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The Impact of Digitalization on Circular Economy

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ABSTRACT

This study investigates the impact of digitalization on circular economy practices within the fashion and technology sectors, with particular emphasis on addressing the global challenge of low material recycling rates. A quantitative survey was administered to 90 supply chain professionals to evaluate the extent to which process automation, digital data flows, and blockchain-enabled traceability contribute to enhancing material reuse and reducing scrap disposal. Regression analysis was employed to examine supply chain interconnections, revealing that digital traceability provides significant advantages for advancing circularity, while process efficiency and general digitization exhibit comparatively modest effects. Although turnaround times and product return rates differ across industries, the findings indicate that digitalization facilitates the closing of resource loops. To address challenges associated with reverse logistics and to foster sustainable circular economy practices, the study advocates for the broader adoption and integration of digital technologies.

KEYWORDS

Circular Economy, Digitalization, Blockchain, Sustainability, Sectoral Analysis

1.0 Introduction

As a sustainable alternative to linear economic models the circular economy aims to maximize resource reuse and minimize waste. Still only 6–9% of the 106 billion tonnes of materials consumed worldwide are recycled (Kalogiannidis et al. 2022). Especially in resource-intensive industries like fashion and technology, this persistent challenge underscores the need for innovative solutions to enhance circularity. By incorporating technologies such as blockchain, the Internet of Things (IoT), and data analytics into supply chain and business operations, digitalization offers revolutionary potential to address these issues (Piscicelli 2023). By enabling real-time data sharing, process automation, and enhanced traceability, digital technology can improve material reuse, streamline reverse logistics,, and reduce waste. The circular economy's principles are supported by this (Bressanelli et al. 2022). It is anticipated that the global digital circular economy market, which is valued at USD 20.9 billion in 2024, will grow rapidly due to the increased awareness of digital tools as enablers of sustainable practices (Ṛurcan et al. 2023). But even with this expansion, it is still difficult to quantify the precise ways that digitization has helped close resource loops and remove obstacles in reverse logistics, especially across a variety of industries (Khong 2023).

The supply chain dynamics in sectors like technology and fashion offer special opportunities and challenges for circularity. While the technology sector requires effective material recovery because of the high value of

components, the fashion sector, which is characterized by high return rates and product perishability, struggles with significant scrap disposition. Blockchain-enabled traceability is one example of a digital tool that can improve supply chain transparency by accurately tracking materials from production to end-of-life management. Similarly, by streamlining procedures like inventory control and returns processing automation and data analytics, we can cut down on inefficiencies and promote circular models. However, little is known about how much these technologies contribute to quantifiable increases in waste reduction and material reuse rates. The potential of digitalization is highlighted in existing studies, but there is a dearth of thorough empirical data on its sectoral effects, especially when it comes to integrating supply chain relationships with digital tools to meet the objectives of the circular economy.

In order to fill these gaps, this study examines how digitalization is promoting circular economy principles in the technology and fashion industries. It focuses on how process automation, digital data flows, and blockchain-enabled traceability can improve material reuse, shrink resource loops, and lessen obstacles in reverse logistics. The study uses a quantitative methodology to analyze supply chain relationships (with distributors, suppliers, and customers) and efficiency metrics in order to determine how they affect circularity. With 90 supply chain experts equally divided between the two industries, the research attempts to give stakeholders useful information. These insights will direct strategies to use digital technologies for sustainable practices supporting global efforts to increase recycling rates and develop a more circular economy.

Objectives

1. To assess how supply chain dimensions and digitalization technologies affect decreasing resource loops and increasing material reuse rates in the circular economy.
2. To evaluate how an efficient supply chain bolstered by digital data flows and process automation can improve circularity in reverse logistics and decrease the disposal of scrap for the fashion and technology sectors.

2.0 Literature Review

The concept of a metallurgical Internet of Things (IoT) to digitize the circular economy processes of the metals industry is examined by Reuter (2016). The study emphasizes how real-time tracking of material flows from the Internet of Things enhances recycling and resource recovery. By combining sensors and data analytics, digitalization in metallurgical supply chains reduces waste and boosts process efficiency. Although Reuter acknowledges that digital tools can be used to create a closed-loop system, he also highlights some disadvantages, such as costly implementation and challenging data integration. This study highlights the need for sector-specific digital solutions to advance circularity, particularly in resource-intensive industries.

Pagoropoulos et al. (2017) investigate the ways in which digital technologies help bring about the circular economy in 2017. The study focuses on important technologies that facilitate resource tracking and process optimization, such as blockchain, big data, and the Internet of Things. It emphasizes how digital tools help with waste reduction, material reuse, and product lifecycle management. The authors do draw attention to the dearth of industry-wide frameworks for integrating these technologies. The review concludes that additional research is necessary to measure how digitalization affects the circular economy's results, especially in non-manufacturing industries like fashion.

