R&D MANAGEMENT

The relationship between digital technologies and the circular economy: a systematic literature review and a research agenda

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Digital technologies are widely recognised as crucial for promoting the circular economy in industry. However, there still needs for clearer guidance for industrial practitioners on properly using digital technologies to support the implementation of the circular economy. Further efforts are needed to characterise such a relationship better. This work conducts a systematic literature review aimed at understanding the nature and scope of the relationship by examining current knowledge at the intersection of the two domains, i.e. digital technologies and the circular economy. Specifically, the analysis focuses on identifying moderators and mediators of this relationship. About the former, the study discusses the relevance of management commitment, competencies, stakeholders and contextual factors; concerning the latter, the study discusses the relevance of supply chain integration and collaboration and examines in more detail the role of digital-enabled dynamic capabilities, given their promising relevance in the current debate. Based on the review, a research agenda is proposed with suggestions for future research directions on the relationship between digital technologies and the circular economy.

1. Introduction

The challenges of mitigating and adapting to climate change and digital transformation are the topics among scholars, practitioners and policymakers. The circular economy is a key policy strategy to reduce the environmental impact of society (Gupta et al., 2021); it is a systematic approach

(Chizaryfard et al., 2021; Susur and Engwall, 2023) and a paradigm shift (Moreno et al., 2019) from a traditional linear production and consumption mode to a circular one. The circular economy can be operationalised at different levels, namely, micro level (individual companies), meso level (industrial systems and networks) and macro level (society or country) (Kirchherr et al., 2017). Parallel to the debate on the circular economy is the discourse on Industry 4.0 as a strategic paradigm to further enhance industrial competitiveness, innovation and efficiency (Stentoft and Rajkumar, 2020). Digital technologies are key to the implementation of Industry 4.0 (Costa et al., 2023; Vimal et al., 2023), as they enable integrated, adapted, optimised and interoperable production processes while also facilitating connections among stakeholders (Upadhyay et al., 2021).

The implementation of circular economy and the digital integration in industries have been largely studied as stand-alone approaches. Still, the literature started to address them simultaneously, discussing the relationship between the adoption of digital technologies and the implementation of circular economy from a conceptual and an empirical perspective. Efforts are aimed at understanding if and how digital technologies in general (e.g. Hojnik et al., 2023; Wiegand and Wynn, 2023), or regarding a specific digital technology (e.g. Psihoyos et al., 2022; Rizvi et al., 2022), can support the implementation of circular economy in general (e.g. Huang et al., 2022; Okorie et al., 2023), or with a focus on practices, such as refurbishing (Assuad et al., 2022), recycling (Kintscher et al., 2020) or remanufacturing (Bag et al., 2021b).

The extant literature generally focuses on a direct relationship between the adoption of digital technologies and the implementation of circular economy (Dmitry et al., 2022; Talla and McIlwaine, 2022), that is, the assessment of the direct effect of the former on the latter (Aguinis et al., 2017); several literature reviews provide a comprehensive summary of the said direct effect (Atif, 2023; Spaltini et al., 2023; Toth-Peter et al., 2023). However, guidance for practitioners on using the wide range of available digital technologies to implement the circular economy remains unclear (Massaro et al., 2021). It is reasonable to assume that the relationship between digital technologies and circular economy could be influenced by factors that moderate (influence the nature of the effect of an antecedent on an outcome) or mediate (transmit the effect of the antecedent on the outcome) said relationship (Aguinis et al., 2017). Regarding the mediators, the literature identifies the pivotal role of dynamic capabilities, particularly those enabled by digital technologies, namely digital-enabled dynamic capabilities (Cherrafi et al., 2022; Neri et al., 2023a). To our knowledge, the literature is characterised by limitations and scattered contributions on mediators and moderators. The scarce focus could compromise the full understanding of the dynamics regulating the said relationship (Huang et al., 2022; Neri et al., 2022) and pose limitations to the understanding of the digital-enabled business transformation leading to the implementation of circular economy (Kristoffersen et al., 2020; Cagno et al., 2021).

