Nexus of Circular Economy and Sustainable Business Performance in the Era of Digitalization: A Comprehensive Review and Network Based Analysis

Abstract

Purpose- This study aims to conduct a comprehensive review and network-based analysis by exploring future research directions in the nexus of circular economy (CE) and sustainable business performance (SBP) in the context of digitalization.

Design/Methodology/Approach- A systematic literature review (SLR) methodology was adopted to present the review in the field of CE and SBP in the era of digitalization. WOS and SCOPUS databases were considered in the study to identify and select the articles. The bibliometric study was carried out to analyse the significant contributions made by authors, various journal sources, countries, and different universities in the field of CE and SBP in the era of digitalization. Further, network analysis is carried out to analyse the collaboration among authors from different countries.

Findings- The study revealed that digitalization could be a great help in developing sustainable circular products. Moreover, the customers' involvement is necessary for creating innovative sustainable circular products using digitalization. A move towards the product-service system was suggested to accelerate the transformation towards CE and Digitalization.

Originality/Value- The paper discusses digitalization and CE practices' adoption to enhance the SP of the firms. This work's unique contribution is the systematic literature analysis and bibliometric study to explore future research directions in the nexus of CE and SP in the context of digitalization. The present study has been one of the first efforts to examine the literature of CE and SBP integration from a digitalization perspective along with bibliometric analysis.

Keywords- Circular Economy; Sustainable Performance; Digitalization; Industry 4.0; Bibliometric; Smart Manufacturing.

Paper type- Review Paper

1. Introduction

The global increase in competition among organizations forces them to shift towards more sustainable practices to sustain in the market (Yadav et al., 2020). Sustainable practices are gaining vital importance by firms, academic researchers, and industrial experts to ensure the global commitment to reducing greenhouse emissions, proper resource utilization, and efficient waste management (Zhang et al., 2019; Dantas et al., 2020). However, it is essential to see that the current industrial era shifts towards digitalization, enabling an organization to minimize resource consumption through information and communication technologies (ICTs) tools (Nascimento et al., 2019). Disruptive technologies emerging under the arena of Industry 4.0 (I4.0) are promoting new business models and opportunities to manufacturing firms (Esmaeilian et al., 2020). Digital technologies of I4.0 are identified as potential enablers for CE business models (Ranta et al., 2021). Circular economy (CE) is also gaining significant importance nowadays because of its cleaner production approach (Kazancoglu et al., 2018). CE ensures material recycling and enhancing resource efficiency. CE is an emerging area and is defined as "a strategy which aims at reducing both inputs of virgin materials and output of wastes by closing economic and ecological loops of resource flows" (Haas et al., 2015; Agrawal et al., 2020).

Digitalization is one important aspect of CE due to its capability to build visibility and intelligence into assets and products (Antikainen et al., 2018). In the era of digitalization, organizations are enhancing their business performance by utilizing digital technologies. The motivation behind this research study is advanced applications of I4.0 technologies to improve sustainable business performance. The use of digital technologies such as blockchain technology or artificial intelligence improves transparency and traceability throughout the life of a product (Fogarassy and Finger, 2020).

Various researchers (Jabbour et al., 2017; Okorie et al., 2018; Nascimento et al., 2019; Yadav et al., 2020; Ozkan-Ozen et al., 2020) have shown the sustainable benefits associated with the integration of I4.0 technologies and CE practices. In this regard, this work aims to identify the potential of CE and sustainable business performance (SBP) in the era of digitalization. From the literature statistics, an increasing trend has been found in research in the field of CE and SBP in the era of digitalization. This study aims to review past and current research work in the field to identify nexus for future research direction in the area of CE and SBP in Digitalization. The following three research questions have been addressed in this study:

RQ1. What are the different application areas of CE and Digitalization in enhancing the SBP of an organization?

RQ2. What are the current research trends in the field of CE and SBP in the era of digitalization?

RQ3. What can be the future research directions in the field of CE and SBP in the era of digitalization?

To answer these research questions, this article possesses several objectives. It starts with the review of published articles in the field of CE and SBP in the era of digitalization. A systematic literature review methodology was followed to review published articles in the selected area. WOS and SCOPUS databases were considered in the study to identify and select the articles. The bibliometric study was carried out to analyse the significant contributions made by authors, various journal sources, countries, and different universities in the field of CE and SBP in the era of digitalization.

Further, network analysis is carried out to analyse the collaboration among authors from different countries. Discussions were made on the study, and practice and research implications were also derived. Finally, conclusions, limitations, and future research directions were also presented, enabling industrial practitioners, research practitioners, and policymakers to adopt CE practices in the nexus of digitalization to enhance SBP.

This article is divided into seven sections; the first section includes introducing the research topic, followed by the formulation of research questions. Section 2 deals with the research methodology and a research framework used in the study. Section 3 deals with the theoretical background of the study. Section 4 consists of a review of articles about CE and SBP in the context of digitalization. Section 5 includes bibliometric research and network analysis of the considered research area. Section 6 consists of a discussion on the findings of the presented work and implications of the study. Finally, conclusions, limitations, and future research directions were given in section 7.

2. Research Methodology

A literature review is the core part of a research article that provides meaningful information and insights on the investigating area. It also helps in offering research direction for future study (Govindan et al., 2015). From the thorough analysis of the research study, several research gaps were found which need to be studied to strengthen the research work. This work uses the review procedure presented by Saunders et al. (2016). An SLR was presented by defining keywords and searching articles about selected keywords in different databases (Vinodh et al., 2020). In this work, articles were identified in the field of CE and SBP in the context of digitalization. Articles were collected from the WOS and SCOPUS database, including the largest publication of peer-reviewed papers (Geraldi et al., 2011). WOS and

SCOPUS include almost all renowned publishers such as IEEE, Emerald insights, Taylor and Francis, Springer, Elsevier, Wiley, and Inderscience. The review methodology used in the present study is shown in the flow chart presented in Figure 1.

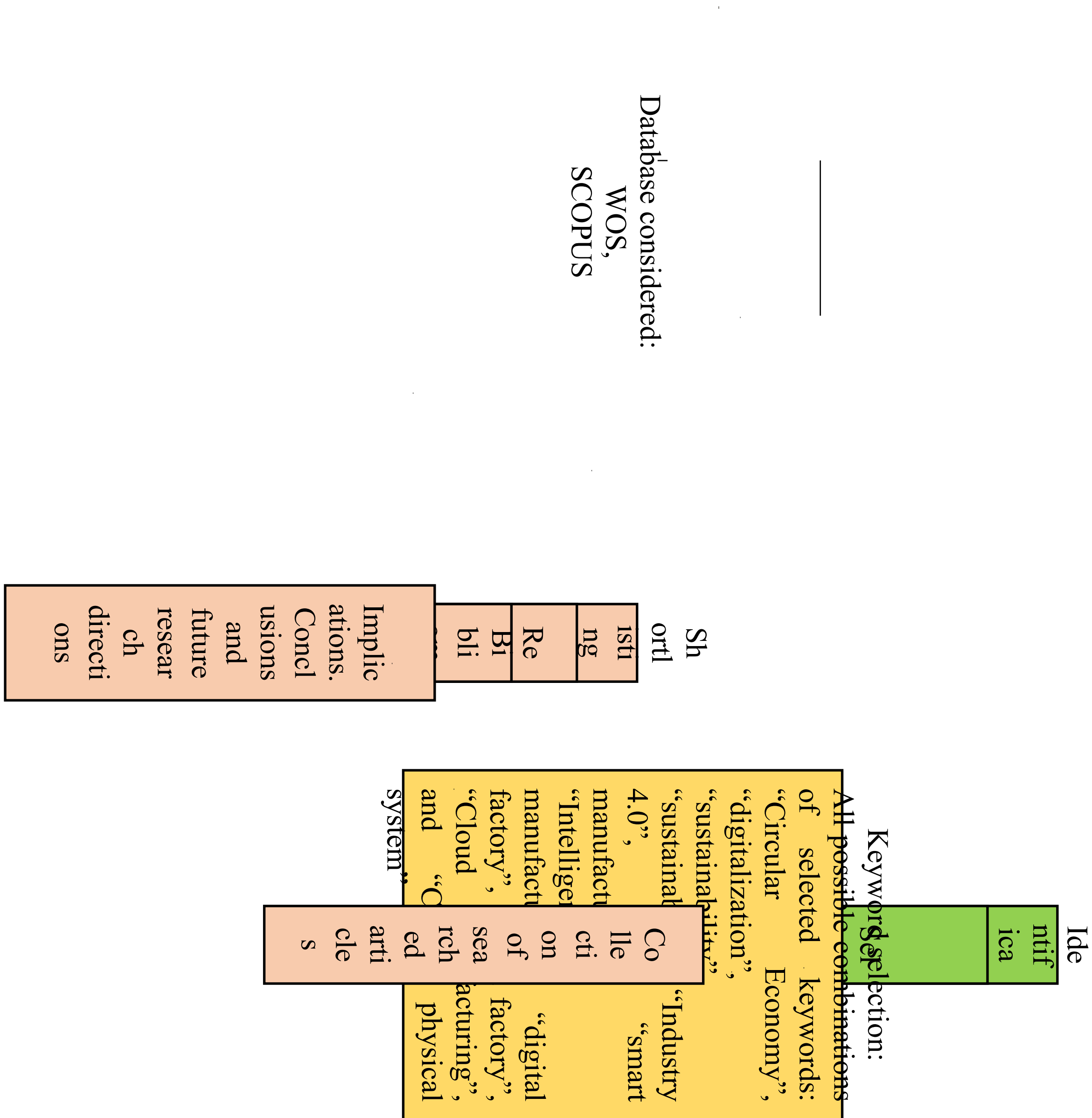

Figure 1. Research methodology

2.1 Database selection

In this work, the authors considered the WOS and SCOPUS database to collect articles about CE and SBP in the context of digitalization. To enable the broad scope of review, both SCOPUS and WOS databases have been considered in this study.

