

Integrating Circular Economy and Industry 5.0 for Sustainable Supply Chain Management in the Food Industry

Mohammed Rakib Sikder, Shah Junaed Ahmed Saif, Syed Abrar Nadim

Khan Ishfar Bin Tarik, Ridika Islam

Abstract

The worldwide food sector continues to contribute an important part in harming the environment in the form of greenhouse gas emissions, water pollution, and degradation of soil. To overcome these difficulties, transformational strategies are required. This study analyzes the combination of Circular Economy (CE) concepts and Industry 5.0 (I5.0) technologies in order to establish sustainable supply chain management in the food industry. The CE tactics, which strives to reduce waste and enhance the use of resources, can be implemented by adopting efforts such as reducing food waste, utilizing recyclable packaging, and repurposing food waste. I5.0 is defined by cutting-edge technology such as AI and IoT and provides real-time data knowledge, automation, and increased supply chain coordination. This integration is consistent with the food industry's aim of growing environmentally conscious. The study delves into the principles of the circular economy, the advantages of merging CE and I5.0, the challenges of doing so, and effective business situations. Despite hurdles such as a lack of expertise as well as elevated implementation costs, the food sector has an interest in implementing this strategy due to the benefits of reduced environmental impact, improved economic efficiency, and enhanced nutrition. Through a tour of crucial material, we explain how CE and I5.0 could transform the ways food is produced, distributed, and eaten. The research

underlines the importance of these principles in assisting the food industry in overcoming its sustainability challenges. Targets in the paper also include talks of environmental sustainability concerns in the food sector, possibilities presented by CE and I5.0 integration, challenges, chances of resolving obstacles, and the groundbreaking influence of company 5.0 on the food company. We find overlaps between CE and I5.0 by reviewing existing research and discussing how they operate together to decrease waste, increase quality, while opening up fresh markets. Furthermore, we emphasize how I5.0's fusion of the digital and physical worlds has facilitated a shift toward human-centric production. In conclusion, this study underscores how vital it is for the food industry to make the transition to sustainability. The integration of Industry 5.0 technologies and Circular Economy principles is one possible future direction. By combining cutting-edge technologies with resource-efficient processes, the food sector can evolve into a more environmentally conscientious and economically viable organization, helping create a more sustainable future.

Keywords: Industry 5.0; Sustainable supply chain; Supply chain management; Circular economy; Green supply chain.

Introduction

A major portion of greenhouse gas emissions, water pollution, and land degradation are caused by the food industry, which is one of the most polluting sectors of the global economy in the current industrial period. The food business must embrace more environmentally friendly techniques to overcome these obstacles.

The supply chain management process can be improved by incorporating the concepts of the circular economy. Keeping goods and materials in use for as long as feasible is the goal of the circular economy, a type of economic system. Reusing, recycling, and upcycling materials are all effective ways to do this, as is creating things that are simple to disassemble and fix.

The fifth industrial revolution, known as Industry 5.0, is defined by the application of cutting-edge technology like artificial intelligence, robotics, and the Internet of Things. The effectiveness and sustainability of supply chain management can be increased with the use of these technologies. For instance, robotics can be used to automate jobs, AI can be used to improve routing and scheduling, and IoT can be used to track and monitor products along the supply chain.

The food business may lessen its negative environmental effects and develop into a more sustainable sector by embracing industry 5.0 and the circular economy. In addition to outlining the difficulties that must be solved, this essay will also discuss the potential advantages of this integration.

The paper would also cover the following subjects in its introduction:

- ☐ The circular economy's guiding principles and how they might be used in the food sector.
- ☐ The advantages of incorporating the circular economy into industry 5.0
- ☐ The obstacles of combining the circular economy and Industry 5.0
- ☐ Successful examples of businesses merging the circular economy and Industry 5.0
- ☐ The next phase of the circular economy and Industry 5.0 in the food industry.

Background of the study

Global environmental issues like climate change, water pollution, and land degradation are mostly caused by the food sector. The "take, make, and dispose" philosophy underlies the conventional linear supply chain paradigm, which cannot be sustained.

The circular economy (CE), a different economic paradigm, aims to reduce waste and increase resource utilization. Applying CE principles to the food business can be done in several ways, including:

- ☐ Reducing food waste by increasing food traceability and decreasing food loss along the supply chain
- ☐ Using recyclable materials to package food
- ☐ Making new goods out of food waste
- ☐ Using renewable energy sources in the processing and production of food

The successor of Industry 4.0, known as Industry 5.0 (I5.0), is defined by the utilization of cutting-edge technology including cloud computing, artificial intelligence (AI), and the Internet of Things (IoT). I5.0 can be used in the food business to support CE by:

- ☐ Offering data and insights in real-time that can be used to optimize resource consumption and lower waste.

- ❑ Automating processes that can decrease manual errors and boost productivity.
- ❑ Establishing connections amongst stakeholders along the supply chain to promote coordination and collaboration.

