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The Role of Digital Technologies in a Data-driven Circular Business Model: A Systematic Literature Review

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Abstract

The Circular Economy (CE) has been identified as a promising solution for reducing emissions, waste, and achieving sustainable development goals while offering economic values for companies. However, the move towards CE requires managers and decision-makers to rethink and redesign their Business Models (BMs) incrementally or radically. In order to achieve proper decisions on resource usage, product designs, material flows, and recirculation of materials, data plays a significant role in CE. Accessible data is considered as an essential enabler of circular solutions and at the heart of circular business models. In this regard, digital transformation can offer innovative tools for efficient execution and sharing of data to help companies generating new business models and to increase their competitive advantages. This study explores different data-driven BMs enabled by digital technologies in CE.

Introduction

The move towards Circular Economy (CE) requires systemic change in how companies create and deliver value to customers (value proposition) and how they can capture and generate revenue (value capture) (Bocken et al., 2016). Therefore, innovating Business Models (BMs) are the fundamentals of the CE concept (Centobelli et al., 2020). Bocken and Ritala (2021) defined two strategic choices in developing circular BM initiatives as innovation and resource strategies. While resource strategy focuses on narrowing, slowing, closing, and regenerating resource and energy loops (Geissdoerfer et al., 2018), innovation strategy focuses on firm-driven internal processes (closed innovation) and collaboration with external partners and stakeholders (open innovation). The value creation in circular BMs for narrowing the loops happens by delivering

Keywords: Circular economy, data-driven business model, digital technologies

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value to customers through efficient design and production, reducing the extraction of virgin materials and resources (Li et al., 2010). In slowing the loops, circular BMs aim to create value by extending products' life by designing products that can have more than one use cycle and are more durable, upgraded, repairable, and easy to disassemble recyclable (Zhu et al., 2010). Finally, BMs for closing the loops generate value through recycling and recovering materials for reuse in new production processes (Bocken and Ritala, 2021). Processes such as resource optimisation, manufacturing products, extending the lifetime of products, offering new use cycles, and improving material flow, include high-volume data, which, if implemented efficiently, can enhance circularity (Ingemarsdotter et al., 2020). Data can create value when transferred to information, which can be integrated with other data sources and interpreted as knowledge. When knowledge is further enriched and developed, it forms wisdom (Kristoffersen et al., 2020). A data-driven CE gives companies more opportunities to develop innovative BMs, create networks and partnerships, as well as expanding ecosystems (Kauppila, 2022). Transparent data on material and components enables measuring the impact of production and operations on material, creating pure and high-quality feedstock by preventing toxic, contaminant and non-renewable material, as well as reducing the cost of material extraction and usage (Blomsma et al., 2020). Hence, it helps companies to make more efficient and accurate decisions on material and process choices to achieve CE goals. In addition, accurate data on material flow internally and across the whole value chain can ensure proper recycling opportunities at the end of product's life while enhancing the recovery processes of materials (Sitra, 2021). Accordingly, data for circular BMs can be categorised as follows: data on product design and production, data on use phase and customer behaviour, data on product and service lifetime, data on system performance, and data on material flows. Implementing such data in circular value creation develops BMs such as servitisation-based models, product as a service model, sharing economy models, collaborative consumption models, product life extension models, and resource recovery models (Luoma et al., 2021).