2.2 keywords selection

Keywords selection is an essential aspect of the collection of articles. The following keywords were used with all possible combination for the collection of articles: "Circular Economy", "digitalization", "sustainability", "sustainable", "Industry 4.0", "smart manufacturing", "Intelligent manufacturing", "digital factory", "smart factory", “Cloud manufacturing”, and “Cyber-physical system”.

2.3 collection of articles

Based on the considered keywords, 236 articles were identified from both SCOPUS and the WOS database. In this study, book chapters, editorial notes, and doctoral thesis were not included in the search result.

2.4 Refinement and shortlisting of articles

For refinement of articles, they were shortlisted based on the scope of the study. Duplicate articles which were present with different keyword combination were removed. After refinement, a total of 126 articles were considered for further research.

3. The theoretical background of the study

3.1 Digitalization and Circular Economy

Digitalization is considered one of CE's enablers due to its capability to build visibility and intelligence into assets and products (Antikainen et al., 2018). CE consist of practices which comprises of 3R principle, reuse, reduce, and recycle resources to decrease environmental impacts, increase economic gain, protect the environment, and provide adequate resource consumption (Gharfalkar et al., 2018). Combining various I4.0 technologies such as data analytics, data mining, the Internet of Things (IoT), and cyber-physical systems provided significant opportunities to obtain sustainable industrial value and CE (Antikainen et al., 2018). Moreover, digital technologies such as blockchain technology or artificial intelligence improve transparency and traceability throughout the life of a product (Fogarassy and Finger, 2020). Understanding product location in real-time allows increased product approachability and improves remanufacturing refurbishment and recycling opportunities. Circular solutions are required to handle the challenges associated with rising environmental problems and depleting resources. The concept of CE has developed from the European Union’s Action Programs, and its scientific background and solutions have been elaborated. As per the circular economic theory, instead of creating cycles of energy flows and material, transforming the business process into sustainable resource systems is defined. Thus, the application of digital tools in CE helps eliminate waste and decrease adverse environmental impacts.

3.2 SBP and Digitalization

Organizations are now entering into the 4th industrial revolution through digitalization and capitalization. Digital technologies such as the IoT, robotics, and predictive analytics making the industries smarter. The advantages of digitalization into industries are speeding up production, profitability and productivity improvement, reduction in errors, and optimization of processes (Parida et al., 2019). Considering economic growth resulting from reducing environmental impacts, a very significant benefit from digitalization is sustainability (Hourneaux et al., 2018). Key stakeholders from different sectors understanding the importance of it and moving towards a more sustainable economy. The adoption of CE and sustainability aspects helps industries to achieve the corporate strategy. Thus, sustainability and CE business performance are interconnected to offer sustainable growth (Tajbakhsh and Hassini, 2015).

4. Review on CE and sustainable practices in digitalization scenario

In this section, the shortlisted articles were reviewed and presented. It includes various aspects of CE and SBP in the era of digitalization such as integration of I4.0 with CE, Smart and sustainable manufacturing, Smart product service system, digitalization in the sustainable supply chain, CE in waste management, CE in a business model, I4.0 in waste management, I4.0 in achieving sustainable operations. This section has been further divided into eight sub-section based on the mentioned aspects of CE and SBP in the era of digitalization

4.1 Integration of I4.0 with circular economy

Integration of disruptive technologies of I4.0 with CE practices provides significant support in reducing waste and enhancing remanufacturing activities. In these regards, Jabbour et al. (2017) integrated the CE and big data to develop the conceptual and practical trends concerning key stakeholders' roles in obtaining sustainable society, the ReSOLVE model of CE, and extensive data management. The research introduced a novel integrated framework to improve the understandings of big data and CE nexus. The developed framework delivered socio-technical insights for industry practitioners, academicians, policymakers, and managers. Okorie et al. (2018) presented a systematic review on CE, I4.0 and presented a framework by integrating CE practices and digital technologies. The study shows an increasing trend in research activity in the field of economy and I4.0. The study recommended exploring the concept of technology nutrients for effective CE strategies. A conceptual framework was developed by Bressanelli et al. (2018) by integrating I4.0 technologies such as IoT and Big data to support the adoption of CE in the firms' supply chain. The study identified eight enabling functionality by adopting I4.0 technologies which enhance three CE drivers, namely, improving resource efficiency, extending product life cycle, and closing the circular loop. Hatzivasilis et al. (2018) proposed Hy-LP, a novel hybrid protocol and establishment framework for industrial IoT systems support CE. The developed protocol supported smooth communication of industrial IoT sensors and actuators and enabled industrial could facilitate integration. Thus, the inclusion of the proposed framework would help smooth industrial transformation and boost competitiveness in CE.

The impact of the adoption of IoT in CE transition was analyzed by Ingemarsdotter et al. (2019). The study analyses how different industries have adopted IoT to promote the CE concept. Further, the study proposed an IoT framework that categorizes IoT-enabled CE strategy based on IoT capabilities. The study recommended using a developed framework that enables product lifetime extension. Rajput and Singh (2019) analyze the barriers of I4.0 in achieving sustainability. The study uses the ISM approach to investigate the relationship among I4.0 barriers and further identify the links between I4.0 technologies and CE practices. The results show that the digitalization process and semantic interoperability show high driving power. The study recommended focusing more on these barriers as these barriers drive other barriers of I4.0, and mitigation of these barriers will lead to successful adoption of I4.0 technologies and CE practices. Pham et al. (2019) discussed the background of I4.0 and explored the influential factors of I4.0 enhancing sharing economy in the context of CE considering the Taiwan electric scooters case study. The results revealed that in CE adoption, I4.0 played an essential role in sharing economy. The authors also discussed the role of workers with autonomous machines in achieving highly efficient operations. The influential factors were identified using the interpretive structural modeling approach. The authors recommended the implementation of big data infrastructure to enhance the readiness of I4.0.

Nascimento et al. (2019) explored integrating I4.0 technologies with CE to develop a business model that enables the reuse of waste materials. The study develops a research model consisting of three stages: the first stage includes, review of factors and barriers associated with the transition towards CE and I4.0 technologies such as CPS, AI, and big data. The second stage consists of the development of a conceptual framework that integrates CE with I4.0. The third stage includes the validation of the proposed framework by collecting data through interviews with experts. Chauhan et al. (2019) aimed to utilize I4.0 technologies to handle the issues associated with CE practices. The study uses the SAP-LAB linkage framework to analyze the application of I4.0 in CE business models. The study results show that the top managers are important actors in deploying I4.0 technologies to achieve sustainability. Also, the study recommended using advanced technologies of I4.0 such as CPS and IoT can be adopted to enhance the adoption of CE practices.

Piscitelli et al. (2020) reviewed the articles about I4.0 technologies and the circular economy. The study examined 72 articles considering a decade (2010-2020). The study found an increasing trend towards research in the field of I4.0 and CE. Zhou et al. (2020) analyzed the combined effect of I4.0 and CE on economic growth. The study concluded that environmental and energy-efficient technologies are the technical driving force behind economic development. Further, Dantas et al. (2020) presented a review of articles about integrating I4.0 technologies with the CE concept to achieve 17 sustainable development goals. The study concludes that the integration of CE and I4.0 technologies would bring enormous opportunities for enhancing sustainable practices and ultimately achieve SDGs.

Shayganmehr et al. (2020) analyzed the I4.0 enablers about CE and cleaner production from the perspective of business ethics. The authors developed a framework to evaluate the significance of I4.0 enablers for adopting cleaner production practices linking with CE. Based on the study, "Technical Capability", 'Policy and Regulation", "Security and Safety", "Education and Participation", "System Flexibility", and "Support and Maintenance," respectively, were found to be the significant I4.0 enablers. The fuzzy evaluation method was deployed to evaluate the readiness score of I4.0 enablers depicting the fair status of Iranian textile manufacturing organizations regarding cleaner production and CE adoption. The study recommended focusing on developing technological infrastructure for enhancing CE and cleaner production implementation. Demestichas and Daskalakis (2020) conducted a literature review on ICT solutions for CE adoption. They categorized answers into two parts, focusing on the main concepts of CE and others on technological aspects of the solutions. The findings suggested the ICT solutions about IoT, blockchain, artificial intelligence algorithms, and data collection and analysis. The results also recommended focusing on the 'reduce' component of CE apart from ICT solutions.

A framework was presented by Yadav et al. (2020) to integrate I4.0 technologies and CE concepts to overcome sustainable supply chain management (SSCM) challenges. The study presents 28 SSCM challenges and 22 solution measures. Further, the study revealed that managerial, economic, and organizational challenges are critical for SSCM. The study recommended adopting effective strategies to identified critical challenges. Ranta et al. (2021) presented a survey from four northern European firms involved in deploying the CE model and digital technologies. The study provides two contributions: first, it offered empirical research to show the resource flow and value creation. Second, the study develops a business model integrating CE and digital technologies.

4.2 Smart and sustainable manufacturing

Manufacturing is under tremendous pressure to reduce cost and minimize environmental impacts as it is becoming more complex and integrated. Smart manufacturing provides a solution to make production more sustainable, and in this regard, Fisher et al. (2018) discussed the applications of cloud manufacturing in making sustainable production. The study presented four critical aspects of cloud manufacturing through which sustainability can be enhanced, namely, enhanced process resilience, collaborative design, improved waste reduction and recycling, and enhanced automation. Further, the study explores integrating cloud manufacturing with other disruptive technologies to improve manufacturing processes' sustainability. Reuter et al. (2019) analyzed the challenges associated with CE practices in the metallurgical, design, and product aspects. The study mentioned three recommendations to minimize associated challenges. The recommendations were the development of a standard flowsheet to predict the recycling rates. Second, creating a material database to help process simulators in the industries. And third, adopt infrastructure criticality rather than metal criticality; this will enable the agile capability.