The food business may become more sustainable because of the integration of CE and I5.0 (industry 5.0). It is conceivable to develop a food supply chain that is more effective, resilient, and sustainable by fusing CE's core values with I5.0's advanced technologies.

Including CE and I5.0 in the food sector has several advantages, some of which are listed below:

- ❑ Lessening of environmental impact: CE and I5.0 can lessen the environmental impact of the food business by reducing waste, increasing resource efficiency, and utilizing renewable energy sources.
- ❑ Greater economic efficiency: CE and I5.0 can boost the food industry's prosperity by lowering expenses, boosting output, and creating new business prospects.
- ❑ Increased food security: By making the food supply chain more shock- and disruption-resistant, CE and I5.0 can contribute to increased food security.

To completely integrate CE and I5.0 in the food business, a few issues must be resolved, including:

- ❑ The lack of knowledge of CE and I5.0 among food industry stakeholders
- ❑ The significant cost of putting CE and I5.0 technology into practice.
- ❑ The requirement for coordination and collaboration throughout the supply chain

The food business is becoming more interested in incorporating CE and I5.0 despite these obstacles. It is expected that as these technologies advance, they will become more crucial in enhancing the sustainability of the food sector.

Here are some of the research papers that have been published on this topic:

1. Integrating circular economy and Industry 4.0 for sustainable supply chain management: a dynamic capability view (2022)

2. Studying the interactions among Industry 5.0 and circular supply chain: Towards attaining sustainable development (2022)
3. Circular economy in food supply chains: A review of the literature (2021)
4. The role of Industry 5.0 in the circular economy (2020)

Problem Statement

A significant cause of environmental issues like climate change, water pollution, and land degradation is the food sector. The food industry must embrace more sustainable techniques to overcome these obstacles.

Implementing the ideas of the circular economy into supply chain management is one approach to achieve this. By preserving products and materials for as long as feasible, the circular economy is an economic system that seeks to reduce waste and pollution. In addition to creating items that are simple to disassemble and repair, this can be accomplished by reusing, recycling, and upcycling materials.

The food industry has several difficulties when attempting to apply the concepts of the circular economy. These difficulties include the following:

- ☐ The high price of applying circular economy principles.
- ☐ The lack of understanding of circular economy principles among participants in the food business
- ☐ The absence of government backing for circular economy projects

Despite these obstacles, a number of companies are successfully incorporating circular economy principles into their supply chain management. These businesses serve as examples of how the food industry can be profitable while reducing its negative effects on the environment.

The article will go over the issue of environmental sustainability in the food industry as well as the potential of the circular economy and business 5.0 to solve this issue. The article will also go through the prospects for overcoming these obstacles as well as the difficulties associated with integrating the circular economy and Industry 5.0.

Objectives

- To have a discussion about the issue of environmental sustainability in the food sector
- Examine the possibilities of Industry 5.0 and the circular economy to solve this issue.
- Discussion about the difficulties integrating the circular economy with Industry 5.0
- To find opportunities to overcome these difficulties.
- Examine how business 5.0 and the circular economy will affect the food business.

Scope of the Article

The article's scope will be on how industry 5.0 and the circular economy might help the food business become more sustainable. The following subjects would be the article's main emphasis:

- ☐ How the food business can use the circular economy's guiding principles
- ☐ The advantages of incorporating the circular economy and Industry 5.0
- ☐ Circular economy and Industry 5.0 integration issues
- ☐ Companies exemplifying how to successfully incorporate Industry 5.0 and the circular economy.
- ☐ How the food business will benefit from the circular economy and business 5.0

The article would be based on a review of the existing literature on circular economy, Industry 5.0, and sustainability in the food industry.

The paper would offer insights into how the food business might adopt business 5.0 and the circular economy to become more sustainable.

The following are some examples of specific subjects that the article might cover:

- ☐ How food waste can be reduced using the concepts of the circular economy.
- ☐ How Industry 5.0 technologies can be applied to increase the efficacy of food distribution and production
- ☐ How to use the circular economy and Industry 5.0 to open up new business prospects in the food sector.
- ☐ The role that the circular economy and sector 5.0 will play in the food sector, as well as how these ideas might completely alter how food is produced, delivered, and consumed.

Literature Review

Studies Related to the Circular Economy (CE) and Industry 4.0 (I4.0)