Systematisation of the available information is urgently needed to distil the evidence from many studies into actionable insights. Despite the availability of several literature reviews on the relationship between digital technologies and circular economy (Skalli et al., 2022; Taddei et al., 2022; Voulgaridis et al., 2022; Toth-Peter et al., 2023), additional insights are needed (Chauhan et al., 2022), as none focuses on understanding the relationship and the related moderators and mediators, including digital-enabled dynamic capabilities. This work, based on a systematic literature review, aims to examine the relationship between the adoption of digital technologies and the circular economy implementation. We pose the following questions:

RQ1 What relationship links the adoption of digital technologies to the circular economy implementation?

RQ2 What factors moderate and mediate said relationship?

RQ3 What are the potential lines of future research to shed more light on said relationship?

In this article, therefore, we provide a detailed overview of the current knowledge base from which we derive still open questions for a proper understanding of the relationship between the adoption of digital technologies and the implementation of the circular economy. The review focuses specifically on the manufacturing sector, which is associated with key environmental impacts. The manufacturing sector also leads the way in circular economy implementation and digital technology adoption (Zamfir et al., 2017; Zangiacomi et al., 2020).

The remainder of the article follows. Section 2 describes the methodology employed for the systematic literature review. Section 3 provides a descriptive evaluation of the findings, while Section 4 provides a qualitative analysis of the emerging themes, offering an answer to RQ1 (Section 4.1) and RQ2 (Section 4.2). Section 5 discusses directions for future research, thus answering RQ3 and Section 6 concludes the article.

2. Methodology for the systematic literature review

For conducting the systematic literature review, we used the procedure by Tranfield and Denyer (2009) and Howard et al. (2017). For better clarity and transparency, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement as the backbone of our analysis (Liberati et al., 2009).

2.1. *Question formulation and source identification*

To answer the research questions posed, we combined keywords related to digital technologies and the circular economy. We relied on previous publications in the same field to identify keywords (e.g. Liao et al., 2017; Awan et al., 2021a; Cagno et al., 2021). We limited our search by focusing only on contributions published in English and published since 2017. The performed query thus follows: [TITLE-ABS-KEY ('circular economy') OR TITLE-ABS-KEY (circular) OR TITLE-ABS-KEY (circularity) AND TITLE-ABS-KEY (digital*) OR TITLE-ABS-KEY (digit*) OR TITLE-ABS-KEY ('industry 4.0') OR TITLE-ABS-KEY (i4.0)] AND PUBYEAR>2016 AND [LIMIT-TO (LANGUAGE, 'English')].

The keyword search of the Scopus database was performed on 21 June 2023. The Scopus database is considered appropriate as it is one of the major scientific databases (Gusenbauer and Haddaway, 2020) and the largest multidisciplinary database (Visser et al., 2021). We retrieved 4,379 contributions. We eliminated contributions for which relevant information needed to be provided (no author/title Information) ($n=235$), obtaining a set of 4,144 contributions considered for the source selection.

2.2. *Source selection*

According to the PRISMA methodology, the source selection process has three stages: screening, eligibility and inclusion (Moher et al., 2009). Each phase can be subject to bias due to personal selection. To increase the validity of the process, source selection was initially carried out separately by three of the authors of this study and the results were then compared to reach a common agreement (Thomé et al., 2016).

The screening phase is divided into a *Title Analysis* and an *Abstract Analysis*. The *Title Analysis* was performed by manual coding, and suggestions were made to exclude contributions considered irrelevant to the present research. Each contribution was assigned a code according to its content; where necessary, the number of codes was reduced by merging them according to associations, similarities and overlaps. To minimise bias, three authors independently categorised each contribution using their codes and later agreed on the specific terms to be used. At this stage, 3,712 contributions were excluded, mainly related to sectors other than manufacturing, such as *Construction* and *Agriculture*, focused on topics outside the scope of the research, such as *Medicine, Biological ecosystem, Electronics, signals and optics* or miscellaneous. Contributions focusing only on circular economy or digital technologies were considered out of scope. The same applies to contributions addressing only the macro level, as a region or country. In all, 432 contributions moved to the *Abstract Analysis*, after which 161 were excluded by applying the same reasoning as for the *Title Analysis*. An additional exclusion criterion was applied at this stage, as 16 contributions were not accessible to us, in line with Carrera-Rivera et al. (2022). After the screening phase, 271 contributions entered the eligibility phase.