A research framework was proposed by Bag and Pretorious (2020) depicting the relationship between I4.0, sustainable manufacturing, and circular economy. The research was performed at two levels, extant literature analysis for extracting barriers, opportunities, and challenges at level one and establishing a research framework at level two. The study's outcome provided a detailed understanding of the integration proposed and developed research framework that helped to offer seven prepositions. The authors recommended manufacturers adopt sustainable manufacturing for a smooth transition towards CE and enhance the CE capabilities. Bag et al. (2020) explored the role of institutional resources and pressures in accepting big data analytics to understand how automotive organizations design their workforce skills to enhance the technological aspects, improve sustainable manufacturing practices and establish CE capabilities. The study collected data from 219 automotive manufacturing organizations based in South Africa regarding the role of institutional resources and pressures in accepting big data analytics. The authors recommended focusing on tangible resources, workforce skills, Big data analytics, and artificial intelligence to enhance sustainable manufacturing practices and CE capabilities.

Ma et al. (2020) proposed a data-driven framework for smart and sustainable manufacturing for industries. The study develops a multi-level model for demand response to reduce energy costs. Further, the study validated the developed framework in a ball mill shop floor and showed that ball mills significantly improved energy efficiencies. The study recommended using the developed framework for energy-efficient production and decision-making in manufacturing firms. Cioffi et al. (2020) performed an SLR on applied industrial technologies and smart manufacturing systems for a sustainable industry. The results depicted two changes, i.e., managerial and legislative, in realizing the CE. Also, the authors suggested paying attention to innovation through the introduction of new technologies and digital designs for establishing CE.

Kerin and Pham (2020) developed a research framework based on the systematic literature review on smart manufacturing supporting CE principles. The authors extracted 329 relevant articles related to the triple bottom line approach to sustainability. The authors claimed that variations in product ownership models would affect the remanufacturing industry. Also, by strengthening the connection between users, product manufacturers, and remanufacturers, remanufacturing in the I4.0 scenario could be achieved. The authors suggested organizations adopt I4.0 technologies for remanufacturing. Kristoffersen et al. (2020) conducted a theory-based review to develop a smart CE framework supporting the translation of CE strategies into manufacturing organization's objectives contributing to the sustainable development goal (SDG) 12, sustainable consumption and production. The developed framework helped the practitioners identify the gaps between existing and required business analytics requirements and strategic initiatives needed to close them. The framework also provided an understanding of the relationship between digital technologies and CE in achieving SDG12, sustainable consumption, and production.

4.3 Smart product-service system

Nowadays, firms are making a shift from product-oriented business to a service-oriented business which is also called servitization, in which firms offer personalized products and services as an integrated solution to meet the needs of customers. This business model is also called a product-service system (PSS). In this regard, Bressanelli et al. (2018) explored the role of digital technologies in tackling CE barriers in PSS business models. The authors performed a case study to identify the role of IoT and Big data analytics in the PSS business model. Findings revealed that these technologies helped in tackling the CE barriers such as operational risks, users' willingness to pay, loss of ownership, return flow uncertainties, and technology improvement in PSS business models. Zheng et al. (2019) presented a smart product-service system review to analyze its technical aspect, associated challenges, and future perspectives. The study demonstrated the significant findings in three aspects: technical, business, and environmental. In the technical aspect, they considered both human and machine intelligence. The business aspect recommends digital servitization. And the environmental aspect suggests the usage of disruptive technologies in the eco-centric environment.

Tunn et al. (2020) analyzed the impact of digitalization on consumer attitudes towards the product-service system. The study presented survey and interview results with the consumers and showed that short-term PSS significantly influences digital media. The author contributes towards the perception of consumers towards digitalization of the product-service system. Wang et al. (2020) presented a predictive maintenance approach based on PSS mode. The main aim of the study was to integrate the PSS delivery process with other maintenance activities to provide better control to their product. It recommends developing a platform for interconnection of equipment to minimize resource consumption and enhance equipment utilization.

4.4 Digitalization in sustainable supply chain

The Digitalization and CE in logistics and supply chain enable the consumer to return products after use. To enhance the circular supply chain, the adoption of I4.0 technologies is the need of the hour. In this regard, Belaud et al. (2019) presented an approach to integrate I4.0technologies in the supply chain to enhance the SBP of the agriculture supply chain. The developed method was applied to four pre-treatment agri-food supply chain industries. The study recommended that a developed approach would benefit from effective decision-making. Martín-Gómez et al. (2019) presented a multistate framework for sustainable SCM for social metabolism. The study provided a relationship between the circular economy, sustainable SCM, and social metabolism. The study recommended that the developed framework enable smooth operations in the real-time process considering the triple-bottom-line benefits of sustainability.

Dau et al. (2019) analyzed the healthcare SSCM in the context of I4.0 by offering CE transition conceptual framework in integration with corporate social responsibility (CSR) glass. The study concluded that the integration among triple bottom line, CSR, and I4.0 helped smooth transition from a linear to circular model and could enhance the health care supply chain's sustainability in the nexus of I4.0. Manavalan and Jayakrishna (2019) presented a case study of a supply chain organization that adopted I4.0 technologies and enabling CE practices. The study highlights opportunities associated with transforming the linear economy to CE.

Sun et al. (2020) studied the impact of material suppliers and 3D printing platforms in the circular supply chain on product and material prices assumed heterogeneity in consumers' sensitivity to product quality made from recycled and virgin materials. The authors analytically evaluated the respective prices, profits, and demands in Stackelberg equilibrium. The findings showed a positive impact on the quality of recycled material prices on materials suppliers and platforms decision making. The authors recommended improving the recycled material quality by offering revenue sharing to gain more profit. Dev et al. (2020) proposed a roadmap of operational excellence for a sustainable reverse supply chain using the adoption of I4.0 principles and the ReSOLVE model of CE practices. The case-based model had been developed to address the linkage between I4.0 and CE. The remanufacturing model examined the compromise between green transportation availability and set-up delays. The findings of the study suggested possible combinations of family-based dispatching rules and information sharing based on the trade-off observed between economic and environmental performances. The study suggested paying attention to the cost of the socially impacting factors and operations such as end-user market size and collection investment while implementing I4.0 and CE.

Bag et al. (2020) investigated the impact of I4.0 on smart logistics, dynamic remanufacturing, and green manufacturing competence. Further, the implications for business logistics sustainability were also studied. The study addressed the hypotheses with the help of Partial Least Squares based on structural equation modeling (PLS-SEM). The findings showed more influence of I4.0 on intelligent logistics than interconnected and instrumental logistics. The impact of dynamic remanufacturing and green manufacturing competence on business logistics sustainability was found to be positive. The recommendations in the form of social benefits of operational changes in business logistics networks were provided. The study also guided the operations managers towards establishing I4.0 resources, namely, financial support from the government, support from the department of science and technology, and technical support from the department of trade and industry. Krüger et al. (2020) analyzed the challenges and opportunities of digitalization in exploiting the planet's microbial diversity. The study also aimed to identify a robust biocatalyst that enables sustainable bioprocessing. The presented research helps manage global challenges and efficient utilization of resources.

Esmaeilian et al. (2020) discussed the adoption of blockchain technology and I4.0 in the supply chain to enhance its sustainability aspect. The study mentioned four significant capabilities of integrating sustainability and CE concepts: promoting green behavior, improving the product life cycle, enhancing system efficiency and reducing processing cost, and enhancing its performance through sustainable monitoring. Jabbour et al. (2020) presented a review of the adoption of big data in SSCM. The study made three significant contributions to the article. First, it discusses the current research on the topic. Secondly, the study provides several literature gaps in the field of big data in SSCM. Third, the study provided four recommendations for enhancing the adoption of big data in SSCM. The study recommended developing complementary capabilities of firms to deal with challenges associated with big data adoption in SSCM.

4.5 CE in waste management

In current years, more concerns are given to proper waste management and to reduce waste generation. CE practices are gaining importance in minimizing waste generation. In this regard, Camacho-Otero et al. (2018) analyzed the issues associated with consumption in the era of CE. The study suggested that digitization as one of the critical driver of CE that will enable new sources of data which can be used for further research. Antikainen et al. (2018) analyzed the enablers of Digitalization in CE. The study also discusses the challenges and opportunities associated with I4.0. The study recommended that virtualization can be an enabler to digitalization that reduces cost and enhance resource consumption and provide accurate data for decision making.

Gravagnuolo et al. (2019) aimed to analyze CE practices adopted in developing circular European cities. The main aim of the study was to explore the key areas where CE practices can be implemented effectively. The study recommended adopting CE practices mainly in the built environment, water management, waste management, industrial production, and agri-food sectors. Rizvi et al. (2020) presented a review on CE in reverse supply chain logistics scenario. The authors discussed various aspects of CE and recommended adopting IT tools such as big data, IoT, and AI to enhance CE adoption.

Pizzi et al. (2020) discussed the case studies linking fintech and CE concepts over diversified industries. The research shows that fintech, which is the adoption of disruptive technologies in the financial sector, plays a significant role in enabling SMEs to adopt a more sustainable model with CE practices. Jabbour et al. (2020) analyzed the drivers, opportunities, and challenges of sharing economy in the Brazilian manufacturing firm context. The main findings of the study are; the authors found that the firm's understanding of sharing economy is not clear; a transition towards sharing economics is more complicated than presented in the literature. The authors recommended that the adoption of I4.0 technologies will significantly influence the sharing economy.