Industry 4.0 is a transformative approach that integrates digital technologies into manufacturing, promoting efficiency, customization, and data-driven decision-making. It extends beyond manufacturing, impacting multiple sectors and influencing economies and societies worldwide. However, it also brings forth challenges that need to be managed for its successful implementation. Industry 4.0 blurs the boundary between the physical and digital worlds through cyber-physical systems. These systems combine computational intelligence with physical processes, enabling automation, self-optimization, and adaptability. Additionally, advanced manufacturing technologies like 3D printing facilitate cost-effective production of customized products without requiring extensive retooling. Numerous Industry 4.0 technologies, which are now employed towards automation, might be further adapted to help human workers engage in more productive practices while also unleashing their creativity and expertise and filling any gaps in their individual skill sets. The same digitally enabled systems can satisfy human centricity and environmentally friendly goals in terms of consumer base in the way things are created, while also acknowledging the growing prominence workers may have in high technology and automated production scenarios of the future. Interests in the subject of human factors, where robots are created to collaborate with humans in the fulfilment of tasks, are currently focusing on the design of manufacturing robots and equipment [1]. A detailed literature network study was carried out in 2020 by the researchers of [2] to look at the dynamic development of the academic literature on digital CE, both cited and uncited. The specific paper's objective is to analyze current trends in specialized research, CE fundamentals, and potential future research subjects. [3] provides an overview of how Digital CE and I4.0 interact in the manufacturing sector. While putting up a potentially useful paradigm, the authors concentrated on I4.0 methods that could apply fundamental CE concepts including reuse, refurbishment, redistribution, and recycling. The fundamental benefit of a digital CE is the integration of technological advances and CE into a single strategy. Different product types can be optimized during the production stage to extend life, enhance quality, and track use-cycle, location, and health condition for appropriate decision-

making methods [4]. The use of data during the stages of collection, analysis, and incorporation has a further strengthening effect on Digital CE properties. Such advantages encourage the development and application of decentralized industrial and manufacturing systems, supporting stakeholder and client engagement while conducting product and service assessment throughout their life cycles [5]. The manufacturing of food is one of the primary industries where Industry 4.0 is having an impact. Smart manufacturing strategies are being used to streamline operations, guarantee consistency in quality, and cut waste. Various parameters are monitored and controlled by sensors and data analytics, enabling real-time modifications to production lines and guaranteeing that quality requirements are satisfied. New potential for implementing Industry 4.0 techniques have emerged with the advent of smart factories [6]. A new era in technology for the food sector is also beginning with the use of the IoT, intelligent process control, process optimization utilizing Big Data, as well as output oversight and control for sustainable objectives [7]. Adoption of Industry 4.0 has significant advantages for small and medium-sized businesses (SMEs). It allows for greater production process flexibility, lowers costs through automation and efficiency improvements, boosts operational effectiveness, enhances product quality, gives businesses a competitive edge through cutting-edge technology, encourages innovation and new business models, broadens their market reach, draws in talent, and aids in sustainability initiatives. This transition calls for preparation, funding, and flexibility in response to shifting technological trends. The main advantages of adopting Industry 4.0 in SMEs are determined to be flexibility, cost, efficiency, quality, and competitive advantage [8]. Understanding I4.0-CE initiatives and how to address the biggest obstacles to I4.0-CE for SFP's successful deployment have been studied in [9]. Enhancing adaptability, effectiveness, and competitiveness while reducing costs and maintaining or raising product quality are the objectives. Proper preparation, technical investments, personnel training, and a dedication to adopting digital transformation across the firm are all necessary for this change. Industry 4.0 has been implemented in the health care (med tech) industry[10]. The goal of the study is to compile a sufficient evaluation of Industry 4.0's implementation. Analysis has been done in the context of the circular economy to look at the long-term viability of the supply chain [11], to change the organization from a linear economy to a circular economy by putting the 6Rs into practice, and to leverage technology throughout the supply chain to make the organization more sustainable in terms of social responsibility,

environmental awareness, and economic practices. Industry 4.0 integrates the digital and physical worlds in order to maximize the benefits of digitalization for the sustainability of organizations, which in turn supports the growth of the circular economy[12]. Industry 4.0 makes it possible to identify quality issues at an early stage, which increases productivity and considerably reduces waste costs [13]. Early quality problem detection is made easier by Industry 4.0. Potential flaws are found early on thanks to real-time monitoring, analysis of data, and interconnected systems. This makes prompt interventions possible, improves overall manufacturing efficiency, and reduces waste and rework-related costs. The investigation of sustainable manufacturing includes remanufacturing, recycling, and reverse logistics, as well as sustainability in corporate processes, product creation, supply chains, production operations, and distribution chains [14]. Utilizing fewer dangerous substances and inputs, modifying production processes to use less energy and supplies, using improved transportation and logistics systems, designing goods that are recyclable, re-manufacturable, reusable, and biodegradable, and collaborating with stakeholders and customers are all examples of sustainable manufacturing practices. Thus, competitive benefits will result from the implementation of sustainable production techniques in Bangladesh's leather sectors.

Studies Related to the Sustainable Supply Chain, risks and Industry 5.0 (I5.0)

In their study [15], the authors discussed how Industry 5.0's circular supply chain methods compare to environmentally friendly manufacturing processes. They list the essential circular supply chain principles that are applicable to I5.0. The advantages of CSCP implementation in I5.0 are covered in the study. The authors contend that through lowering waste, raising resource efficiency, and enhancing the circularity of goods and resources, CSCPs can contribute to the sustainability of industrial processes. Focusing on a certain portion of circular supply chain activities has limits. While waste reduction, closed-loop chains of supply, environmentally friendly sourcing, and circular product design are crucial circular activities. Another study investigates I5.0's potential to promote the circular economy. The authors contend that I5.0 technologies can be used to monitor a product's environmental impact throughout its lifecycle, which can be useful for spotting circularity chances. The latest industrial revolution known as "I5.0" is defined by the utilization of cutting-edge technology like cloud computing, artificial intelligence, and the Internet of Things.