As shown in Figure. 1, data is at the core of the CE model, which can be collected, stored, measured and analysed by digital technologies such as big data, Artificial Intelligence (AI), Blockchain and the Internet of Things (IoT), also known as Industry 4.0

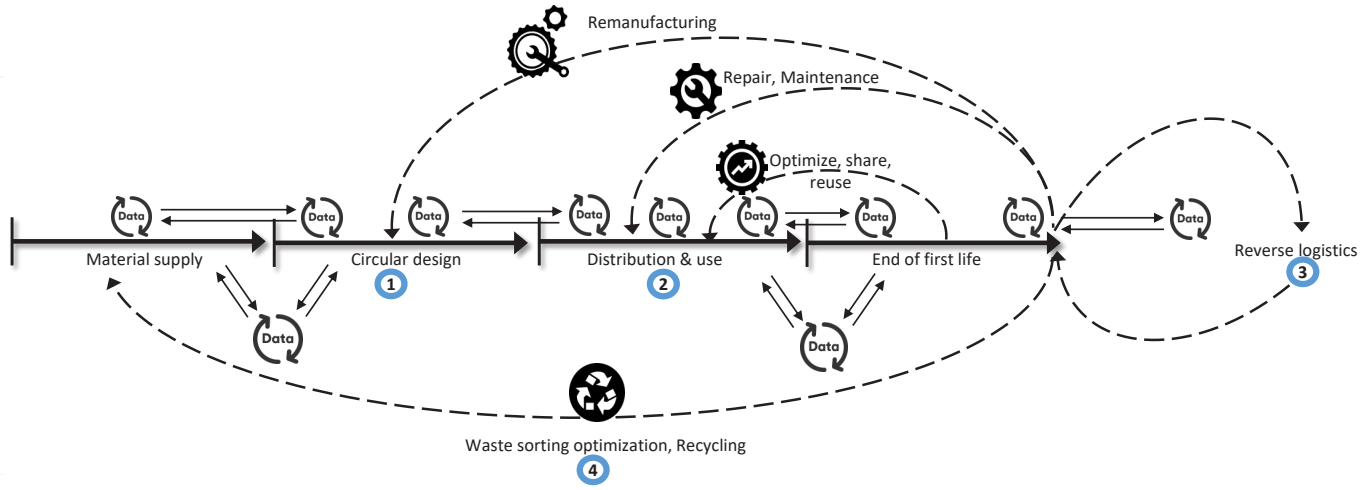

Figure 1: Role of data and digital technologies in CE (based on Ghoreishi et al., 2022)

(Ghoreishi et al., 2022). Digital technologies are revolutionising BMs in CE by:

- enabling tracking and tracing products and materials to develop product-as-a-service system which reduces product ownership while increasing reuse, repair and refurbishment opportunities (Alcayaga et al., 2019);
- enabling data sharing within the whole supply chain that improves retaining of value from products and materials (de Sousa Jabbour et al., 2019);
- enabling higher efficiency and circularity in manufacturing products and material processes (Ranta et al., 2021);
- enabling platforms that connect companies and customers, support development of service and dematerialisation, and facilitate industrial symbiosis (Täuscher and Laudien, 2018);
- enabling shared databases for sharing waste information and reusing waste as a resource (Radamaekers et al., 2011).

Although research on the role of data in CE has recently gained the attention of practitioners and researchers (Luoma et al., 2021), only limited studies were conducted on the role of digital technologies in data-driven circular BMs (Ranta, 2021). Therefore, the research questions of this study are as follows:

RQ1. What are the existing data-driven business models in CE?
RQ2. What is the role of digital technologies in data-driven circular BMs?

Methodological approach

To answer the research question and to understand the existing literature on the role of digital technologies on data-driven circular BMs, a systematic literature review was conducted in this study (Xiao and Watson, 2019). Scopus and EBSCO Business Source Complete were the selected academic databases. The search was conducted using the main terms 'circular business model', 'digitalization', and 'data-driven business model'. The set of keywords for each term was selected based on the domain literature (Table 1). The search terms were selected in the title, abstract, keywords, or subject, with 'data' chosen as any part of the text. In addition, the search was limited to articles and reviews published in peer-reviewed journals, English language, between January 2000 and March 2022 (1.1.2000-31.03.2022).

Table 1.