4.6 CE and business models

The organizations develop business models to analyze the opportunities towards their growth. It also enables providing a competitive environment among the different organizations. In this regard, Maffei et al. (2019) discussed the concept of a business model through which firms can adopt a sustainable business model. The study highlights that digitalization has a positive impact on the business model towards sustainable manufacturing. Jayakumar et al. (2019) developed the optimized mathematical model integrating concepts of sharing economy and CE for leading laptop manufacturers in India. The optimization package used for the study was a multi-objective mixed-integer linear programming model. The study's findings demonstrated the inverse relationship between environmental and economic advantages and provided solutions based on the organization's goals, logistic capabilities, and capacities. The author suggested conducting similar research considering multiple companies to maximize collaboration.

Turner et al. (2019) developed business models for redistributed manufacturing (RdM) with the help of Icam DEFinition for function modeling (IDEF) to help key stakeholders in the implementation of RdM in the consumer goods industry. The developed model was applied in the shoe manufacturing sector to realize its sustainability issues. The results showed the requirement of robust facilities close to the customer. The authors recommended implementing the RdM model to increase customer involvement throughout the process and reduce transportation. Parida et al. (2019) reviewed the literature related to business model innovation, digitalization, and sustainable industry to identify the gaps in analyzing the advantages of digitalization in transforming business models to attain sustainability in Industrial organizations. Further, the authors contributed a research framework to communicate future research directions by integrating business model innovation, digitalization, and sustainable industry. Schwanholz and Leipold (2020) analyzed the CE principles and objectives and shared business models of 73 German-based digital sharing platforms. The findings showed a positive relationship between all the digital sharing platforms and CE. The authors developed digital sharing platforms typological orientation consisting of profit and sustainability, social interaction, and mixed goals and business models. The findings of the study recommended beginning the research on the role of digitalization for sharing practices in the context of CE.

4.7 I4.0 in waste management

In recent years, significant work has been done to minimize waste generation using digital technologies. In this regard, Yang et al. (2018) reviewed the challenges faced by remanufacturing organizations and discussed the importance of I4.0 in addressing these issues. The study performed two case studies to demonstrate the capability of technology enablers of I4.0 in increasing reliability, efficiency, and digitalization of the remanufacturing process. The study observed increased digitalization through the supply chain and improved cyber-physical intelligence within the factory had efficiently addressed significant concerns faced by remanufacturers. The authors recommended focusing on economic analysis of utilizing I4.0 technologies for the smart remanufacturing system. Parida and Wincent (2019) discussed sustainability competence with the help of a literature review. The study focussed on the new dimension of network-level or firm-level transformation for sustainability. It also provided various trends and alterations required to modernize and create entrepreneurial solutions.

A framework was proposed by Kerdlap et al. (2019) to address the challenges associated with zero waste management consisting of six broad themes, i.e., design for zero waste, smart waste collection, intelligent waste audit, and reduction planning, collaborative platform for industrial symbiosis, high-value mixed waste processing, and waste to resource conversion and recycling. The research showed that the integration of various waste measurement, conversion and collection technologies, and IoT and collaborative platforms helped develop a zero-waste management ecosystem. The author recommended analyzing the barriers hindering the implementation of zero waste management as to future studies. Garcés (2019) defined the global barriers to I4.0 adoption existing into the manufacturing organizations and based on which empirical research was carried out to address these barriers to support the organizations in the transformation process. The study extensively reviewed the previous literature in the domain of I4.0 terminologies, areas to be implemented, levels of implementations, lean approaches, sustainability implications, and human resources requirements. Based on the review, the barriers, i.e., lack of commonly accepted software, hardware and standards, and interoperability of heterogeneous networks found to be critical barriers to be addressed. The study recommended developing further research on human resources attributes for I4.0 to help manufacturing organizations in a smooth transition towards the smart factory.

Kumar et al. (2020) analyzed the challenges associated with the adoption of I4.0technologies in SMEs. The response was collected from experts, and DEMATEL was used as a solution methodology to analyze the data. Lack of motivation to adopt I4.0 technologies is the most crucial challenge, whereas fear of failure was the main challenge. Fatimah et al. (2020) investigated the fundamental opportunities and issues and established a smart and sustainable country-wide waste management system. The waste management business process was developed using an extensive literature review. The study contributed to the sustainable development goals and proposed a novel design of sustainable and smart waste management to achieve reliable environmental, social, and economical waste management performances. The study suggested using IoT and ICT to improve the effectiveness and efficiency of a waste management system.

4.8 I4.0 in achieving sustainable operations

In the current scenario, sustainable operations are being promoted to minimize resource consumption and gain competitive advantages. The adoption of I4.0 technologies enables smooth, sustainable operations and minimizes the environmental impacts associated with operations. In this regard, Jabbour et al. (2019) proposed a roadmap based on the state of art literature review for sustainable operations to improve the CE principles in organizations using I4.0 methods. The key topics discussed under study were the significant relationship between CE and I4.0, possible contributions of smart technologies to the ReSOLVE CE business models, and further research directions regarding the integration of CE and I4.0. The study suggested policymakers develop infrastructural plans to address the challenges hindering I4.0adoption, such as lack of talent and cybersecurity. Also, managers were advised to focus on implementing CE for enhancing productivity and profit along with I4.0 adoption. Lu et al. (2020) examined Carroll's pyramid model in SMEs to improve the organizational performance of developing countries aiming to initiate the I4.0 implementation. The authors developed the conceptual model and then used SEM for the analysis. The findings illustrated that the modified Carroll's CSR pyramid had a positive influence on SMEs' organizational performance if they were appropriately addressed in their innovation strategies. The authors recommended adopting developed corporate social responsibility Carroll's pyramid model in SMEs for a competitive business strategy which in turn quicken the I4.0 implementation process.

Kintscher et al. (2020) presented an approach of integrating I4.0 and recycling processes resulting in Recycling 4.0. To explore the possibility of integration, electric vehicles and their traction batteries were used as an example. Also, the robot connection was used in the information marketplace for appropriate decision-making in traction batteries disassembly. The findings revealed the capability of the robotic system of analyzing the situation of the battery for smooth information transmission from robot to marketplace. Ozkan-Ozen et al. (2020) presented the analysis of synchronized barriers to I4.0 and circular supply chains in the Industry 3.5 stage for sustainable resource management. The barriers were identified from the literature review and further analyzed using a fuzzy analytical network process to rank the synchronized barriers. The study's findings revealed a lack of knowledge about data management, high investments in I4.0 technologies and circular approaches, and a lack of understanding of decentralized organizational structure for supplier collaborations as the significant barriers that organizations need to overcome. The authors recommended concentrating on potential solutions for I4.0 and circular supply chain barriers in the future. Also, the cause and effect relationship of these barriers could be established.

Ramchandani et al. (2020) investigated packaging waste by using new technologies to move towards CE in large multinational emerging economies. The authors developed a framework with the application of blockchain and artificial intelligence for fast-moving consumer goods packaging. The authors further attempted to integrate CE with new technologies to influence the CE framework and practices. Bag et al. (2020) developed a theoretical model connecting essential resources of I4.0 required for enhancing technological progress and its impact on sustainable production and CE capabilities. Thirty-five resources about I4.0 adoption had been identified, and a theoretical model was developed using the PLS-SEM approach. Findings showed that human resources, project management, production systems, green logistics, management leadership, information technology, collaborative relationships, and big data analytics were the key resources for I4.0 implementation. The authors suggested paying more attention to the key resources for the smooth adoption of I4.0 in the context of sustainable manufacturing.

Takhar and Liyanage (2020) analyzed data reporting requirements of sustainability and CE using I4.0 technologies. The authors identified reporting requirements concerning CE and sustainability and identified the relevant I4.0 technologies impacting CE and sustainability reporting requirements. The research suggested using I4.0 technologies could enhance the integration of people, organizations, and networks to build the potential for machine learning, data gathering, artificial intelligence, etc., which would further help tackle CE issues. Bag et al. (2021) examined the impact of I4.0 on 10R advanced manufacturing capabilities and sustainable development. The dynamic capability and practical-based view theories were utilized to conceptualize the developed model. The authors validated the model using statistical analysis in the form of developing a survey questionnaire. The findings of the study revealed a significant relationship between the adoption of I4.0 and 10R advanced manufacturing capabilities. Also, the 10R advanced manufacturing capabilities were found to have a positive impact on sustainable development outcomes. The authors suggested management implement I4.0 at all managerial levels from top management to bottom management. The study on the role of artificial intelligence in handling 10R advanced manufacturing to enhance the I4.0 and sustainability aspects was suggested as future scope. Kumar et al. (2021) analyzed the barriers associated with sustainable operations in the era of CE and I4.0 to improve supply chain sustainability. The study utilizes an integrated Analytic Hierarchy Process (AHP) approach and Elimination and Choice Expressing Reality (ELECTRE) to analyze these barriers. The findings of the study showed that combined with a lack of funds for I4.0initiatives and ineffective strategies for the integration of I4.0 with sustainability measures served as the significant barriers. To overcome the obstacles and obtain SSCM operations, the authors recommended exploring sustainable practices and I4.0 technologies.

5. Bibliometric and network analysis

The bibliometric study was performed to visualize the relevant contributions made by researchers, countries, and institutes in the research field. Bibliometric analysis is a highly sensitive tool used to analyze the research outputs through statistical methods (Hui et al., 2020). Network analysis helps in analyzing collaboration among researchers. It includes co-citation analysis and collaboration among various country authors. There are many software packages available for bibliometric study, each with specific advantages and certain limitations. Some of the packages are Histcite, publish and perish, Gephi, R package, and VOS viewer. R package and VOS viewer have been selected in the presented study because of their robustness. One advantage of the R package is its web interface, Biblioshiny, which provides an excellent user interface to perform a bibliometric study. In this work, we used the R package for bibliometric analysis and VOS viewer for network analysis.