By recycling and reusing materials, the circular economy is a production and consumption model that seeks to minimize waste and pollution [16]. The study [17] revealed the major barriers of GSCM implementation. Implementing Green Supply Chain Management (GSCM) can be a complex endeavor, as organizations often encounter various barriers that hinder the successful integration of environmentally sustainable practices into their supply chain processes. A research was conducted on the food industry in paper [18]. The objective of the research was to develop a framework that would guide efforts to reduce wasted food in the food industry. This study offers some advice on how to cut down on food waste and recommend that future studies on food waste employ sensitivity analysis to enhance the outcome. Sustainability was indicated by this study. Any industry that can use this procedure will be able to manage the food chain sustainably and with the least amount of waste. Automation in Supply Chain Management (SCM) involves leveraging technology to enhance and optimize various processes within the supply chain. This strategy aims to improve efficiency, accuracy, and overall performance while minimizing manual interventions and potential errors. Multiple aspects of the supply chain can benefit from automation. Supply chain executives should get ready for the future by embracing new technology and its capacity to utilize more data than any time before. However, because of enhanced manufacturing capacities, their integration might have a transformative impact on your organization and open up new business options [19]. Another study where we can see supply chain disruption risks in Pharmaceutical Supply Chain through Reverse Logistics [20]. The paper's proposed model demonstrates how to prevent the severe consequences of supply chain disruptions. Additionally, let the user concentrate on identifying the risk. The ability to foresee downflows and take appropriate action to reduce loss and improve return will result from the identification of risks and their likelihood of occurring. The solution can be viewed as a way to identify the risks that the industry faces and to prevent them in order to improve the overall performance of the system.

A different research investigation in which lean, agile, and green supply chain practices for superior performance in recommerce has been found out in [21]. Recommerce supply networks, in general, have a lot of potential to combine lean and agile features with sustainable and environmentally conscious green qualities to create a hybrid supply chain model. The supply chain in the recommerce industry involves a mix of mass-produced and custom-made products. Mass-produced items are sourced from returns and overstock, refurbished, and resold through various

channels. Custom-made products are manufactured based on customer orders. Inventory management, sales channels, order fulfillment, and customer engagement strategies differ for both types. Reverse logistics handle returns. Sustainability and technology integration are key considerations for both, and collaboration is essential to ensure a smooth supply chain process for both mass-produced and custom-made products in recommerce.

Case Studies

A few case studies on Industry 5.0, sustainable supply chains, and circular economy integration are provided below:

Dow Chemical: A Pioneer in Circular Economy

A leader in the chemical sector on a worldwide scale, Dow Chemical was a pioneer in implementing the circular economy concepts in its supply chain. By employing materials that have been recycled in its packaging, Dow, for instance, has been attempting to limit the amount of trash it produces. Dow has also been creating new goods that are intended for both recycled and reused.

The "Packaging for Tomorrow" program at Dow is among the company's most effective circular economy efforts. The objective of this initiative is to develop novel recyclable, biodegradable, or reusable packaging materials in order to establish a circular economy for packaging. Additionally, Dow has been attempting to utilize less energy throughout its production procedures. For instance, the business has solar panels placed at its production buildings, and it also uses energy-efficient lighting.

The adoption of circular economy ideas by Dow has been a success. The corporation has cut waste by 20% and energy expenditures by \$1 billion. Dow is dedicated to advancing the circular economy movement and is certain that following these ideas will make it easier for the business to be more sustainably run in the future.

Following are some specifics concerning Dow Chemical's efforts in the circular economy:

- **Packaging for Tomorrow:** Through the development of innovative recyclable, biodegradable, or reusable packaging materials, this initiative aspires to establish a circular economy for packaging. Under this effort, Dow has already created several novel packaging materials, such as:

- **Recyclable plastic film:** Made of recycled plastic, this film may be recycled once again at the end of its useful life.
 - **Film composed of plant-based materials** that decomposes in a landfill or compost bin is biodegradable plastic.
 - **Reusable packaging:** This kind of packaging may be recycled or used again by the manufacturer after being used several times.
- **Advanced recycling:** Dow is also putting money into cutting-edge recycling systems that can disassemble plastic trash into its constituent parts. As a result, the parts may be reused to make new items rather than being disposed of in landfills.
 - **Product design:** Dow collaborates with its clients to create goods that are easier to recycle and more environmentally friendly. For instance, the business is collaborating with automakers to create automobiles that utilize recycled plastics.
 - **Green manufacturing:** Dow is attempting to increase the sustainability of its production practices. For example, the business employs water-saving technology and renewable energy sources.