Eligibility was assessed by *Full-text Analysis*, after which 102 contributions were eliminated, resulting in a set of 169 contributions. An additional exclusion criterion was introduced at this stage, as 14 contributions, though related to the topic, needed to provide more insights and implications to answer the research questions, in line with Carrera-Rivera et al. (2022). Following the suggestion of Heckathorn and Cameron (2017) and Page et al. (2021), we applied the snowball method to the set of 169 contributions. The snowball method suggests retrieving new contributions for analysis by examining the references and the citations of an initial set of contributions (Wohlin, 2014). Therefore, the method is considered interesting in complementing systematic literature reviews. Snowballing allowed for the identification of one additional contribution, namely Acerbi et al. (2021), resulting in 170 contributions in the literature analysis.

Figure 1 shows the complete list of codes related to the excluded and included contributions during the different phases.

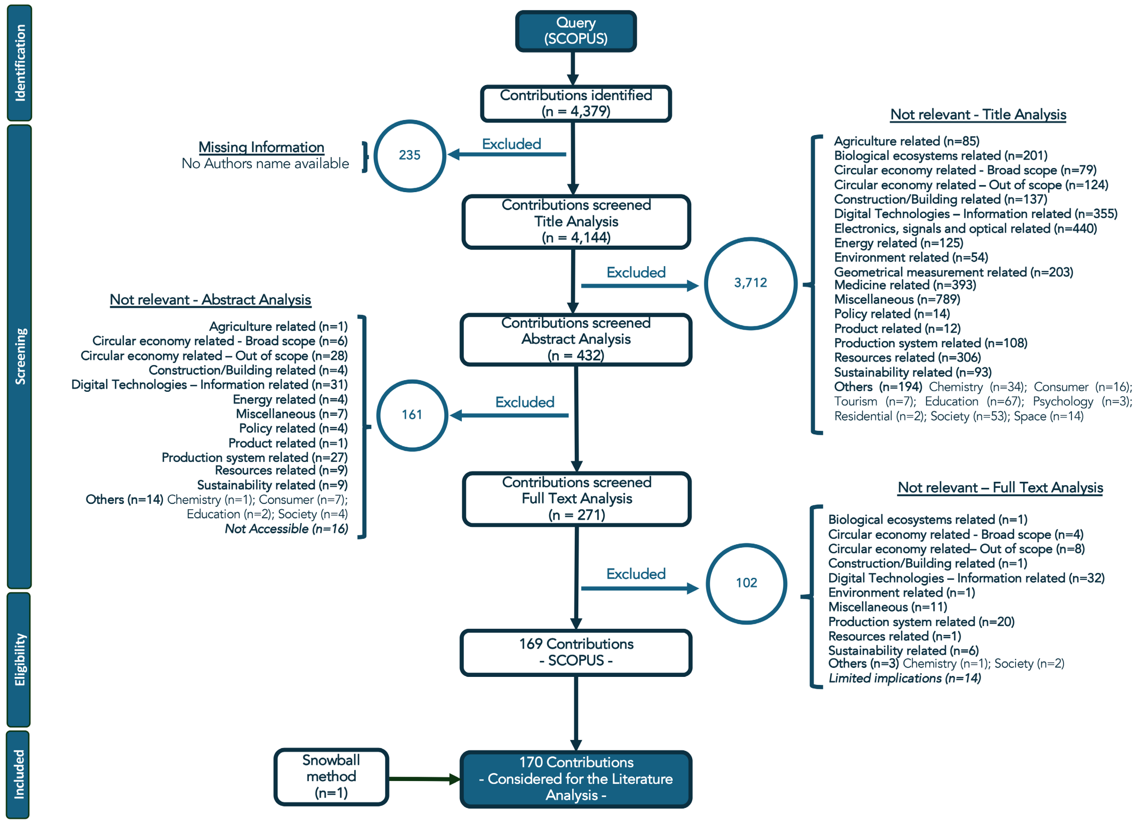

Figure 1. PRISMA methodology.