The number of articles published year-wise in the field of CE and SBP in the era of digitalization is presented in Figure 2. An increasing trend can be seen in figure 2, especially from 2018. The number of articles published in the year 2018, 2019, and 2020 is 17, 40, and 52 respectively in the field of CE and SBP in the era of digitalization

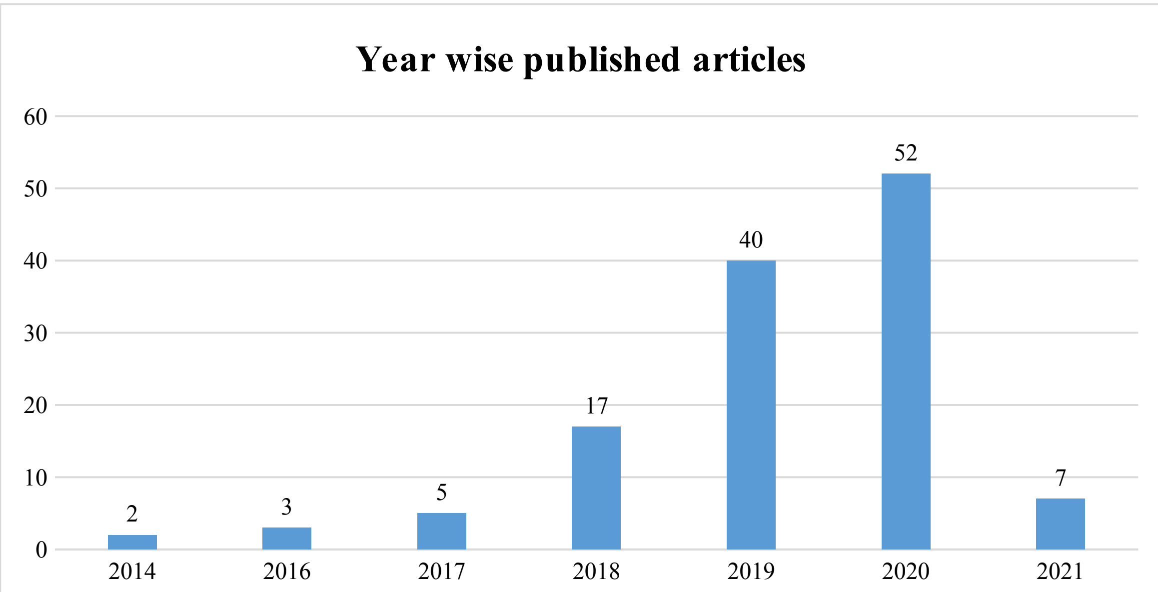

Figure 2. Year-wise published articles in the field of CE and SBP in the era of digitalization.

The top contributing sources of articles have been analysed using the R package and are presented in Figure 3. Figure 3 represents the leading ten contributing sources in the field of CE and SBP in the era of digitalization. From the figure, it can be seen that the top contributing sources are journal of cleaner production, resource conservation and recycling, and sustainability, with 12, 11, and 9 articles in the field of CE and SBP in the era of digitalization.

Figure 3. Source wise published articles in the field of CE and SBP in the era of digitalization

Country-wise statistics have been analysed using the R package in the field of CE and SBP in the era of digitalization. Figure 5 shows country-wise articles, and it is found that UK, China, and Italy were the top contributing countries with 35, 25, and 24 articles in the field of CE and SBP in the era of digitalization.

Country-wise citation has also been analysed and is presented in figure 5. It is found that France, Italy, and India were the highly cited countries with 239, 84, and 61 citations in the field of CE and SBP in the era of digitalization.

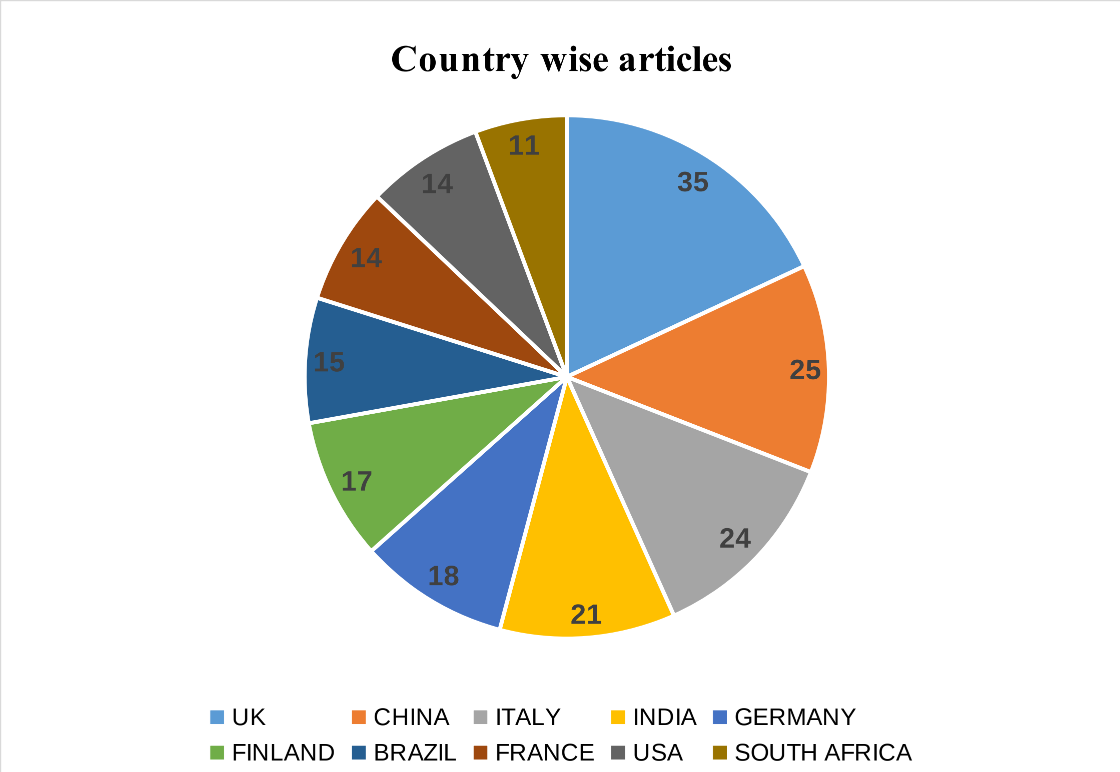

Figure 4. Country-wise published articles in the field of CE and SBP in the era of digitalization

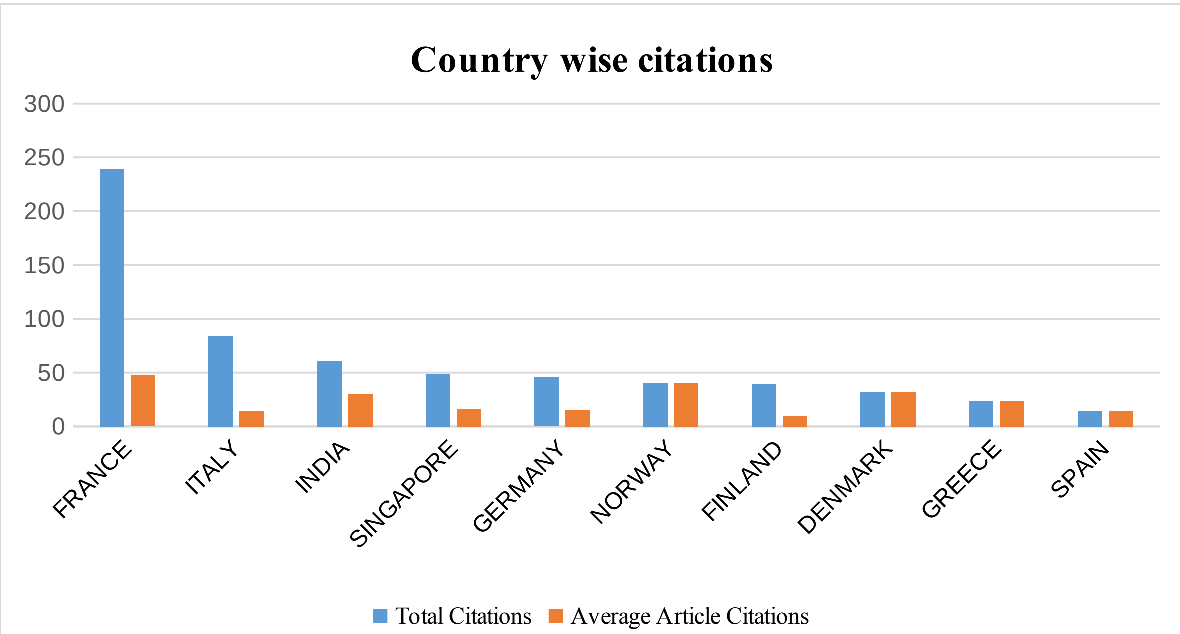

Figure 5. Country-wise citation in the field of CE and SBP in the era of digitalization

The top ten universities publishing articles in the field of CE and SBP in the era of digitalization have been analysed and are presented in figure 6. From the figure, it is found that the University of Johannesburg, Montpellier business school, and the University of

Vaasa were the top universities from where authors were researching the field of CE and SBP in the era of digitalization.