Numerous groups have praised Dow's work in the area of circular economy. Dow received the Circular Economy Leadership Award from the Ellen MacArthur Foundation in 2021. Companies who have made substantial strides toward a circular economy are honored with the prize.

The circular economy project will continue to be a priority for Dow. The organization thinks that adhering to these values is crucial to building a more sustainable future.

A few advantages of Dow's work on the circular economy include:

- **Reduced trash:** Dow's efforts to promote a circular economy have contributed to a decrease in the quantity of garbage the firm produces. As an illustration, the business's usage of recyclable packaging has assisted in lowering the quantity of plastic trash that ends up in landfills.

- **Resource conservation:** Dow's efforts to promote a circular economy have contributed to resource preservation. One way the business has reduced the requirement for virgin plastics is by using recycled plastics.
- **Added jobs:** Dow's efforts to promote the circular economy have added positions. For instance, the business's investment in cutting-edge recycling technology has supported the creation of jobs in the sector.

Business may contribute to the development of a more sustainable future, as demonstrated by Dow's work on the circular economy. Businesses may cut waste, save resources, and generate jobs by using circular economy ideas.



Patagonia: A Clothing Company with a Circular Mindset

Dedicated to sustainability, Patagonia is a clothing brand that has long incorporated the ideas of the circular economy into its supply chain. As an illustration, Patagonia promotes the repair and recycling of its customers' Patagonia items through its "Common Threads Initiative" initiative.

Customers may extend the life of their Patagonia items with the aid of a number of materials provided by the Common Threads Initiative. A network of approved repair facilities is one of these resources, as well as manuals on how to maintain and fix Patagonia items. Additionally, Patagonia has a program for the take-back of worn Patagonia goods. Customers who own Patagonia goods can send them in for repair or recycling by sending them to the business.

Supply Chain Insider

Patagonia's trash production has been successfully decreased because to the Common Threads Initiative. Through the initiative, Patagonia recycled more than 1 million pounds of clothes in 2018. In addition, the firm avoided spending over \$1 million by fixing its items rather than replacing them.

Patagonia is dedicated to carrying out its circular economy research. The business thinks that these ideas are fundamental to building a future that is more environmentally friendly.

Patagonia's specifics are as follows: An Outfitter with a Circular Mindset:

- **Overview of the business:** Patagonia is an American apparel company that specializes in marketing and selling outdoor clothes. Yvon Chouinard, a rock climber and mountaineer, started the business in 1973. More than 5,000 people work at Patagonia, which has its headquarters in Ventura, California.
- **Sustainability:** Patagonia is dedicated to sustainability and has established several objectives to lessen its environmental effect. Employing recycled resources in its goods, lowering the amount of water used during manufacturing, and offsetting the carbon it generates are some of these objectives. Additionally, Patagonia is making an effort to raise the standard of living for supply-chain employees.
- **Circular economy:** Patagonia is a leader in the use of circular economy ideas in the apparel sector. The corporation has many programs in place to increase the lifespan of its goods, including its Worn Wear program and Common Threads Initiative. Patagonia is also attempting to create brand-new items from repurposed materials.

The circular economy efforts of Patagonia include the following:

- **Common Threads Initiative:** It encourages customers to fix, repurpose, and recycle their Patagonia goods. The program provides consumers with a variety of tools to assist them prolong the lifespan of their Patagonia items, including how-to manuals for maintaining and repairing Patagonia products and an extensive network of approved repair facilities.

- **Worn Wear program:** With this program, clients of Patagonia may exchange their used purchases of Patagonia goods for discounted prices on brand-new goods. Additionally, the program provides a Patagonia product repair service.
- **Recycled components:** Patagonia is dedicated to utilizing recycled components in its products. The business sells a variety of recycled goods, including the 100% recycled Responsibility-Tee.
- **Creation of new products:** Patagonia is aiming to create new items from recycled materials. The business is now working on a variety of new goods, including its Worn Wear recreated collection, which uses recycled Patagonia apparel.

The circular economy activities of Patagonia are assisting in lowering the environmental effect of the company's goods. Patagonia contributes to waste reduction, resource preservation, and the development of a greener tomorrow by extending the useful lives of its goods and utilizing recycled materials.

Positive effects of Patagonia's circular economy initiatives:

- **Less garbage produced:** Patagonia's efforts to promote a circular economy have reduced the amount of waste the firm produces. The firm, for instance, has prevented millions of Patagonia goods from ending up in landfills through its Common Threads Initiative.
- **Conserved resources:** Resources have been conserved thanks to Patagonia's efforts in the circular economy. One way the business has reduced the requirement for new resources is by using recycled materials.
- **Added jobs:** Circular economy ideas from Patagonia have done the same. For instance, the business's Worn Wear initiative has produced jobs in the mending and selling of worn garments.

The circular economy activities of Patagonia are an illustration of how companies may contribute to the development of a more environmentally friendly future. Businesses may decrease waste, save resources, and generate jobs by using circular economy ideas.