2.3. Source evaluation

The 170 contributions in the final set were analysed according to critical dimensions based on a content analysis (Engert et al., 2016). The following were considered: general information, context and content (see Maestrini et al., 2017; Neri et al., 2022). For the content analysis, we focused on the digital technologies and circular economy aspects that were considered. To coherently summarise the existing knowledge, we reconducted the digital technologies to the families proposed by Rüßmann et al. (2015) and Neri et al. (2023b), and the circular economy aspects to those proposed by Rosa et al. (2020) and Cagno et al. (2021), complementing them with additional entities emerging from the reviewed contributions. Table 1 shows the complete list of considered entities and their interpretation. The analysis is reported in Tables 2 and 3 for literature reviews and original contributions respectively. We complemented the source evaluation with the analysis of additional axes (see Appendices A and B): motivation and contribution, findings, limitations, future research, type of relationship, mediators and moderators and details on dynamic capabilities.

2.4. Data analysis and reporting

The analysis was carried out as a descriptive review to identify quantitative trends and a content analysis to identify emerging themes for a qualitative evaluation of the research findings. To increase the process validity, three authors carried out data analysis separately, and the results were then compared at a second stage until agreement was reached. The analyses helped to identify key messages and areas for further research.

3. Descriptive analysis

This section provides a descriptive analysis of the 170 contributions included in the final set according to the main axes of analysis presented in Section 2.3.

3.1. General information

The temporal distribution of the contributions underlines the growing interest in the topic (Figure 2), especially from 2021 onwards.

Most of the reviewed contributions are journal papers (84%; $n = 142$), while the rest are

Table 1. Circular economy aspects and digital technologies emerging from the reviewed contributions

		Interpretation	Supporting references
Circular economy aspects	Circular business model	'Business models cycling, extending, intensifying and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission out of an organisational system'	Geissdoerfer et al. (2020), Rosa et al. (2020)
	Circular design	Embedding circular economy principles into the design process	Moreno et al. (2016), Pinheiro et al. (2022)
	Circular manufacturing	'The concurrent adoption of different circular manufacturing strategies, which enable to reduce resources consumption, to extend resources life cycles and to close the resources loops, by relying on manufacturers' internal and external activities that are shaped in order to meet stakeholders' needs'	Acerbi and Taisch (2020, 2021)
	Circular procurement	Purchases of products or services that follow the principles of the circular economy	Khan et al. (2021b), United Nations Environment Programme (2021), Xu et al. (2022)
	Digital transformation	'Displacing resource use and delivering utility virtually'	Rosa et al. (2020), Cagno et al. (2021), Yuan and Pan (2023)
	Disassembly	The ability to access or remove certain components or assemblies from products to facilitate repair, remanufacture or reuse process	Venegas Vallejos et al. (2020), Rosa et al. (2020)
	Green manufacturing	The approach to the design and engineering activities involved in product development and/or system operation aimed at minimising the environmental impact	Deif (2011), Tang et al. (2022)
	Life cycle assessment	'It is a standardised (ISO 14,040–14,044:2006) and science-based methodology for assessing the impacts associated with the life cycle of a product or service, which can help understand the environmental implications of circular economy strategies'	Negri et al. (2021), Peña et al. (2021)
	Life cycle (thinking)	'The way of thinking that includes the economic, environmental and social consequences of a product or process throughout its life'	Rosa et al. (2020), Jacob-Lopes et al. (2021), Ertz and Gasteau (2023)
	Recover	The waste that is used as a source of energy or valuable biochemical compound	Kirchherr et al. (2017), Potting et al. (2017)
	Recycle	The waste materials are reprocessed into products, materials or substances for the original or other purposes, obtaining the same or lower quality	Potting et al. (2017), Rosa et al. (2020)
	Reduce	The use of fewer natural resources, e.g. energy, raw materials, water	Potting et al. (2017), Rosa et al. (2020)
	Refurbish	The restore of an old product bringing it up to date	Potting et al. (2017), Rosa et al. (2020)
	Regenerate	Regenerate and restore natural capital	Ellen MacArthur Foundation (2015), Gebhardt et al. (2022), Fernando et al. (2023)
	Remanufacture	The use of parts of a discharged product in another product with the same function	Potting et al. (2017), Rosa et al. (2020)
	Repair	The repair and maintenance of a defective product so it can be used with its original functions	Kirchherr et al. (2017), Potting et al. (2017)
	ReSOLVE	Regenerate, share, optimise, loop, virtualise, exchange	Ellen MacArthur Foundation (2015), Kouhizadeh et al. (2020)
	Resource efficiency	The creation of 'more (economic) value with less input of resources'	Hirschnitz-Garbers et al. (2013), Rosa et al. (2020)
	Reuse	The reuse of a discharged product that is still in good condition and fulfils its original function, by another or the same owner	Potting et al. (2017), Rosa et al. (2020)
	Reverse logistics	Operations related to reverse movements that take place in a supply chain, including the effective use of resources to handle product returns	Kirchherr et al. (2017), Rizvi et al. (2021), Fernando et al. (2023)
	Circular supply chain	The adoption of circular economy aspects in the context of a supply chain	Rosa et al. (2020), Cagno et al. (2021)
	Smart products and services, servitisation	'Platform-centred value creation systems that contain intelligent products and/or data-driven services and place the individual customer benefit at the centre of value creation'	Rosa et al. (2020), Deif (2011), Halstenberg et al. (2021)
	3Rs	Reduce, reuse, recycle	Ministry of the Environment Government of Japan (2004), Koksharov et al. (2019)
	9Rs	Refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle	Okorie et al. (2018), European Commission (2020)
	10Rs	Refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover	Kirchherr et al. (2017), Bag et al. (2021c)