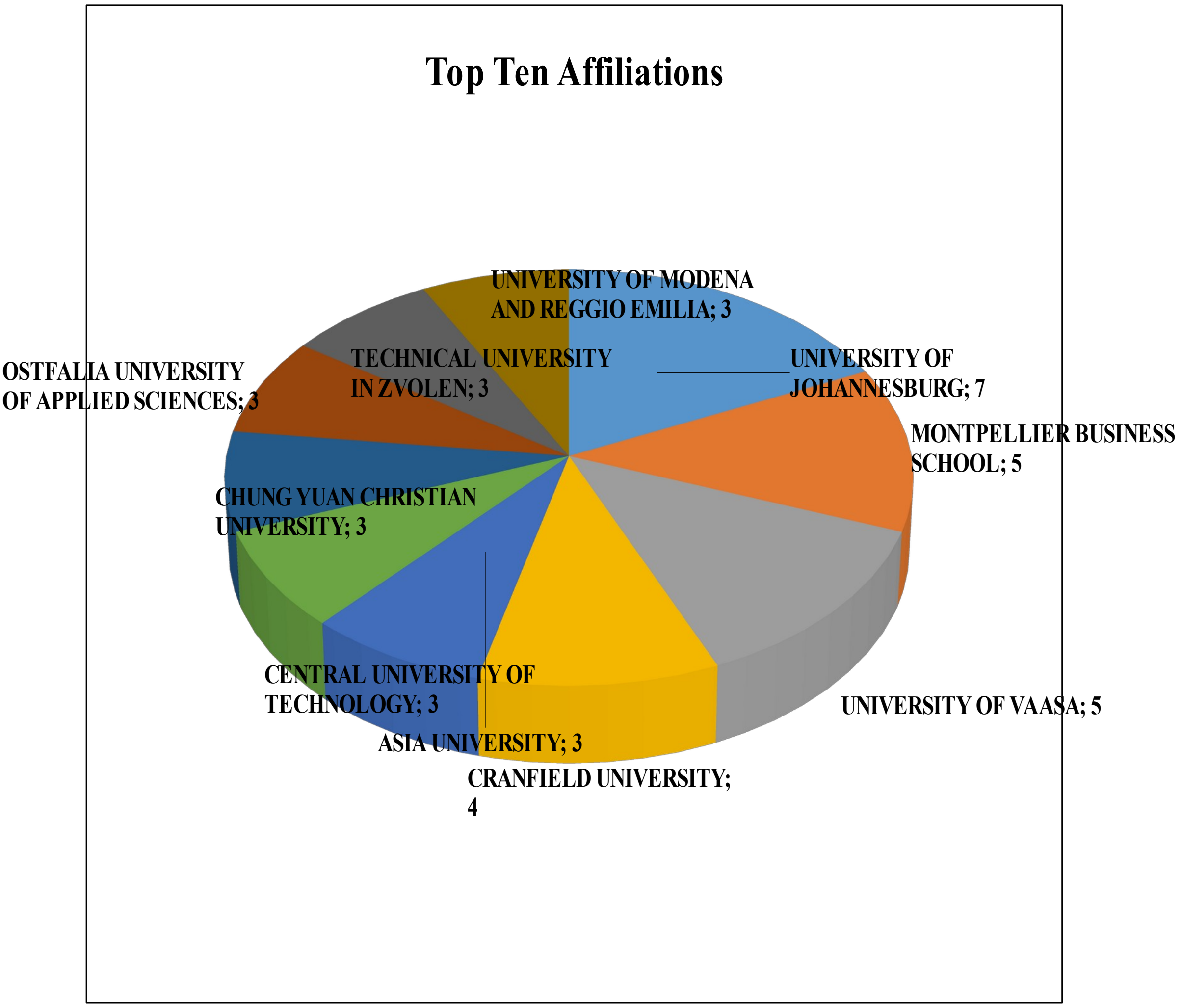

Figure 6. Top ten universities publishing articles in the field of CE and SBP in the era of digitalization

Keywords in the field of CE and SBP in the era of digitalization have been analysed using the R package, and a keyword treemap has been developed using the Biblioshiny web interface and is presented in figure 7. The figure shows that the most frequently used words are sustainable development, circular economy, industrial economics, and I4.0. Figure 8 shows a pie chart of word occurrence in the field of CE and SBP in the era of digitalization.

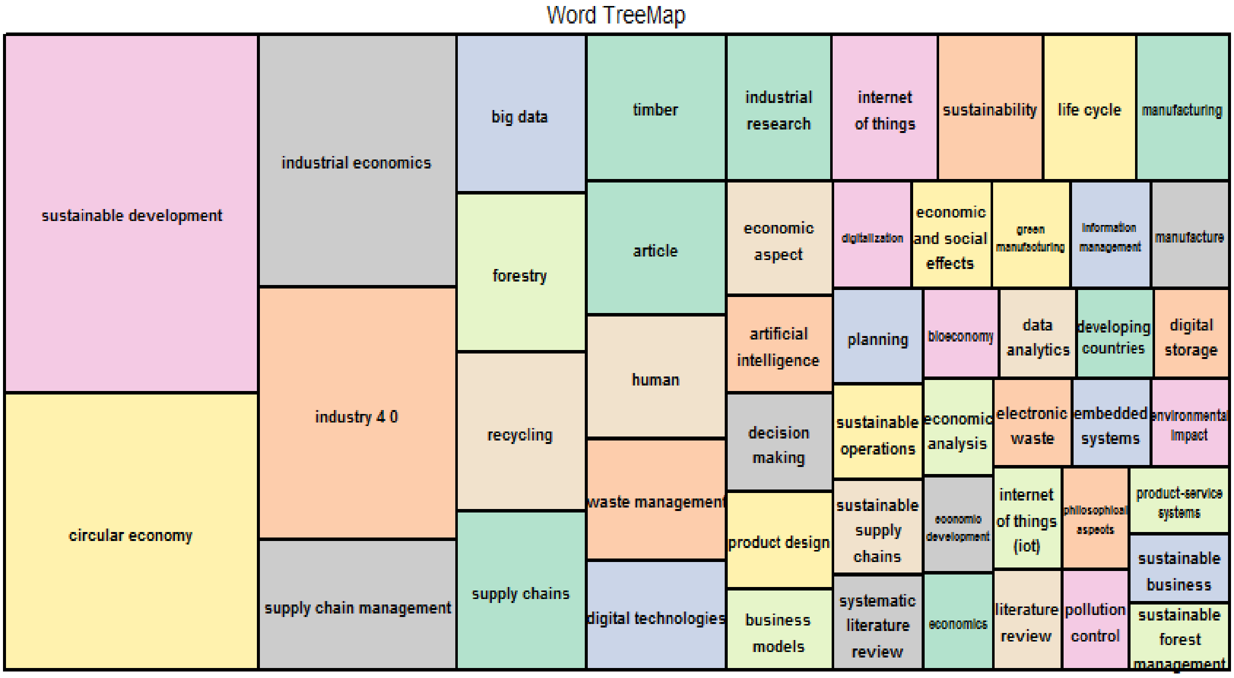

Figure 7. Keyword treemap in the field of CE and SBP in the era of digitalization

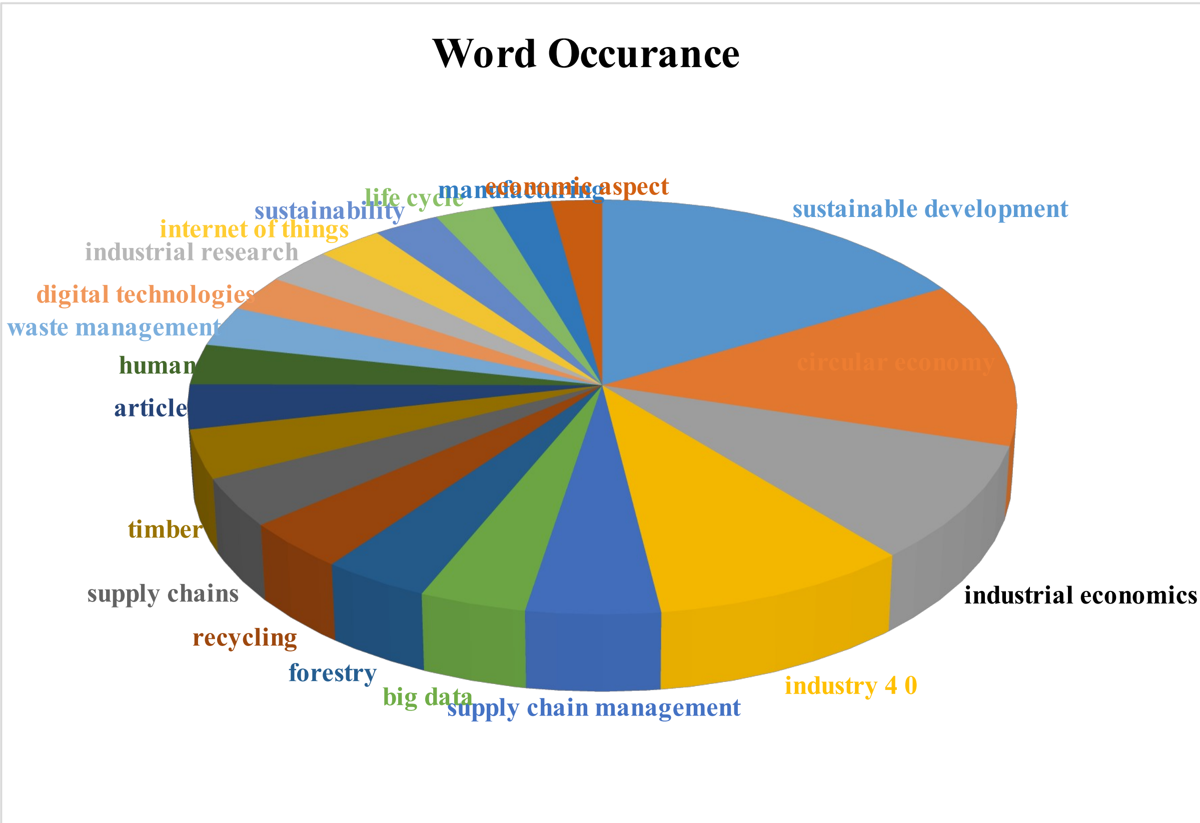

Figure 8. Word occurrence in the field of CE and SBP in the era of digitalization

Thematic evolution of keywords has been identified in the field of CE and SBP in the era of digitalization using the R package and is presented in Figure 9. It shows the evolutions of different keywords used by authors in the field of circular economy and sustainable business performance in digitalization. For example, the product-service system is evolving from 2020, as shown in figure 9.