Nestlé:

The multinational food and beverage business Nestlé has been making efforts to lessen its influence on the environment. Nestlé declared in 2019 that it will spend \$2 billion over the following five years on circular economy projects.

- **Business overview:** Swiss global food and beverage corporation Nestlé has its headquarters in Vevey, Vaud. With more than 200 brands sold in more than 180 nations, it is the biggest food corporation in the world. Food, drinks, candies, food for pets, and dairy goods are all offered by Nestlé.
- **History:** Nestlé was established in 1866 by Swiss pharmacist Henri Nestlé. Farine Lactée Nestlé, a milk-based infant food, was the business's initial offering. Early in the 20th century, Nestlé expanded quickly and bought several of other food businesses. Nestlé started to enter new markets in the 1970s, including the US and Asia.
- **Sustainability:** Nestlé is dedicated to sustainability and has established a variety of objectives to lessen its influence on the environment. These objectives include utilizing less water, emitting fewer greenhouse gases, and using packaging that is more environmentally friendly. Additionally, Nestlé strives to enhance the standard of living for farmers and other supply chain employees.

- **Criticism:** Nestlé has received criticism for a number of actions, such as the exploitation of child labor, the usage of genetically modified organisms (GMOs), and the promotion of unhealthy meals to children. In response to these concerns, Nestlé stated that it was dedicated to ethical business operations.

Initiatives taken by Nestlé in support of the circular economy: Nestlé has been trying to integrate these concepts into its supply chain. As an illustration, the business has been attempting to limit the amount of trash it produces by using recycled materials in its packaging and by creating new goods that are intended to be recycled or reused.

Nestlé declared in 2019 that it will spend \$2 billion over the following five years on circular economy projects. The goals of these programs will be waste reduction, resource conservation, and the development of a food system that is more ecologically sound.

Nestlé has implemented a number of circular economy efforts, some of which include:

- Creating innovative packaging components that are recyclable, biodegradable, or reusable.
- Assisting farmers in enhancing farming methods and minimizing food waste.
- Creating brand-new goods from recycled resources.
- Developing an economy that is circular for coffee by cooperating with farmers to increase coffee production and decrease waste.

Nestlé is dedicated to making a difference, even if its circular economy efforts are still in their infancy. Nestlé can contribute to the development of a food system that is more environmentally conscious and lessen the company's impact on the environment by embracing the concepts of the circular economy.

Source: [How Nestle Makes Billions Bottling Free Water | Direct From With Dena Tadruri - AJ+ : \(buttondown.tv\)](#)

H&M

- **Company overview:** Swedish multinational apparel business Hennes & Mauritz AB (H&M) is based in the United States. After Inditex, it is the world's second-largest apparel

Supply Chain Insider

store. Erling Persson established H&M in 1947, and Stockholm, Sweden serves as the company's primary location.



H&M company logo

- **Sustainability:** H&M is dedicated to sustainability and has a variety of targets in place to lessen its environmental effect. employing less water during manufacturing processes, employing more environmentally friendly materials in goods, and lowering carbon emissions are some of these objectives. In addition, H&M is making efforts to raise the standard of living for supply-chain employees.
- **Circular economy:** H&M was a trailblazer in the garment business in using circular economy ideas. With programs like its Sustainable Selection and garment recycling program, the firm has taken a variety of steps to increase the lifespan of its products. New goods manufactured from recycled materials are something another H&M is aiming to create.

The circular economy projects of H&M

- **The Conscious Collection:** This line of apparel is constructed from more environmentally friendly materials including cotton that is organic and recycled polyester.



H&M Conscious Collection

- **Garment recycling program:** The H&M shop offers consumers the opportunity to recycle their worn items through the program for recycling garments. The previously worn material is then recycled and utilized to make new goods or produce energy.
- **New product development:** H&M is attempting to create new items using recycled materials. The firm is currently working on several new goods, including its Conscious Exclusive line of recycled and organic cotton clothing.

Reduced environmental impact of H&M's products is made possible through the company's circular economy activities. H&M contributes to lowering waste, conserving resources, and building a future that is sustainable by extending the lifespan of its goods and utilizing recycled materials.

- **Less trash generated:** H&M's circular economy activities have contributed to a decrease in the quantity of garbage the firm produces. For instance, the company's initiative for recycling clothing has kept millions of items from ending up in landfills.
- **Resources conserved:** Circular economy efforts from H&M have also contributed to resource preservation. For instance, using recycled resources by the firm has reduced the requirement for raw materials.

- **Produced employment:** H&M's circular economy efforts have done the same. For instance, the company's initiative for recycling unwanted clothing has produced jobs in the areas of collecting and processing.

The circular economy activities of H&M are an illustration of how companies may contribute to the development of an environmentally conscious future. Businesses may cut waste, save resources, and generate jobs by using the concepts of the circular economy.

IKEA:

Here are some IKEA specifics:

- **Business overview:** Swedish-based IKEA is a global furniture store. It is the third-biggest retailer in the world after Walmart and Amazon and the leading retailer of furniture. Ingvar Kamprad created IKEA in 1943, and the company is based in Delft, Netherlands.