Terms	Keywords
Circular business model	(circular*) AND "business model*" OR "Value creat*")
Digitalization	(digitali*ation OR "digital technolog*" OR "digiti*ation" OR "digital transformation" OR "big data" OR "IT" OR "Industry 4.0" OR "Internet of Things" OR "IoT" OR "remote control" OR "remote monitoring" OR "RFID" OR "Artificial Intelligence" OR "data analytics" OR "predective analytics" OR "machine learning" OR " automat* robots" OR "smart robots" OR "smart data" OR " digital manufacturing")
Data-driven business model	(data OR "data collection" OR "data gathering" OR "data analysis" OR "data analytics" OR "data mining")

Table 1: Keywords used in the search settings

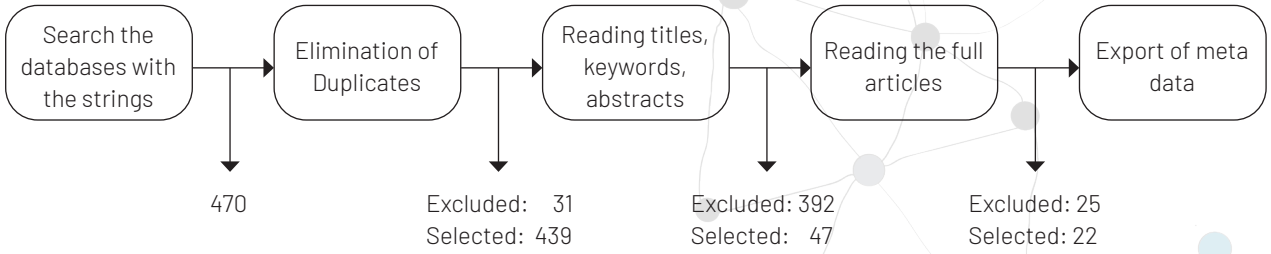

Figure 2: Research design for the literature review.

After removing duplicates, the screening process was continued by reading titles, keywords, and abstracts. To ensure the final sample, the articles should 1) include the concepts of circular BMs and circular value creation, 2) address the digital technologies and CE, 3) address the utilisation of data in circular BMs by digital technologies. Accordingly, the articles that did not meet these criteria were excluded. Furthermore, the author read the full articles for a more accurate decision, specifically the results sections. The literature search process is shown in Figure 2, based on which 47 articles were selected for full article screening. After reading the full text of each article carefully, the irrelevant articles were excluded and resulted in 22 selected articles for a systematic review regarding the theoretical, conceptual and empirical contribution to answering the RQs of this study.

Furthermore, the relevant data was collected manually and documented systematically in an Excel sheet. The aspects of the articles related to the role of data in circular BMs and value creation by digital technologies were assessed and identified. The main terms of circular BMs, the definition of the BMs, the role of data in circular BMs and the description of how digital technologies enable data for circularity in these BMs were identified and coded after the data analysis. This way, the contents of articles were classified and compared to form a systematic finding.

Results of the literature review

The role of digital technologies as an enabler of circular strategies, ReSOLVE strategies, and circular BMs has been discussed in various research and studies since 2017 (Alcayaga et al., 2019; Blomsma et al., 2020). However, according to the results of this study, the vital role of data, how data creates value in circular BMs through digital technologies, has only been argued by limited researchers since 2018. The results from the systematic literature review indicate the increasing trend in research on this topic, with three publications in 2018, two publications in 2019, three publications in 2020, seven publications in 2021, and seven publications by the Spring of 2022 (Figure 3).

Moreover, the journals with the highest publications are respectively as follows: Sustainability open access Journal with six publications, four publications in Business Strategy and the Environment Journal, two publications in Journal of Cleaner Production and two publications in Journal of Resources, conservation and Recycling, and the rest were published in various Journals (Figure 4).