(Continues)

Table 1. (Continued)

		Interpretation	Supporting references
Digital technologies	Artificial intelligence	'Development of systems that can perceive and interact with the environment in the form of text, video, audio and more through approaches such as speech, vision and natural language processing'. These systems 'can learn from the experience provided by historical data' and 'can accomplish similar tasks to humans while also performing parallel computing'	Bag et al. (2021a), Cannas et al. (2023), Praful Bharadiya (2023)
	Additive manufacturing	'Production of items directly from computer-aided designed models, with fabrication performed layering the material'	Guo and Leu (2013), Rüßmann et al. (2015), Cagno et al. (2021)
	Augmented reality	Use of digital tools to access virtual spaces superimposed on actual physical spaces through virtual information data	Rüßmann et al. (2015), Abari et al. (2017)
	Automation	'Industrial automation is the use of control systems such as computers, robots and other electronic devices to handle different processes and production tasks in a manufacturing environment'	Vaidya et al. (2018), Lu et al. (2022)
	Big data analytics	'Information assets characterised by high volume, velocity and variety, requiring specific technology and analytical methods for being transformed into value'	Rüßmann et al. (2015), De Mauro et al. (2016), Cagno et al. (2021)
	Business intelligence and analytics	Technologies and methodologies for acquiring useful information and analysing, and reporting data about an organisation's performance and operations and the market environment	Awan et al. (2021b), Praful Bharadiya (2023), Shiau et al. (2023)
	Cloud computing	'Architectural models enabling pervasive, convenient and on-demand network access to shared resources such as networks or servers'	Cagno et al. (2021), Mell and Grance (2011), Rüßmann et al. (2015)
	Cyber-physical systems	'Embedded systems that are distributed over several control units, communicate with each other and interact with their physical environment'	Geismann and Bodden (2020), Rosa et al. (2020)
	Cybersecurity and blockchain	Technologies, tools, guidelines and policies guaranteeing the protection of the cyber environment, allowing confidentiality, integrity and availability of data	Rüßmann et al. (2015), Schatz et al. (2017), Cagno et al. (2021)
	Data mining	Methods to analyse data to uncover patterns; the methods be applied to predict possible issues, find ways for improvements and make appropriate decisions	Hettiarachchi et al. (2022b), Baek and Doleck (2023)
	Digital platform	'Software-based external platforms consisting of the extensible code base of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate'	Tiwana et al. (2010), Del Vecchio et al. (2021)
	Digital product passport	Tool that contains information related to the entire life cycle of a product, from design to recycling	Adisorn et al. (2021), Plociennik et al. (2022b)
	Digital thread	'Digital thread describes an integrated systems engineering process that digitally manages the processes' – it is mainly used to support and create informed decisions in the acquisition and in the design phases	Ciano et al. (2021), Deng et al. (2021)
	Digital twin	'Digital replica, i.e. a virtual representation, of physical reality' – it is mainly used to support decisions in the operation and service phases	Ciano et al. (2021), Kayikci et al. (2022b), Saporiti et al. (2023)
	Information and communication technology	'Technological resources that include software, hardware and peripherals'	Hidalgo et al. (2020), Marodin et al. (2023)
	Internet of things	'Technologies allowing the interaction, cooperation, collection and exchange of data among people, devices, things or objects through the use of modern wireless telecommunications'	Rüßmann et al. (2015), Nasiri et al. (2017), Cagno et al. (2021)
	Horizontal/vertical systems integration	'Universal data integration network, enabling an automated value chain within or among firms by means of linking products, plants, manufacturers, customers, suppliers'	Rüßmann et al. (2015), Pérez-Lara et al. (2020), Cagno et al. (2021)
	Machine learning	Techniques that rapidly and intelligently manage big data and handle non-linear problems; machine learning is a subfield of artificial intelligence	Cannas et al. (2023), Praful Bharadiya (2023)
	Autonomous robots	Manufacturing systems 'able to operate completely autonomously, to interact with each other and to cooperate with human beings; sensors and control units allow the autonomous decision-making process and a symbiotic work with humans'	Rüßmann et al. (2015), Fragapane et al. (2020), Cagno et al. (2021)
	Simulation	'Real-time reflection of the physical world (products, machines, human beings) in virtual models, allowing testing and optimising systems before implementing the physical change'	Rüßmann et al. (2015), Rosa et al. (2020), Cagno et al. (2021)