IKEA company logo

- **Sustainability:** IKEA is dedicated to sustainability and has established a variety of objectives to lessen its environmental effect. These objectives include utilizing less water during manufacturing operations, employing more environmentally friendly materials in goods, and minimizing carbon emissions. The livelihoods of the people who work in IKEA's supply chain are also being improved.

- **Circular economy:** IKEA was a pioneer in introducing the ideas of the circular economy to the furniture sector. In order to increase the lifespan of its products, the firm has implemented a variety of initiatives, including its Buy Back program and its Re:Store idea. IKEA is also attempting to create new items using repurposed materials.

The circular economy programs at IKEA:

- **Buy Back program:** IKEA's buy-back program enables consumers to return their used furniture to the retailer. After that, the furniture is either discarded or restored.



IKEA Buy Back program.

- **Re:Store concept:** This idea is for a network of IKEA second-hand shops where people can purchase and sell used furniture.
- **New product development:** IKEA is aiming to create new items with recycled components. A variety of new items are now being developed by the firm, including its PLATSA range of recycled plastic goods.

The environmental effect of IKEA's products is being lessened because to the company's circular economy activities. IKEA is assisting in lowering waste, conserving resources, and building an environmentally friendly future by extending the lifespan of its goods and utilizing recycled materials.

Advantages from IKEA's circular economy initiatives:

- **Less trash generated:** IKEA has reduced its waste production through its circular economy programs. By way of illustration, the company's Purchase Back program has stopped hundreds of million units of furniture from ending up in landfills.
- **Conserved resources:** Resource conservation has also been aided by IKEA's circular economy activities. One way the business has reduced the requirement for new resources is by using recycled materials.
- **Created jobs:** Produced jobs, thanks in part to IKEA's circular economy initiatives. In the gathering and processing of secondhand furniture, for instance, the company's Re:Store idea has generated employment.

A good example of how corporations may contribute to the development of a healthier tomorrow is IKEA's circular economy efforts. Businesses may cut waste, save resources, and generate jobs by using circular economy ideas.

Conclusion

A swift transition to sustainability is required since the food business contributes significantly to environmental deterioration. This study demonstrates how supply chain management in this industry could be revolutionized by fusing the principles of the Circular Economy (CE) with Industry 5.0 (I5.0) technologies. The literature demonstrates that the circular economy offers a comprehensive strategy for resource optimization and waste reduction that smoothly integrates with Industry 5.0 technologies like AI, robotics, and the Internet of Things (IoT).

The present literature highlights the mutually beneficial relationship between CE and I5.0, demonstrating how their convergence can reduce environmental impact, improve economic efficiency, and increase food security. Overcoming obstacles like low awareness, expensive start-up costs, and the requirement for cross-sector collaboration are necessary for successful implementation. The study also emphasizes the substantial potential advantages, which include new business prospects and decreased waste and resource usage.

Recommendations

The research leads to the following suggestions for leveraging the potential combination between CE and I5.0 for sustainable supply chain management in the food industry:

1. **Awareness and Education:** To promote a culture of sustainability and innovation, initiatives are required to improve stakeholders' knowledge of CE principles and I5.0 technologies.
2. **Public-Private Partnerships:** By working together, enterprises, governments, and academic institutions may lessen the cost of deploying CE and I5.0 technologies, hastening their uptake and integration in the market.
3. **Incentive Systems:** Governments and regulatory organizations should set up laws and programs that encourage firms in adopting Industry 5.0 technology and circular business practices.
4. **Capacity Building:** Investing in worker skill-upgrading and reskilling programs would guarantee the seamless integration of cutting-edge technology and circular economy concepts.
5. **Demonstration Projects:** Showcasing effective case studies where companies have successfully merged CE and I5.0 can encourage others to adopt similar tactics by demonstrating the viability and advantages of this strategy.
6. **Research and Innovation:** The food industry may innovate and improve sustainable practices by continuing to study the technology developments of Industry 5.0 and looking into new applications of CE principles.
7. **Communication and Coordination:** Industry organizations and networks may promote information sharing, enabling partners to exchange best practices, work together to solve problems, and develop an innovative community.

In conclusion, the fusion of the circular economy and industry 5.0 shows enormous promise for making the food business a more resilient and sustainable sector. This integration can pave the way for a day when waste is minimized, efficiency is improved, and the production, distribution, and consumption of foods are sustainable over the long term by balancing economic, environmental, and technological pressures.