According to the results, as illustrated in Figure 5, IoT is the most discussed digital technologies in different research due to the capability of IoT sensors and links in connecting physical products and online services. Therefore, it can enable tracking, tracing and transferring of real-time data, which results in saving resources, optimisation of processes, transportation and material flows, as well as minimizing unnecessary expenses on material extraction throughout the entire network of supply chains (Ivanov et al., 2022; Chauhan et al., 2022; Ranta et al., 2021; Ingemarsdotter et al., 2020).

Furthermore, Data-based services are a rising trend aiming at increasing transparency and creating new value from supply chain data. According to the results, 13 publications discussed the "Product-service System (PSS)" BM in the concept of CE and highlighted the significant role of digital technologies, specifically IoT. Servitisation and PSS model provides services and performance instead of products,

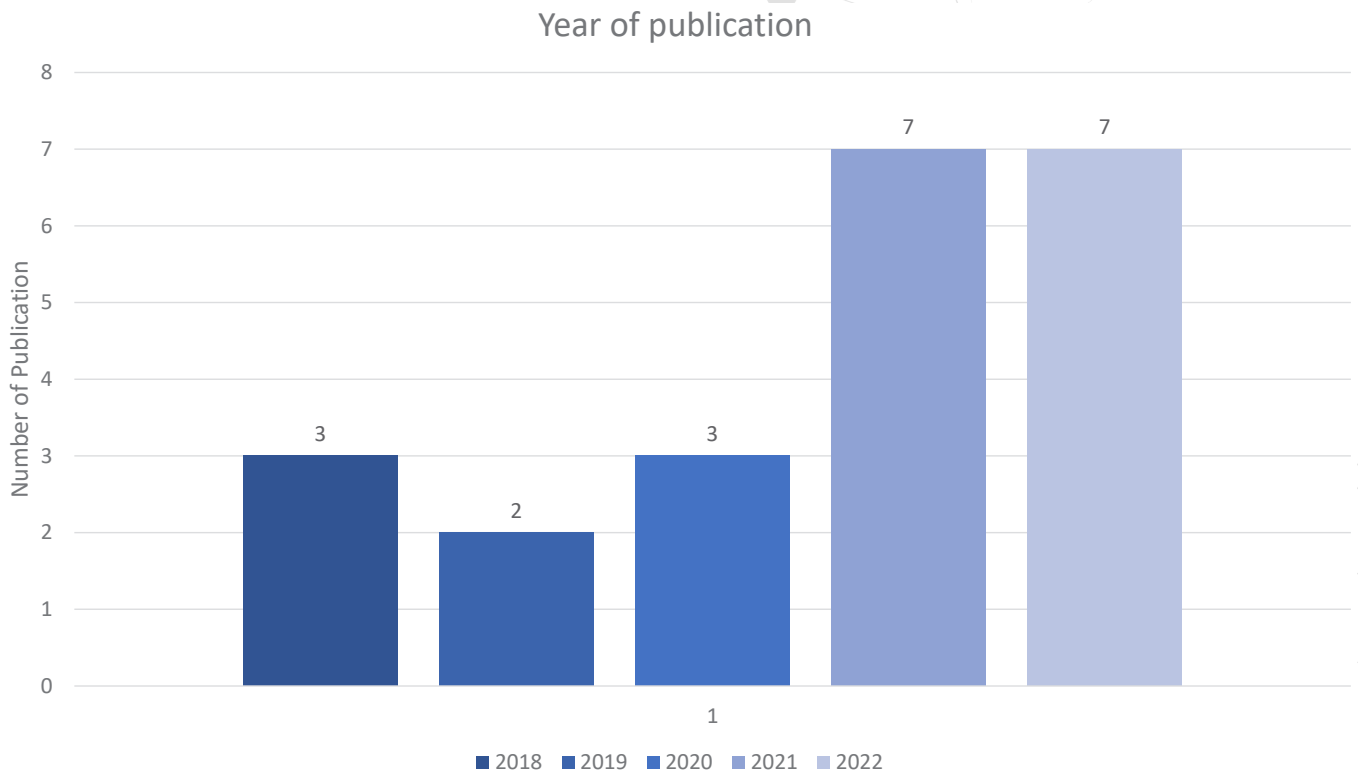

Figure 3:

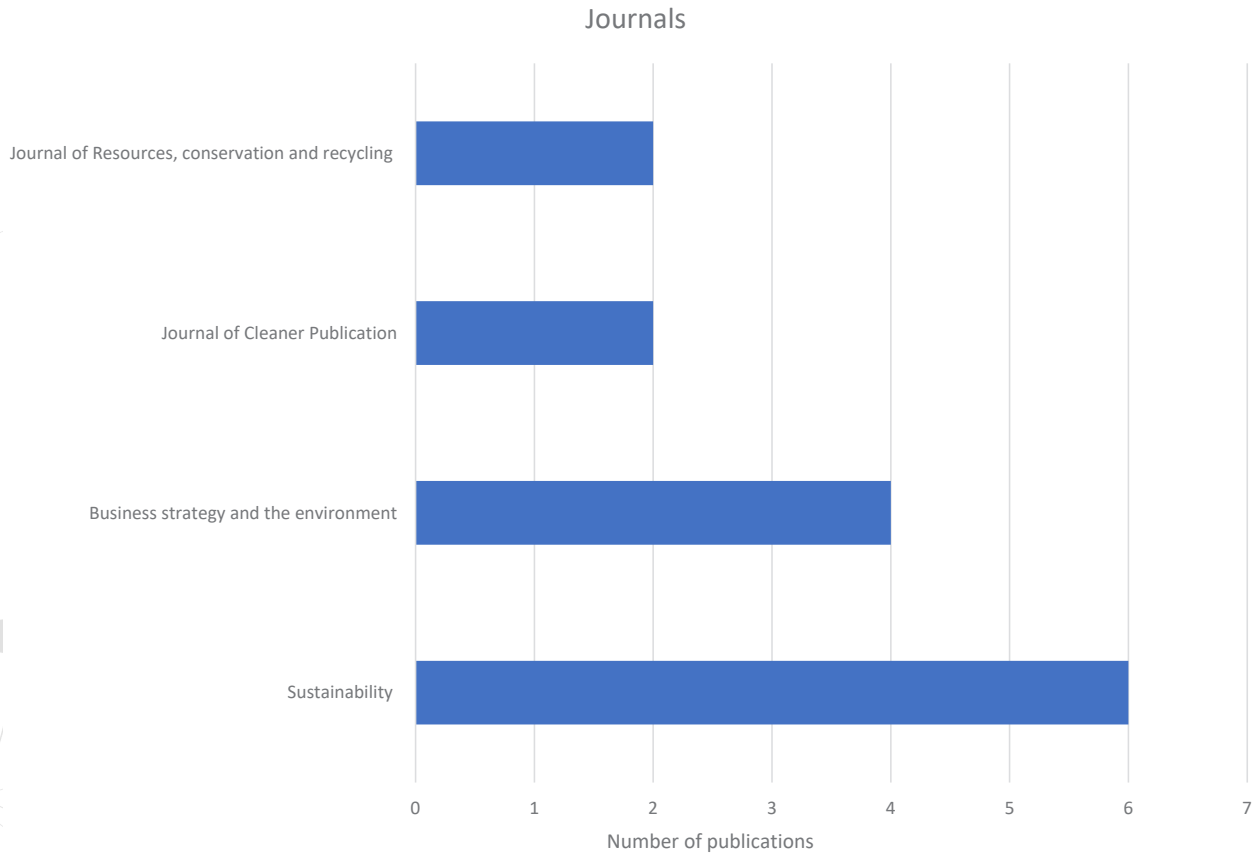

Figure 4:

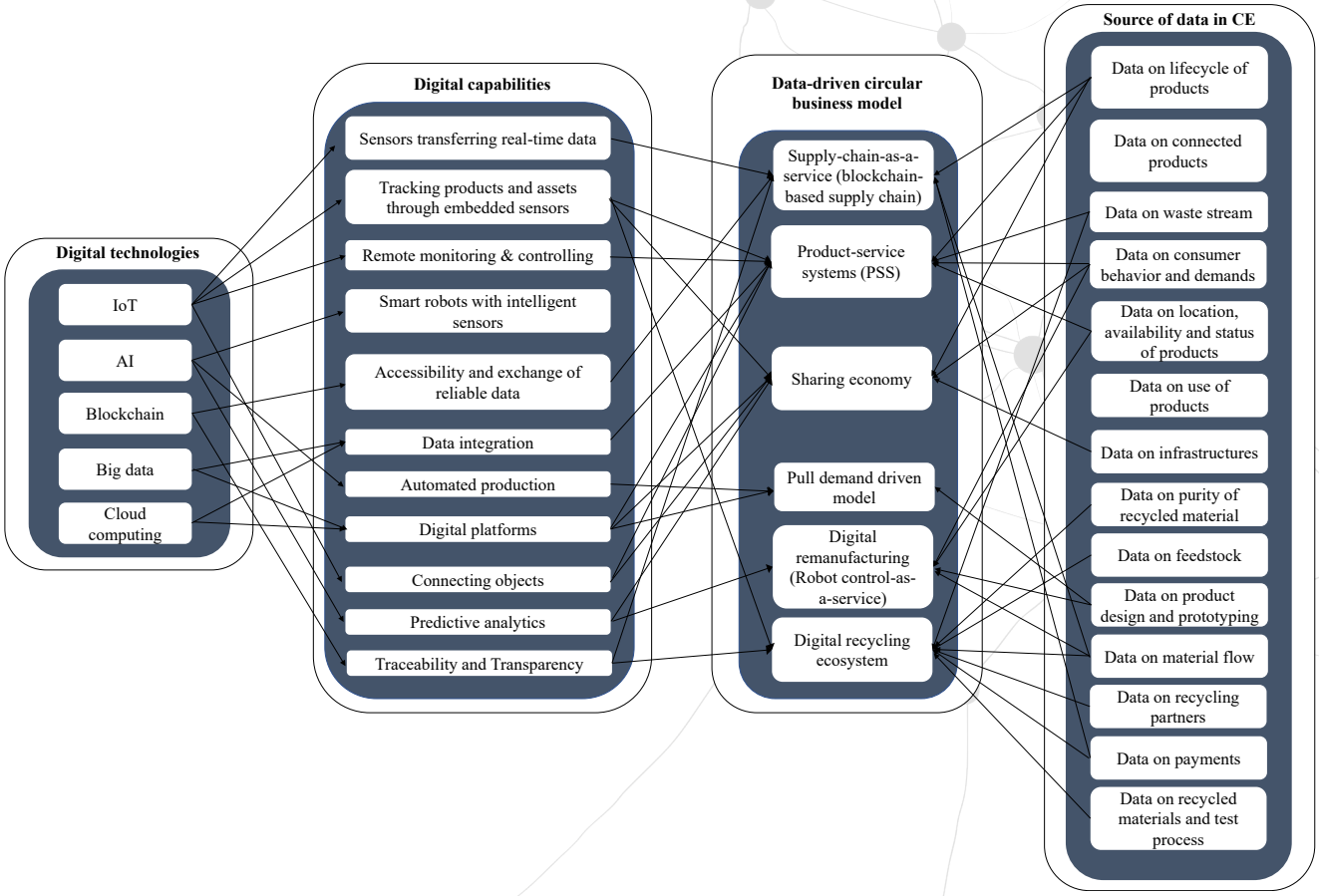

Figure 5. Data-driven BMs, source of data and digital technologies

which increases resource and material optimisation. Various authors emphasized the role of data in extending the life of products for creating value and developing service-based BMs. In this regard, data enables repair, reuse, maintenance services and recycling while helping companies to optimize product design. The second vital circular BM highlighted by the authors was "Blockchain-based supply chain", with the important role of Blockchain technology in creating a transparent and trustable data transaction throughout the entire supply chain. Many authors mentioned that the tight connections between Blockchain and IoT sensors, create a trustworthy environment for different actors within the supply chains and enable safe and visible transactions without the need for a third party. "Sharing Economy", "Digital remanufacturing", "Digital Recycling Ecosystem", and "Pull demand-driven model" were respectively the most discussed circular BMs, highlighting the role of digital platforms and cloud-based technologies. Table 2 below includes an overview of the data-driven BMs in CE identified through the literature review.

Discussions and Conclusions

The findings of this paper offer a greater understanding of the role of data in CE and why data is crucial in developing circular BMs. The existing data-driven BMs have been identified and why data is important in circular BMs has been discussed through this research. Data is the source of value in various decision-making processes in CE and enables material and process optimisation. Precise and accurate data supports the best choices and decisions in changing supply chains, ecosystems, and networks dynamically. The results from the systematic review show the increasing trends in this topic and the increasing potential for more emperical studies in future. There is huge potential for research in identifying the benefits of data by utilizing digital technologies

Table 2.

Data-driven Circular BM	Definition of circular BM	Role of Data	Industry 4.0 Technologies	Reference examples