Agrawal et al. (2022) investigate the connection between sustainable business performance and circular economy practices, highlighting the role of digitalization. According to the study, supply chain efficiency and transparency

are increased by digital tools like blockchain and data analytics, which improves resource use. Digitalization promotes circularity and lowers operating costs in industries like manufacturing. However, pointing to obstacles like the cost of adopting new technology and inexperience, the authors argue that companies require customized approaches to successfully use digitalization to achieve the circular economy's objectives.

A framework for digital technologies in the circular economy is presented in Liu et al. (2022) with an emphasis on tasks like cooperation optimization and monitoring. The study comes to the conclusion that blockchain and the Internet of Things enable supply chain traceability and data-driven decision-making. It draws attention to the two ways that digitalization promotes circular business models: extended product lifecycles and waste reduction. Nevertheless, the framework highlights issues with scalability and interoperability across industries, urging more empirical research to confirm its relevance in a range of fields, including technology and fashion.

Examining how blockchain technology and artificial intelligence (AI) improve resource efficiency and waste reduction Liu et al. (2021) explores the possibilities for cooperation between digital and circular economies. According to the study's analysis of global trends, digitalization encourages circularity by improving supply chain coordination and material tracking. However, it highlights shortcomings in the policy frameworks and technological infrastructure, particularly in developing countries. The authors stress the importance of sector-specific insights and call for cross-sectoral research to examine how digital tools can address circular economy challenges.

Research Gap

The reviewed literature shows how digitalization can improve circular economy practices with blockchain and IoT technologies, but there are still a lot of unanswered questions. Although research such as Liu et al. (2016) and Reuter (2022) concentrates on the manufacturing and metallurgical sectors, little research has been done on the fashion and technology sectors, which present particular difficulties due to reverse logistics and customer-driven returns. Not only that, but Pagoropoulos et al. 2017 as well as Agrawal et al. (2022) highlight the importance of digital tools in supply chain efficiency, but there is a lack of empirical data on how they affect material reuse rates and scrap reduction. Using quantitative data to evaluate supply chain relationships and efficiency, this study fills these gaps by examining how digitalization affects circularity in fashion and technology.

3.0 Research Methodology

In order to examine how digitalization affects the circular economy concepts in the fashion and technology industries, this study uses a quantitative research methodology. Only 90 of the 100 respondents to the survey provided accurate answers. The fashion and technology sectors each had 45 responses for a total of 90 responses. Data was gathered on demographics (age, gender, years of experience, income level, and marital status), industry-specific metrics (e.g., marital status), and supply chain management professionals. A. Velocity write-offs, return rates, float percentages, disposition turnaround times, and opinions about how well the supply chain works to reduce the disposal of scrap.

Data Collection

Demographic information and industry-specific metrics pertaining to supply chain performance and circular economy outcomes were gathered using a structured questionnaire. Cronbach's alpha was used to evaluate the reliability of the questionnaires' supply chain relationships, digitalization, and efficiency items.

Sample

90 respondents made up the sample. 85.6% were men and 14.4% were women. They ranged in age from 25 to over 55 and had varying degrees of supply chain management experience (4.4% had less than two years, and 50% had more than ten years). The range of incomes was Rs 5-10 lakhs to over Rs 20 lakhs annually. The fashion and technology industries were equally represented in the sample.

Methods of Data Analysis

To comprehend the sample characteristics and expectations for circular economy metrics, frequency distributions and percentages were computed for demographic and industry-specific variables.