Table 2. Content analysis of the analysed literature reviews

General information			Context		Content				
Authors and year	Journal	Document type	Geographical area	Sector	Circular economy aspects	Digital technologies	Years covered	Database	# Contributions reviewed
Pagoropoulos et al. (2017)	*Procedia CIRP*	CP			General	General	N.A.	SCOPUS, WOS	12
Okorie et al. (2018)	*Energies*	JP			General	General	2000–2018	SCOPUS	174
Cioffi et al. (2020)	*Applied Sciences*	JP			Circular business model	General	1985–2020	SCOPUS	31
Cwiklicki and Wojnarowska (2020)	*Engineering Economics*	JP			General	General	N.A.	WOS, SCOPUS, EBSCO, SD	32
Demestichas and Daskalakis (2020)	*Sustainability*				Reduce, reuse, recycle, recover	General	N.A.	SCOPUS, GS	63
Ghoreishi and Happonen (2020)	*Conference Proceedings*	CP			Circular design	Artificial intelligence	N.A.	N.A.	N.A.
Piscitelli et al. (2020)	*Procedia CIRP*	CP			Circular business model	General	2010–2020	SCOPUS, EBSCO, GS	78
Poschmann et al. (2020)	*Chemie Ingenieur Technik*	JP			Disassembly	Autonomous robots	January 1989–March 2019	Semantic scholar	178
Rosa et al. (2020)	*International Journal of Production Research*	JP			General	General	2000–2018	SCOPUS, WOS	158
Abideen et al. (2021)	*Sustainability*	JP			Circular business model, circular supply chain	Internet of things, big data analytics, blockchain, augmented reality, autonomous robots, machine learning, simulation, cloud computing, cyber-physical system	2010–2021	WOS	96
Acerbi et al. (2021)	*Conference Proceedings*	CP			General	Artificial intelligence	Until July 2020	N.A.	29
Acerbi and Taisch (2021)	*Conference Proceedings*	CP		Manufact.	Circular manufacturing	Information systems	N.A.	SCOPUS	236
Atif et al. (2021)	*Sustainability*	JP		Manufact.	General	General	2013–2021	SCOPUS, WOS, SD, Emerald	139
Awan et al. (2021a)	*Business Strategy and the Environment*	JP		Manufact.	General	Internet of things	2006–2019	SCOPUS, WOS	81