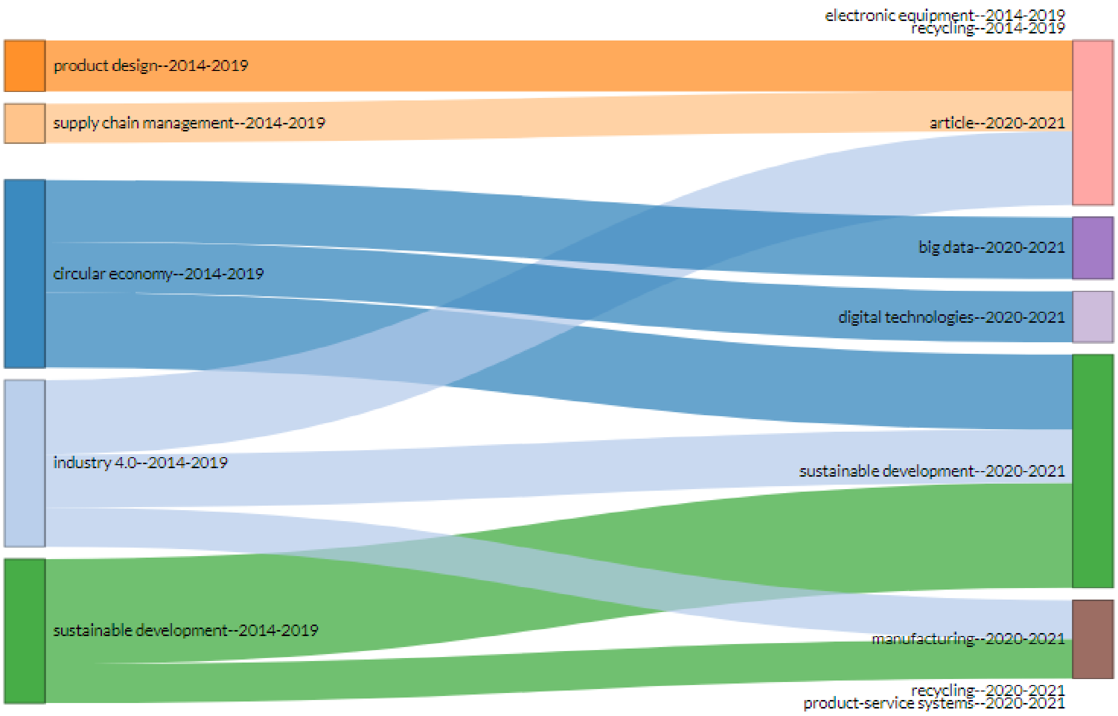

Figure 9. Thematic evolution of keywords in the field of CE and SBP in the era of digitalization

The top ten cited articles in the field of CE and SBP in the era of digitalization have been found using the R package and are shown in Table 1. From table 1, it is found that de Sousa Jabbour et al. (2018), Tseng et al. (2018), and Bressanelli et al. (2018) were the top three highly cited document with 158, 115, and 85 citations, respectively in the field of CE and SBP in the era of digitalization.

Table 1. Top ten cited articles in the field of CE and SBP in the era of digitalization

Paper	Total Citations	TC per Year
de Sousa Jabbour et al. (2018)	158	52.667
Tseng et al. (2018)	115	38.333
Bressanelli et al. (2018)	85	28.333
Nascimento et al. (2019)	78	39
Fisher et al. (2018)	72	24
Jabbour et al. (2019)	64	32
Parida et al. (2019)	54	27
Garcia-Muiña et al. (2018)	43	14.333
Camacho-Otero et al. (2018)	40	13.333

Antikainen et al. (2018)	37	12.333
Reuter (2016)	37	7.4

Network analysis has been done by authors using VOS viewer. It presents a network among authors from various countries and with multiple documents. Figure 10 illustrates co-author collaboration from different countries collaborated to research in the field of CE and SBP in the era of digitalization.

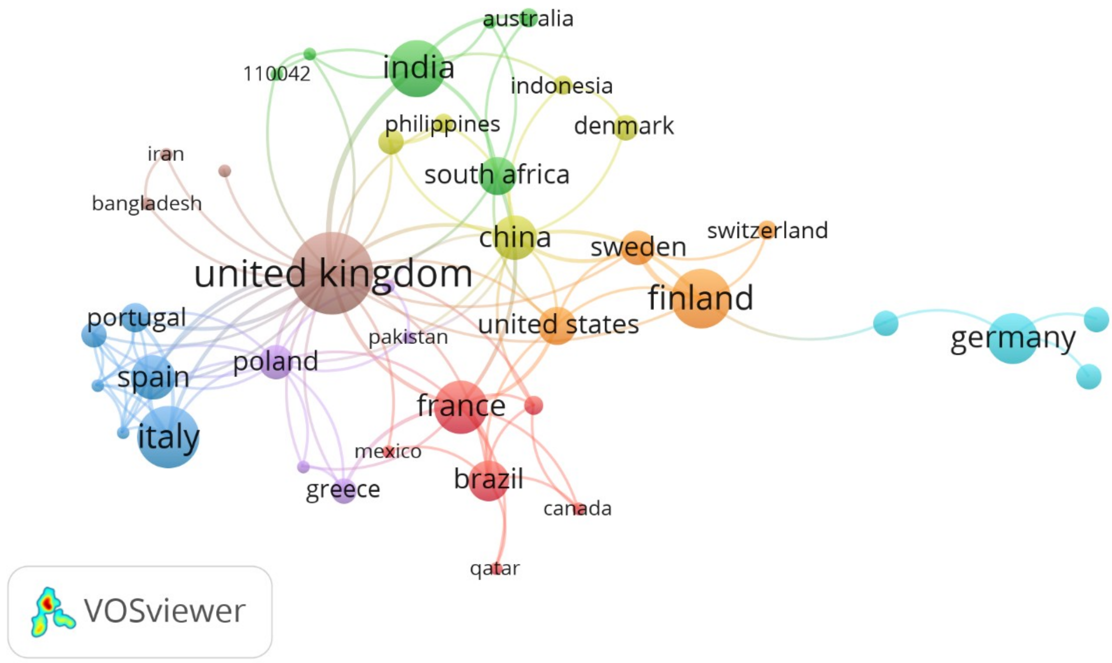

Figure 10. Country collaboration in the field of CE and SBP in the era of digitalization

Co-citation of articles has been analyzed using VOS viewer. Co-citation of articles occurs when two different articles are cited in another article. Co-citation of articles about CE and SBP in the era of digitalization is presented in Figure 11.

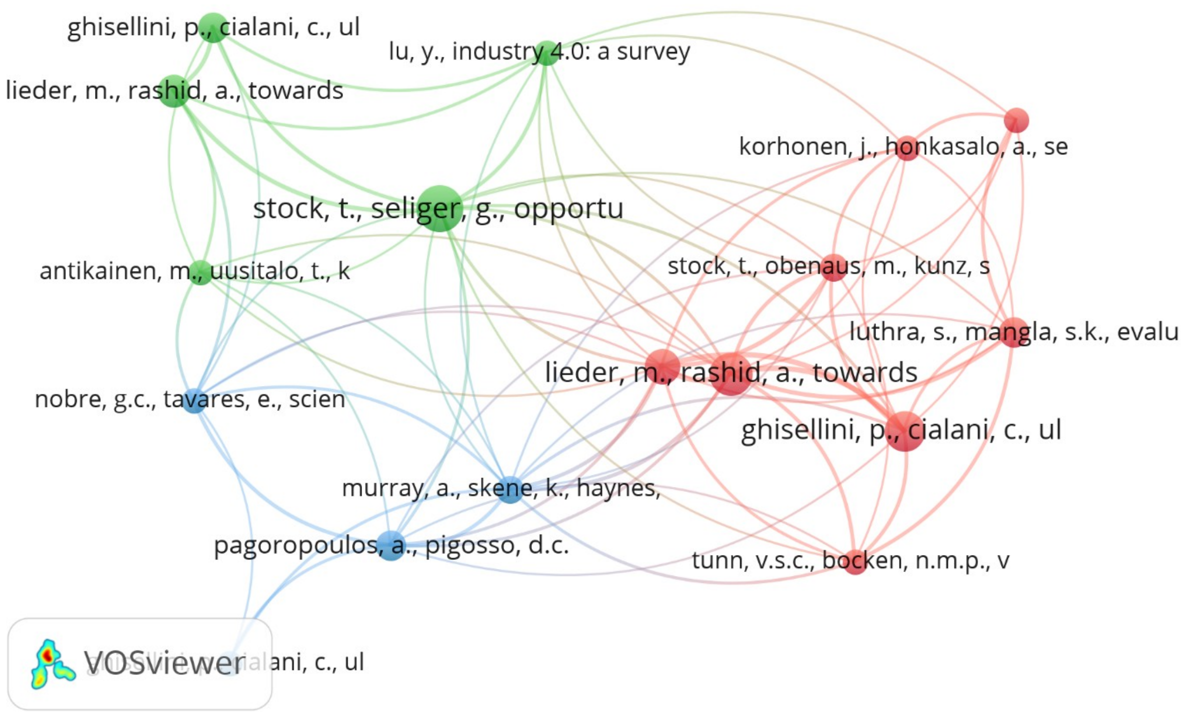

Figure 11. Co-citation of articles in the field of CE and SBP in the era of digitalization

6. Discussions

The study presents the previous studies' analysis on the CE and SBP in the context of digitalization. In this regard, an SLR and bibliometric analysis of CE and SBP research from the perspective of digitalization was conducted, recognizing 126 articles from the Scopus and web of science database. First, the SLR, articles, conference proceedings, and book chapters published from significant publishers like Emerald, IEEE, Springer, Elsevier, and Taylor and Francis were considered. The systematic review on shortlisted articles considering different criteria such as I4.0and CE integration, smart and sustainable manufacturing, smart product-service system, digitalization in the sustainable supply chain, CE in waste management, CE in the business model, I4.0 in waste management and sustainable operations using I4.0 was performed.