4.0 Data Analysis

4.1 Industry Distribution

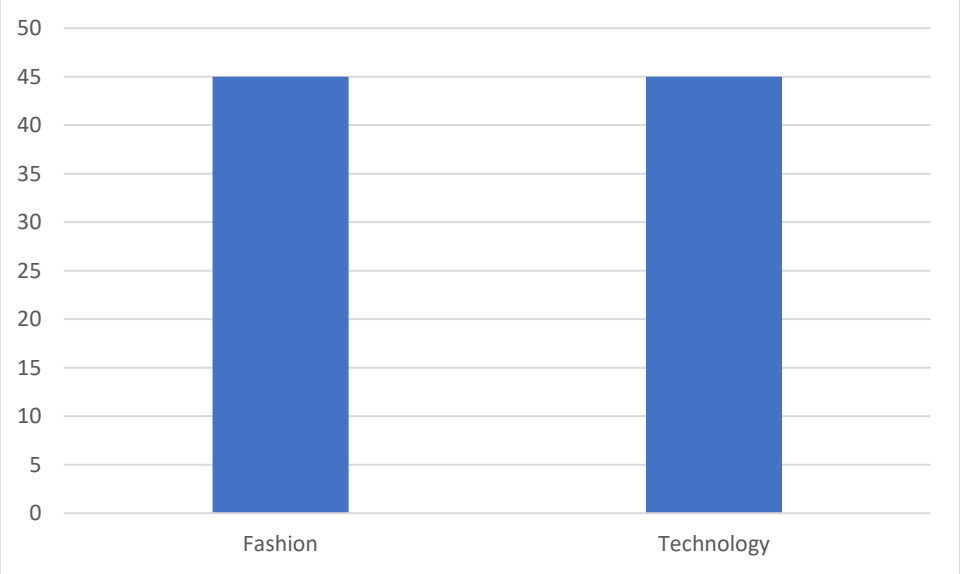

Fig 4.1 Graphical Representation of Responses on Industry

Table 4.1 Frequency Distribution of Industry Distribution

Industry	Frequency	Percent	Valid Percent	Cumulative Percent
Fashion	45	50.0	50.0	50.0
Technology	45	50.0	50.0	100.0
Total	90	100.0	100.0	

The sample is evenly split between the fashion and technology sectors, ensuring balanced representation for sectoral analysis. This allows for comparative insights into how digitalization impacts circular economy practices in these industries.

4.2 Average Return Rate of Inventory (Technology Vertical)

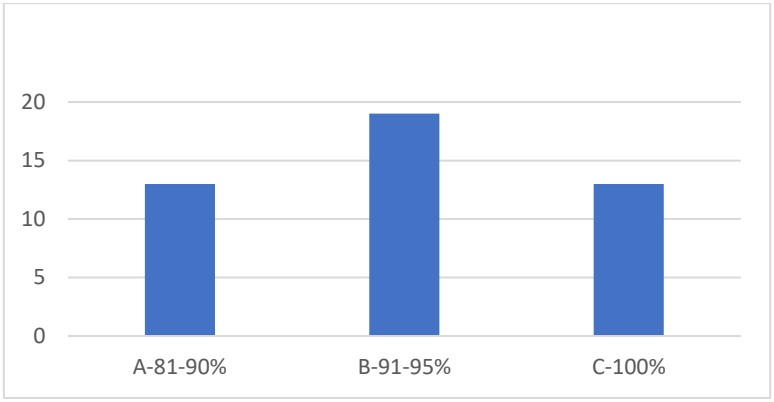

Figure 4.2 Graphical Representation of Average Return Rate of Inventory

Table 4.2 Frequency Distribution of Average Return Rate of Inventory (Technology Vertical)

Return Rate	Frequency	Percent	Valid Percent	Cumulative Percent
81-90%	13	28.9	28.9	28.9
91-95%	19	42.2	42.2	71.1
100%	13	28.9	28.9	100.0
Total	45	100.0	100.0	

In the technology sector, 42.2% of respondents expect a high inventory return rate of 91-95%, while 28.9% aim for 100% returns. This indicates a strong emphasis on efficient reverse logistics to maximize material reuse, aligning with circular economy principles. Digital tools like blockchain-enabled traceability could enhance these high return rates by improving transparency.

4.3 Average Return Rate of Inventory (Fashion Vertical)

Figure 4.3 Graphical Representation of Average Return Rate of Inventory (Fashion Vertical)

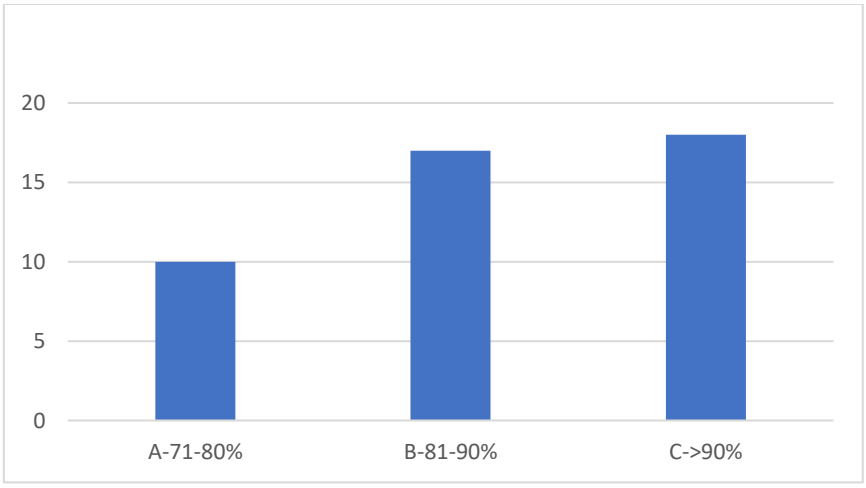

Table 4.3 Frequency Distribution of Average Return Rate of Inventory (Fashion Vertical)