References

- [1] Turner, C. J., Emmanouilidis, C., Tomiyama, T., Tiwari, A., & Roy, R. (2019). Intelligent decision support for maintenance: an overview and future trends. *International Journal of Computer Integrated Manufacturing*, 32(10), 936-959.
- [2] Skobelev, P. O., & Borovik, S. Y. (2017). On the way from Industry 4.0 to Industry 5.0: From digital manufacturing to digital society. *Industry 4.0*, 2(6), 307-311.
- [3] Okorie, O. S., Turner, C., Charnley, F., Moreno, M., & Tiwari, A. (2018). A review of data driven approaches for Circular Economy in manufacturing.
- [4] Askoxylakis, I. (2018, May). A framework for pairing circular economy and the Internet of Things. In *2018 IEEE International Conference on Communications (ICC)* (pp. 1-6). IEEE.
- [5] Rizvi, S. W. H., Agrawal, S., & Murtaza, Q. (2021). Circular economy under the impact of IT tools: A content-based review. *International Journal of Sustainable Engineering*, 14(2), 87-97.
- [6] Crnjac, M., Veža, I., & Banduka, N. (2017). From concept to the introduction of industry 4.0. *International Journal of Industrial Engineering and Management*, 8(1), 21.
- [7] Režek Jambrak, A., Nutrizio, M., Djekić, I., Pleslić, S., & Chemat, F. (2021). Internet of nonthermal food processing technologies (Iontp): Food industry 4.0 and sustainability. *Applied Sciences*, 11(2), 686.
- [8] Masood, T., & Sonntag, P. (2020). Industry 4.0: Adoption challenges and benefits for SMEs. *Computers in Industry*, 121, 103261.
- [9] Dwivedi, A., Moktadir, M. A., Jabbour, C. J. C., & de Carvalho, D. E. (2022). Integrating the circular economy and industry 4.0 for sustainable development: Implications for responsible footwear production in a big data-driven world. *Technological Forecasting and Social Change*, 175, 121335.
- [10] Wei, B., & Alius, K. (2021). Industry 4.0 Analysis of the implementation of Industry 4.0 in a medical technology enterprise with a comparison with automotive enterprises and options for improvement.

- [11] Manavalan, E., & Jayakrishna, K. (2019). An analysis on sustainable supply chain for circular economy. *Procedia Manufacturing*, 33, 477-484.
- [12] Iyer A. Moving from Industry 2.0 to Industry 4.0: A case study from India on leapfrogging in smart manufacturing. *Procedia Manufacturing*. 2018;21: p. 663-70.
- [13] Lopes de Sousa Jabbour, A. B., Jabbour, C. J. C., Godinho Filho, M., & Roubaud, D. (2018). Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations. *Annals of Operations Research*, 270, 273-286.
- [14] Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M., & Paul, S. K. (2018). Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. *Journal of cleaner production*, 174, 1366-1380.
- [15] Sami, A., Manzoor, U., Irfan, A., & Sarwar, F. (2023). Characterizing Circular Supply Chain Practices in Industry 5.0 With Respect to Sustainable Manufacturing Operations. *Journal of Management and Research*, 10(1).
- [16] Turner, C., Oyekan, J., Garn, W., Duggan, C., & Abdou, K. (2022). Industry 5.0 and the circular economy: Utilizing LCA with intelligent products. *Sustainability*, 14(22), 14847.
- [17] Rahman, M., Sakib, M. I., Mim, J. F., & Sarker, S. (2020). Barriers of Implementing Green Supply Chain Management Bangladesh Perspective. *Supply chain insider*, ISSN 2617-7420, 5(1).
- [18] MD. Sabbir Hosen Pulok, Anusree Sen, Souvik Das, Farea Farhana Nishita, & MD. Mushfiquzzaman. (2022). MODELING SUSTAINABLE CHALLENGES TO WASTE REDUCTION IN THE FOOD INDUSTRY. *Supply Chain Insider* | ISSN: 2617-7420 (Print), 2617-7420 (Online), 7(1). Retrieved from <https://supplychaininsider.org/ojs/index.php/home/article/view/9>.
- [19] SHAHRIAR MAHMUD, NAZMUL HAQUE PARTHIB, TAHMID MUNTASIR, & MUZAHIDUL HASAN. (2020). SUPPLY CHAIN AUTOMATION: KEY STAGE IN SUPPLY CHAIN THAT CAN BENEFIT. *Supply Chain Insider* | ISSN: 2617-7420 (Print), 2617-7420 (Online), 3(1). Retrieved from <https://supplychaininsider.org/ojs/index.php/home/article/view/33>.

[20] Taki Tajwar, Tasnia Islam, Debnath Saumya Protay, Mahdia Akter, & Namira Afrose. (2022). Managing Supply Chain Disruption Risks in Pharmaceutical Supply Chain through Reverse Logistics. *Supply Chain Insider* | ISSN: 2617-7420 (Print), 2617-7420 (Online), 7(1). Retrieved from <https://supplychaininsider.org/ojs/index.php/home/article/view/13>.

[21] Ishrat Jahan Holy,, Marwa Kazi Mohammed, & Tasfia Tasnim Revu. (2022). Lean, Agile, and Green Supply Chain Practices for Superior Performance in Recommerce: An Empirical Study. *Supply Chain Insider* | ISSN: 2617-7420 (Print), 2617-7420 (Online), 7(1). Retrieved from <https://supplychaininsider.org/ojs/index.php/home/article/view/14>.