Supply-chain-as-a-service (cloud-based enabled supply chain) , Blockchain-based supply chain	Supply chain-as-a-service enables major principles of resilience and viability. Main resilience strategies such as multi-sourcing, collaboration, visibility, and flexible re-routing. Viability is the ability of a supply chain to survive in a changing environment through a redesign of structures and replanning of performance with long-term impacts.	Data on each stage of product's life enhances transparency and visibility in the supply chains which is highly important for efficiency, resilience and sustainability while tracing performances. Data from connected products, plants and systems enables operation optimization and create better quality products.	Tightly connected IoT sensors and platforms to Blockchain technology allow contracting in the platform context and creating improvements in performance through transferring real-time data, visibility and trust. Blockchain registers each transactions of products and materials throughout the value chain, thus enabling access and exchanging of reliable data without the need for third party operators. AI and big data analytics can enable visibility and outsourcing in pricing and revenue decisions.	Ivanov et al., 2022, Huynh 2021
Product-service systems (PSS)	The PSS business model offers products entirely as a service or supportive services in addition to products such as maintenance contracts. Support services that can improve and extend lifecycle of the products through reuse, recycling, and remanufacturing operations. PSS enables resource efficiency.	Data on lifecycle of products helps in prolonging life of products. data on waste stream, data on consumer behavior. Data on location, availability and status of products. Data on product facilitates decision making.	IoT enables tracking of the products during and after use, enables durability in products, connects objects and enables service-based model. Utilizing data enables remote monitoring and controlling of products. Big data, and cloud computing enable digital platforms that manage operational activities and services. Blockchain enhances the sorting process. Cloud technologies integrate and show data to the company and consumer, enabling the potential for offering context-specific maintenance services.	Chauhan et al., 2022, Huynh 2021, langley 2022, Subramoniam et al., 2021, Cetin et al., 2021, Okorie 2020, Ranta et al., 2021., Ingemarsdotter et al., 2020., Rossi et al., 2020., Lieder et al., 2020, Garcia et al 2018, Bressanell et al., 2018, Lindström et al 2018

Table 2.