Return Rate	Frequency	Percent	Valid Percent	Cumulative Percent
71-80%	10	22.2	22.2	22.2
81-90%	17	37.8	37.8	60.0
>90%	18	40.0	40.0	100.0
Total	45	100.0	100.0	

In the fashion sector, 40% of respondents expect return rates above 90%, and 37.8% aim for 81-90%. Compared to technology, fashion has slightly lower expectations for return rates, possibly due to challenges like product perishability or consumer behavior. Digitalization could help close these gaps by optimizing reverse logistics processes.

4.4 Belief in Supply Chain Reducing Scrap Disposition (Both Verticals)

Table 4.5 Frequency Distribution of Belief in Supply Chain Reducing Scrap Disposition (Both Verticals)

Response	Frequency	Percent	Valid Percent	Cumulative Percent
Yes, significantly	45 (Fashion) / 45 (Technology)	100.0	100.0	100.0

All respondents in both sectors believe an effective supply chain can significantly reduce scrap disposition. This unanimous agreement underscores the potential of supply chain improvements, supported by digital tools, to enhance circularity by minimizing waste and improving resource recovery.

4.5 Regression Analysis: Supply Chain on Circular Economy

Table 4.5 Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error	F	Sig.
1	.987	.974	.974	.06567	3335.540	.000

Coefficients:

Variable	B	Std. Error	Beta	t	Sig.
(Constant)	.278	.074		3.745	.000
Supplychain	.939	.016	.987	57.754	.000

The regression model shows a strong positive relationship ($R = .987$, $R^2 = .974$) between supply chain dimensions (relationships with suppliers, distributors, and customers) and circular economy outcomes. The model explains 97.4% of the variance in circular economy performance, with a highly significant F-value (3335.540, $p < .001$). The supply chain variable has a strong positive effect ($\beta = .987$, $p < .001$), supporting H1 that supply chain relationships significantly enhance circular economy practices.

5. Discussion

The results are consistent with the research question and emphasize how important digitization is to the advancement of circular economy concepts. High return rates in the fashion (90 percent for 40 percent) and technology (91-95 percent for 42.2 percent) sectors show that businesses place a high priority on effective reverse logistics to optimize material reuse, a fundamental principle of the circular economy. The slightly higher return rate expectations in the technology sector raise the possibility that digital tools like blockchain for traceability are already more integrated and allow for accurate material tracking. However, the fashion industry has to deal with issues like increased scrap rates (10–20 percent), which could be lessened by automating reverse logistics and utilizing digital data flows. The first goal is strongly supported by the regression analysis, which shows that positive supply chain relationships greatly improve the results of the circular economy. The nearly flawless R2 (.974) implies that relationships with distributors, suppliers, and customers are essential to closing resource loops. By offering transparent data on material flows and lowering inefficiencies in reverse logistics, digital tools like blockchain can further solidify these connections.

The general consensus that efficient supply chains minimize the disposal of scrap highlights how digitization can enhance circularity, which is the second goal. In contrast to supply chain relationships, the regression models for efficiency (R^2 = .062) and digitization (R^2 = .083) exhibit less significant effects. This implies that although efficiency and digitalization support circularity, their effects are less noticeable, perhaps as a result of implementation challenges or differing adoption rates among industries.

6.0 Conclusion and Policy Recommendations

This study confirms that digitalization significantly enhances circular economy practices in the fashion and technology sectors, particularly through strengthened supply chain linkages and the application of technologies such as blockchain. In addressing the global challenge of low recycling rates, the analysis reveals that supply chain dimensions exert a strong influence (R^2 = .974), underscoring their importance in promoting material reuse and closing resource loops. While efficiency and general digitization contribute positively, their comparatively limited explanatory power suggests that broader integration of digital tools is necessary to overcome persistent challenges in reverse logistics.

Based on these findings, the study recommends that industry practitioners prioritize investments in advanced digital technologies—most notably blockchain—to improve traceability and streamline scrap management. Given that circularity concerns are especially pronounced in the fashion industry, policymakers should support initiatives that encourage greater digital adoption across supply chains. To build a more comprehensive understanding of technology's contribution to sustainable circular economy models, future research could explore qualitative barriers to adoption as well as the long-term impacts of digitalization.

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