harmful chemicals, processes and materials commonly found in industrial processes. Bio-based technologies can effectively recycle products back into the environment with lower levels of waste, while limiting harmful chemicals being released into the environment.

Bio technologies offer benefits to supply chains in addition to environmental ones. The use of natural inputs and biomass-based sources decreases their dependence on raw materials, thus saving costs in their production processes (Norris et al., 2021; Popp et al., 2021). Moreover, bio-based technologies can be designed to be more energy- and water-efficient with the intent to help enterprises achieve their sustainability goals.

Environmental-wise, biosynthetic processes help reduce manufacturing systems dependent on fossil fuels and chemical wastes. They lower the greenhouse gas emissions, fossil fumes, pollutants in air and water, and consequently protect biodiversity (Stevenson et al., 2021). It is therefore evident that the inclusion of bio-based technologies into circular supply chains is a concrete mechanism that would play a pivotal role in achieving the 'sustainable development goals.'

Within supply chains, bio-based technologies in the circular economy paradigm focus on environmental conservation, less waste generation, and preserving natural resources. Bio-based technology is economical because it ensures sustainability and efficiency. Furthermore, bio-based technologies in supply chains would certainly support the circular economy approach, provide a level of competitive advantage to companies, and more significantly, contribute to the global sustainability agenda.

3.7 Sustainable and Responsible Supply Chain

A responsible supply chain is a management model that corresponds to ethical principles and sustainability standards in all operational activities with materials from procurement to product distribution while also incorporating social and environmental considerations. This management model does not only focus on economic profit but also takes into consideration the social responsibility and environmental stewardship. Different stages of the responsible supply chain involve different types of activities, ranging from identifying and assessing appropriate suppliers, production activities within the organization, logistics processes, and recycling activities related to products provided to people by organizations. In this sense, the intersection of the responsible supply

chain and the circular economy would aim to maximize the efficient use of materials and resources, minimize waste, and maximize the life cycles of products (Rajeev et al., 2022).

Integrating a circular model within a responsible supply chain entails having less environmental impact and fulfilling social responsibilities. However, circular integration can only occur when there is a high level of transparency, traceability, and trust in supply chain management and this is heavily supported by robust corporate environmental information disclosure, which holds firms accountable to green standards (Chen et al., 2022). The basis for this process involves environmental; but, also, the practices which respect labor conditions, human rights, and the rights of local communities. In short, this process protects the state of ecosystems while seeking to uphold and safeguard against labor code, human rights, health, and environmental conditions. By integrating these two, companies can still achieve their sustainable development objectives while improving their social relations (Gligor et al., 2021).

When circular economy technologies are adopted within responsible supply chains, many advantages will appear. Environmentally, they foster material efficiency and recycling of waste but, in every context, diminish to consuming less resources and reducing environmental damage. Socially, circular integration promotes fair working conditions, develops communities and strengthens local economic structures. However, circular integration can only occur when there is a high level of transparency, traceability, and trust in supply chain management.

The principles of the circular economy (CE), when integrated with a responsible supply chain (RSC), provide a means to have environmental, social, and economic sustainability in the primary of the business. This way of working advocates better use of resources, less waste, and conditions of work while still allowing for the more sustained operations of business. The coupling of CE principles with RSC creates a desirable starting place for sustainable development, with an inherent competitive nature.

3.8 Industrial Symbiosis

Industrial symbiosis refers to the process of industries sharing resources by transforming organizational waste into valuable resources. Waste produced in one industry can be used as a raw material for use in production in another industry. The circular economy theory of industrial symbiosis is based on reducing the waste produced by optimizing the management of waste and resources within an industrial area. The concept of industrial symbiosis can be defined as an opportunity for different industries to divert each other's material waste into raw material, which will improve resource efficiency and reduce environmental impacts from waste. The circular economy theory ultimately relies upon the premise of an industrial symbiosis where waste is diverted into production inputs to allow for improved resource utilization and environmental protection (Neves & Marques, 2022).

Industrial symbiosis follows the patterns in natural ecosystems, where each organism ideally exists in mutualistic or beneficial interactions with others. This concept makes it possible to network within supply chains in an ecosystem-like manner through the recycling and reuse of waste, similar to the closed-loop flows of materials in nature (Bimpizas-Pinis & Angelis-Dimakis, 2023).

One of the goals of an industrial symbiosis aspect functioning within the circular supply chain is to optimize material recovery, flows, and waste. Implementing this model requires the cooperation of sectors in the supply chain since one sector's waste might be another's precious raw material. This cooperative behavior improves resources while reducing the environmental impacts of waste. Successful industrial symbiosis implementation, therefore, enhances the environment while generating enormous economic and social value. Greater efficiency in resources and waste contributes to reducing costs, while fostering sectoral solidarity and long-term patched collaborations (Taddeo, 2021).