Further, to extract the additional useful information on this integration research, a bibliometric analysis was conducted. In this study, the bibliometric analysis considered four major groups, i.e., document type, authors, countries, and word analysis. Using bibliometric analysis, top journals, influential organizations, leading authors and countries, and significant research trending were identified. Leading journals such as Sustainability (Switzerland), Resources, Conservation and Recycling, and Journal of Cleaner Production showed articles from CE and SBP integration (Figure 3). Among the top trending articles, de Sousa Jabbour et al. (2018), Tseng et al. (2018), Bressanelli et al. (2018), Nascimento et al. (2019), and Fisher et al. (2018) are identified in the domain of CE and SBP in the era of digitalization after co-citation analysis.

The previous studies attempted to integrate CE and I4.0 technologies considering many approaches. The framework developed by Jabbour et al. (2017) integrated CE and big data and delivered socio-technical understandings for industry practitioners, academicians, policymakers, and managers. A significant relationship between CE and I4.0 was found, and possible contributions of smart technologies to the ReSOLVE CE business models were observed (Jabbour et al., 2018). The development of infrastructural plans to address the challenges hindering I4.0adoption, such as lack of talent and cybersecurity, was suggested. Managers were advised to focus on implementing CE to enhance productivity and profit and I4.0 adoption (Jabbour et al., 2018). Hatzivasilis et al. (2018) developed the framework for industrial IoT systems to support CE smoothen the communication of industrial IoT sensors and enabled industrial cloud integration. The application of digital technologies in tackling CE barriers, i.e., users' willingness to pay, loss of ownership, return flow uncertainties, and technology improvement, was observed in Product service systems (PSS) business models (Bressanelli et al., 2018). The focus on economic analysis of utilizing I4.0 technologies for the smart remanufacturing system was recommended in previous studies (Yang et al., 2018). The barriers hindering zero waste management could be overcome by integrating it with digital technologies such as IoT (Kerdlap et al., 2019; Garcés, 2019). The implementation of big data infrastructure enhances the readiness of I4.0 and sharing economy in the context of CE (Pham et al., 2019).

The previous studies also discussed developing mathematical models integrating CE and sharing economy concepts to provided solutions as per the case organization's goals, logistic capabilities, and capacities (Jayakumar et al., 2019). Turner et al. (2019) recommended implementing the RdM model in the industry to increase customer involvement throughout the process and reduce transportation. The integration of CSR, I4.0, and triple bottom line helps a smooth transition from linear to circular model and enhances sustainability of health care supply chain in the context of I4.0 (Dau et al., 2019). The study performed by Dev et al. (2020) recommended paying attention to the cost of the socially impacting factors and operations such as end-user market size and collection investment while implementing an integration of I4.0and circular economy. I4.0 influences more intelligent logistics than interconnected and instrumental logistics (Bag et al., 2020). The use of IoT and ICT improves a waste management system (Fatimah et al., 2020). "Technical Capability", 'Policy and Regulation", "Security and Safety", "Education and Participation", "System Flexibility", and "Support and Maintenance" respectively were found to be the significant I4.0 enablers for adopting cleaner production practices linking with CE (Shayganmehr et al., 2020). A significant relationship between the adoption of I4.0 and 10R advanced manufacturing capabilities and sustainable development was observed (Bag et al., 2021).

6.1 Implications of the Study

6.1.1 Implications for industry practitioners

Digitalization can enhance the transformation towards a sustainable circular economy. The CE not only supports saving resources but also monetizes and creates value across supply chains. However, industrial practitioners and key stakeholders need to start thinking about transforming their linear economy model to sustainable CE in the era of digitalization. Digitalization also facilitates more efficient processes in organizations and reduces waste by promoting the longer life of products. The present study depicted various advantages of digitalization in achieving SBP in CE, suggesting the implementation of digital technologies such as IoT and artificial intelligence. The analysis performed by Dantas et al. (2020) suggested integrating the CE and digital technologies for enhancing sustainable practices and achieving sustainable development goals.

Moreover, cloud manufacturing integration with other disruptive technologies boosts the sustainability of manufacturing processes. Despite various advantages of CE and sustainability integration, the practitioners will also have to address the technical difficulties associated with it. The significant technical challenges that need to be looked out by the practitioners include sensor technology, design for zero waste, smart waste collection, intelligent waste audit and reduction planning, collaborative platform for industrial symbiosis, high-value mixed waste processing, and waste to resource conversion and recycling. However, the integration among various business areas could also bring further business opportunities. The present study throws light on circular economy practices in each business area, influencing the entire businesses value chain. Collaboration among various business actors is essential for achieving sustainable business performances in the era of digitalization.

Moreover, the circular thinking involvement in strategic planning would help industry practitioners or decision-makers to reduce the environmental impacts of several businesses.

The finding from the present study would help industry practitioners to analyze the circular economy barriers and take advantage of digital technologies to overcome them. The use of digital technology helps in achieving a sustainable society, thereby supporting sustainable business performance.

6.1.2 Implications for researchers

Based on the literature review, the following future research directions are suggested for the researchers:

6.1.2.1 Integration of I4.0 with circular economy

- Analysis of disruptive technologies of I4.0 with CE integration factors providing significant support in the reduction of wastes and enhancement of remanufacturing activities
- Development of a conceptual framework to improve the knowledge on big data and circular economy
- Exploration of technology nutrients for effective CE strategies.
- Although past studies established various frameworks regarding CE and I4.0 technologies, there is still a need to develop a guideline framework revealing the application of digital technologies in different CE implementation stages to achieve SBP.
- Analysing challenges associated with the nexus of CE and SBP in the context of digitalization using suitable modeling techniques to understand the adoption strategies.
- Implementation studies on big data infrastructure
- Developing a framework suggesting digital technology solutions to overcome the circular economy barriers for sustainable business performance.

6.1.2.2 Smart and sustainable manufacturing

- Exploring the integration of cloud manufacturing with other disruptive technologies to enhance the sustainability of manufacturing processes.
- Development of standard flowsheet to predict the recycling rates and creating a material database to help process simulator in the industries.
- Adoption strategies of sustainable manufacturing for a smooth transition towards CE and enhance the CE capabilities in the digitalization era.

6.1.2.3 Smart product-service system and digitalization in sustainable supply chain

- Integration of digital technologies and CE in logistics allows the consumer to return products after use, thereby promoting a circular supply chain.
- Establishment of a framework enabling smooth operations in the real-time process considering triple-bottom-line benefits of sustainability.
- Studies about combinations of family-based dispatching rules and information sharing based on the trade-off observed between economic and environmental performances.
- Analysing the cost of the socially impacting factors and operations such as end-user market size and collection investment while implementing an integration of I4.0 and CE.
- Establishment of core I4.0 resources, namely, financial support from central government, support from the department of science and technology, and technical support from the trade and industry department.

6.1.2.4 Digitalization in achieving sustainable operations

- Developing infrastructural plans to address the challenges hindering I4.0 adoption, such as lack of talent and cybersecurity for the sustainable CE.
- Concentrating on potential solutions for digitalization and circular supply chain barriers to achieving sustainability.
- Analysing barriers associated with sustainable operations in the era of CE and I4.0 to improve supply chain sustainability.

6.2 Unique Contribution of the Research

The unique contribution of this work is the systematic literature analysis along with bibliometric study to explore future research directions in the nexus of CE and SBP in the context of digitalization. The present study has been one of the first efforts to examine the literature of CE and SBP integration from a digitalization perspective along with bibliometric analysis. The paper discusses the systematic literature review of articles about CE and SBP to identify the research gaps for future research. The literature review has been focussed on eight different perspectives, i.e., I4.0 and CE integration, smart and sustainable manufacturing, smart product-service system, digitalization in the sustainable supply chain, CE in waste management, CE in a business model, I4.0 in waste management, and sustainable operations using I4.0.

Also, the bibliometric analysis was executed using R programming software and VOS viewer software considering four major groups, i.e., document type, authors, countries, and word analysis. Using bibliometric analysis, top journals, influential organizations, leading authors and countries, and significant research trending were identified. Also, the study performed a cluster analysis to analyse the network among authors, publications, and Co-citations.

7. Conclusions

The present study aimed to perform systematic literature analysis and bibliometric analysis of CE and SBP in the context of digitalization. The paper discusses the systematic literature review of articles about CE and SBP to identify the research gaps for future research. The literature review has been focussed on eight different perspectives, i.e., I4.0 and CE integration, smart and sustainable manufacturing, smart product-service system, digitalization in the sustainable supply chain, CE in waste management, CE in business model, I4.0 in waste management and sustainable operations using I4.0. Also, the bibliometric analysis was executed using R programming software and VOS viewer software considering four major groups, i.e., document type, authors, countries, and word analysis. Using bibliometric analysis, top journals, influential organizations, leading authors and countries, and significant research trending were identified. The study revealed that digitalization could be a great help in developing sustainable circular products. The development of infrastructural plans to address the challenges hindering digital technologies adoption, such as lack of talent and cybersecurity, was suggested, and managers were advised to focus on implementing CE for enhancing sustainability and profit along with I4.0 adoption.

Moreover, the customers' involvement is necessary for creating innovative sustainable circular products using digitalization. The present study limits to only published journals and conference articles on CE and SBP in the context of digitalization for literature review. Since digitalization is a growing field, more information regarding SBP could be gathered from other sources such as book chapters, white papers, magazines, etc. Although the literature review provides a significant contribution to realizing the circular economy and SBP in the era of digitalization, the implementation framework on the integration of CE and SBP could be developed to support industrial development. A move towards the product-service system was suggested to accelerate the transformation towards CE and Digitalization. The research framework could be developed based on literature analysis performed by identifying more criteria about the nexus of CE and SBP in the era of digitalization. Implications and future research directions are described.

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