(Continues)

Table 2. (Continued)

General information			Context		Content				
Authors and year	Journal	Document type	Geographical area	Sector	Circular economy aspects	Digital technologies	Years covered	Database	# Contributions reviewed
Cagno et al. (2021)	*Applied Sciences*	JP		Manufact.	ReSOLVE, Life cycle (thinking), reuse, circular business model, digital transformation, disassembly, recycle, remanufacture, resource efficiency, smart products and services, servitisation, circular supply chain	Internet of things, big data analytics, cloud computing, cybersecurity and blockchain, horizontal/vertical systems integration, simulation, augmented reality, autonomous robots, additive manufacturing	2000–2021	SCOPUS	66
De Felice and Petrillo (2021)	*Sustainability*	JP			General	General	2006–2021	SCOPUS	104
Hettiarachchi et al. (2021)	*Conference Proceedings*	CP			Circular supply chain	Internet of things, big data analytics, cyber-physical system, additive manufacturing	N.A.	WOS	126
Lopes de Sousa Jabbour et al. (2021)	*Production Planning & Control*	JP		Food	General	General	Until October 2017	SCOPUS	52
Massaro et al. (2021)	*Business Strategy and the Environment*	JP			General	General	2007–2020	SCOPUS	369
Okorie et al. (2021)	*Sustainable Manufacturing*	BC			Remanufacture, refurbish	General	2010–2019	SCOPUS	N.A.
Ponis et al. (2021)	*Sustainability*	JP		Manufact.	General	Additive manufacturing	2014–2020	GS, SCOPUS	206
Rizvi et al. (2021)	*International Journal of Sustainable Engineering*	JP			Reversed supply chain	General	N.A.	SCOPUS, GS, WOS	63
Sassanelli et al. (2021)	*Journal of Manufacturing Systems*	JP		WEEE	Disassembly	Simulation	2000–2019	SCOPUS	63
Tavares-Lehmann and Varum (2021)	*Sustainability*	JP			General	General	Until 2020	WOS, SCOPUS	393
Tiwari et al. (2021)	*Sustainability*	JP	The UK	Electric motors	Recycle, reuse, remanufacture	General	2011–2021	SD, GS, SCOPUS	69
Trevisan et al. (2021b)	*Proceedings of the Design Society*	JP			General	General	Until February 2020	SCOPUS, WOS, SD, EBSCO, ProQuest	40

Table 2. (Continued)

General information			Context		Content				
Authors and year	Journal	Document type	Geographical area	Sector	Circular economy aspects	Digital technologies	Years covered	Database	# Contributions reviewed
Trevisan et al. (2021a)	*Procedia CIRP*	CP		Multiple	General	Internet of things, big data analytics, information and communication technology	Until September 2020	SCOPUS	7
Upadhyay et al. (2021)	*Journal of Cleaner Production*	JP			General	Blockchain	N.A.	WOS, SD, EBSCO, CrossRef	N.A.
Walden et al. (2021)	*Chemie-Ingenieur-Technik*	JP			General	Digital product passport	N.A.	N.A.	N.A.
Agrawal et al. (2022b)	*Business Strategy and the Environment*	JP		Logistics	General	General	2011–2020	SCOPUS	165
Agrawal et al. (2022a)	*International Journal of Productivity and Performance Management*	JP			General	General	N.A.	SCOPUS, WOS	126
Awan et al. (2022)	*Sustainability*	JP		Manufact.	General	General	N.A.	SCOPUS, WOS	79
Burmaoglu et al. (2022)	*International Journal of Productivity and Performance Management*	JP		Manufact.	General	General	N.A.	WOK	169
Chauhan et al. (2022)	*Technology Forecasting and Social Change*	JP			General	Artificial intelligence, machine learning, big data analytics, Internet of things, blockchain, cloud computing, augmented reality, cyber-physical system	2010–2021	GS, WOS, SCOPUS	123
Ertz et al. (2022)	*Industrial Marketing Management*	JP			Life Cycle (Thinking), Disassembly, Remanufacture, Reuse, Resource efficiency, Circular Supply Chain	Internet of things, big data analytics, additive manufacturing, artificial intelligence	2010–2021	Scopus, ABI/Inform, WOS, IEEE Xplore, PubMed, Taylor & Francis and others	131