The implementation of industrial symbiosis practices in supply chains faces multiple obstacles which affect their successful deployment. The successful implementation of industrial symbiosis faces three main obstacles which stem from poor supplier-manufacturer communication and insufficient collaborative infrastructure and complicated process management systems. The successful implementation of industrial symbiosis faces challenges because of sectoral and geographic restrictions. The obstacles in industrial symbiosis development create opportunities to reach sustainable development targets and circular economy objectives. Industrial symbiosis

functions as a development platform which enables different sectors to create innovative solutions and business approaches while enhancing social accountability thus delivering environmental sustainability benefits to companies (Oughton et al., 2022).

Industrial symbiosis exists as a very critical waste-management path and, subsequently, a resource-efficiency pathway within the supply chain under the marginalism of a circular economy. Its integration into the supply chain, therefore, guarantees environmental and economic sustainability. Beyond this integration and due to their nature, strong alliances between suppliers are required. These alliances should combine investments in infrastructure and long-term perspectives. Among the opportunities brought forth by the industrial symbiosis are the possibilities of environmental impact reduction and economic efficiency.

Key Developments for the Future of Circular Models

The increased use of artificial intelligence, big data technologies and Industry 4.0 applications to optimize circular processes and drive environmental sustainability (Zhang & Sutherland, 2021; Oláh et al. 2020).

Blockchain technology enhancing supply chain transparency and strengthening traceability (Kouhizadeh et al., 2021).

A rise in demand for sustainable products and services driven by increased consumer awareness (Kirchherr et al., 2023).

Global regulations make circular economy practices mandatory (Lopes de Sousa Jabbour et al., 2022).

Steps for Broader Adoption by Businesses:

Corporate Transformation and Education: Reshaping corporate culture around circular economy principles, educating employees on sustainability and the circular economy, and ensuring top management leads this transformation by allocating necessary resources (Centobelli et al., 2021).

Technological Infrastructure and Innovation: Establishing the technological infrastructure to support circular processes, directing R&D activities toward circular design, and aligning digital transformation projects and IoT integration with circular economy objectives across the value chain (Garcia-Muina et al., 2023; Nagy et al. 2018).

Collaboration and Ecosystem Approach: Strengthening collaboration with suppliers, customers, and other stakeholders, creating industrial symbiosis networks, and increasing sectoral cooperation and information sharing (Kalmykova et al., 2022).

Financial and Legal Incentives: Diversifying funding sources for circular economy investments, creating tax reductions and incentives, and updating legal regulations to support the circular economy (Wang & Tseng, 2021).

Hence, this is a transformation from a traditional linear model to systems of reuse, recycling, and remanufacturing. Circular models promote efficient usage of resources and thus ensuring economic sustainability and social welfare, limiting much waste requiring landfill. This concept of circular diagram gives an integrated approach toward giving another identity to waste as a resource and extending the life cycle of a product as a way of mitigating environmental impacts. In the end, this presents a great opportunity to attain economic and environmental goals by merging the concepts of circular models into the supply chain to sustain management.

4 Conclusions And Recommendations

Circular models within sustainable supply chains occupy a space defined on a strategic-economic continuum, creating value while, at the same time, minimizing costs to the environment (Ünlü, 2022). The assertion is that they will become more salient in the future. These hourly circle economy models have all but become accepted practices in their development of sustainable supply chains because of climate change, material resources depletion, and increased pressure to abide by environmental regulations.

With respect to conserving natural resources, reducing waste, in all forms, and reducing environmental nuisance circular models in sustainable supply chains are the most relevant. These models still provide some environmental and economic efficiencies to the manufacturers while positioning them favorably within the marketplace to help in bridging the sustainable development

goals. In short, environmental protection is one of the benefits of the modeling endeavor and is also attempting the establishment of a socially just economic model.

The models described in this paper adopt sustainable practices which extend past the conventional "take-make-dispose" supply chain operations of the circular economy framework. The models function to address worldwide issues that stem from natural resource depletion and environmental damage and climate change. The circular business models require companies to reduce environmental impact but they also create a framework that leads to increased profitability. Businesses that implement circular models achieve better sustainability results in their operations. The circular economy model enhances supply chain stability while making businesses more resistant to upcoming resource shortages. The current pandemic together with global supply chain disruptions have exposed major weaknesses in conventional supply chain systems. The circular business model creates resilient supply chains through resource reuse and local manufacturing capabilities.

Businesses that adopt circular models for sustainable supply chain management achieve environmental and economic advantages while meeting their social obligations. This paper demonstrates how circular models drive sustainable supply chain transformation through their business value contributions. The future of sustainable supply chains depends on circular models to maintain their essential position.

The future of sustainable supply chain management depends on circular models which bring competitive advantages to businesses. Successful transformation requires all stakeholders to work together while adopting extended time horizons. Organizations that execute circular business models effectively will protect the environment while securing their financial stability.

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