Data-driven Circular BM	Definition of circular BM	Role of Data	Industry 4.0 Technologies	Reference examples
Sharing Economy (SE)	Sharing economy business model aims to optimize resource consumption through collaborative consumption (sharing, exchangin, and renting resources leads to reduction in resource and energy usage). Improving operation mangement. Enables sharing access to assets and resources instead of owning assests.	Data on entire lifecyle of product, data on consumer behavior, data on use of products, data on products and systems demand, data on infrastructures.	Big data platforms, Embedded sensors and IoT enabling data collection for products and services. Installing sensors on assets enables tracking and monitoring the condition of products, allowing predictive maintenance. Artificial intelligence enables new product development, preventive maintenance services .	Vecchio et al., 2021, Massaro eta l., 2020
Digital recycling ecosystem (extended blockchain service)	Reducing waste and carbon footprint across the supply chain.Creating a closed-loop supply chain by innovating products from post-consumer materials which are fully certified through a traceable and transparent supply chain.	Data on purity of recycled material for customers' trust. Accurate data on payments for waste collectors and other partners. Data on recycling partners' capacities. Data for choosing the right feedstock and how to use it for which end product. Data for handling types of feedstock. Data for test process of the content of recycled materials.	Blockchain secures transparent process and cost of the entire value chain. Blockchain system enables tracing post consumer recycled materials to their source. Private Blockchain with a customized token system enables setting transparent rules as well as a tokenizer reward system.	Chaudhuri et al., 2022
Pull demand-driven model	Facilitating a radical shift in the entire production-consumption paradigm of supply and demand as well as upstream/downstream businesses. The pull demand-driven business model reforms the linear model to a more collaborative and integrative circular process. This model increases the speed from design to delivery, producing more personalized products and more flexible for small-scale production.	Real-time data helps to solve two main problems: overproduction and underuse. Data on design and prototyping help in prodcut development and production phases, making involve all the stakeholders from the first stage.	Digital plaforms enable communication and interaction between end-users and designers and business partners. AI enables automated production which reduces labour costs while increasing higher acuracy in production.	Huynh 2021

Table 2.

Data-driven Circular BM	Definition of circular BM	Role of Data	Industry 4.0 Technologies	Reference examples
Digital re-manufacturing business model (Power-by-the-Hour, Robot control-as-a-service)	Provides remanufacturing companies the capacity to gain access to the customer base and to enable rapid respond to the changes in demands, reducing resource consumption while increases competitiveness. Integration of digital remanufacturing is crucial for product development, process development, production, and after sales in CE. Improves real-time inventory management.	Data on different parts' condition enables high quality remanufacturing. Historical data enhances decision-making to qualify or separate the returned products. Data on product design (design for disassembly, design for repair, design for upgrade…) enhances taking consideration parameters for better remanufacturing. Data on material flow and returns improves design processes, lack of information results in enhanced processing of the product. Data on customers' behavior and demand reduces response time to drive changes.	IoT enables tracking the parts to ensure availability of replacement parts. Sensors enables tracking part performances and facilitating predictive analytics such as predictive maintenance. Transferring real-time data on returned product defects and demands helps plant managers to schedule operations. A cloud-based service supports the development of distribution process planning in decentralized dynamic remanufacturing environment. Smart robotic remanufacturing using intelligent sensing and real-time adaptation.	Subramoniam et al., 2021, Kerin and Pham 2019

in supply chains, ecosystems and various value creation strategies in CE with the focus on different industries such as textile and fashion which have more complex supply chain.

This research is limited to understanding the role of data and digital technologies in circular BMs. Hence, the study only examined the papers that included the term "data" and excluded articles that only focused on digital circular BMs and not mentioned data utilization. Moreover, the concepts "circular BMs" and "digital technologies" are showing strong and fast development recently, especially from the data-driven perspectives. Future research will benefit from a comprehensive study on the role of data on different CE strategies, process and product designs. Moreover, a deeper understanding of the role of data as a driver of circular BM innovation and configuration, the role of data in enhancing collaborative ecosystems, and the role of data in creating and capturing value in the circular supply chain are required through studies of different cases. Finally, although the role of IoT has been identified considerable as an enabler of data-driven BMs in CE, there is still potential to explore the capabilities of AI, analytics and blockchain technologies in this field.

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