(Continues)

Table 2. (Continued)

General information			Context		Content				
Authors and year	Journal	Document type	Geographical area	Sector	Circular economy aspects	Digital technologies	Years covered	Database	# Contributions reviewed
Gebhardt et al. (2022)	*International Journal of Production Research*	JP			Recycle, Remanufacture, Refurbish, Recover, Repair, Regenerate, Circular Supply Chain	Internet of things, additive manufacturing, cyber-physical system, machine learning, artificial intelligence, big data analytics, cloud computing, blockchain, process mining, simulation	Until 2022	SCOPUS, WOS, EBSCO	76
Ghoreishi and Happonen (2022)	*Conference Proceedings*	CP		Textile	Circular Business Model	Internet of things	N.A.	N.A.	N.A.
Hallioui et al. (2022)	*Journal of Cleaner Production*	JP			General	Artificial intelligence, blockchain, big data analytics, cloud computing	2005–2022	SCOPUS, WOS, SD and others	181
Happonen and Ghoreishi (2022)	*Conference Proceedings*	CP		Textile	General	General	2011–2021	SCOPUS	27
Hennemann Hilario da Silva and Sehnem (2022)	*Revista de Gestao*	JP			General	General	Until October 2020	SCOPUS, WOS	63
Hettiarachchi et al. (2022b)	*Operations Management Research*	JP			10Rs	Additive manufacturing, big data analytics, cloud computing, Internet of things, cyber-physical system, augmented reality, simulation, smart production and manufacturing, data mining	N.A.	WOS	414
Lei et al. (2022)	*Industrial Management and Data Systems*	JP			10Rs, ReSOLVE	27 digital technologies(all)	2011–2021	WOS	62
de Oliveira Neto et al. (2022)	*International Journal of Environmental Science and Technology*	JP			General	Cyber-physical system, big data analytics, Internet of things, cloud computing, autonomous robots, augmented reality, additive manufacturing, simulation, horizontal/vertical systems integration	Until 2019	WOS, Scopus, Emerald Insight, Capes, Wiley, SciELO, SD, ProQuest, Taylors & Francis	122
Patyal et al. (2022)	*Journal of Enterprise Information Management*	JP			ReSOLVE, circular supply chain, reuse, recycle, remanufacture, resource efficiency	Internet of things, big data analytics, cloud computing	2010–2020	SCOPUS	76
Rejeb and Appolloni (2022)	*Sustainability*	JP			Circular procurement	General	Until September 2022	SCOPUS, WOS	89

Table 2. (Continued)

General information			Context		Content				
Authors and year	Journal	Document type	Geographical area	Sector	Circular economy aspects	Digital technologies	Years covered	Database	# Contributions reviewed
Rejeb et al. (2022)	*Journal of Cleaner Production*	JP			General	Internet of things	2007–2021	SCOPUS, WOS	170
Sahu et al. (2022)	*Journal of Enterprise Information Management*	JP		Manufact.	General	General	2000–2020	SCOPUS, WOS, ProQuest, Google Scholar	204
Skalli et al. (2022)	*Conference Proceedings*	CP			General	General	2012–2021	SCOPUS	86
Taddei et al. (2022)	*Computers and Industrial Engineering*	JP		Industrial	General	General	2010–2021	SCOPUS	198
Voulgaridis et al. (2022)	*Computer Networks*	JP		Multiple	General	Internet of things	2016–2021	GS	79
Atif (2023)	*Business Strategy and Development*	JP			Digital transformation	General	2013–2022	Scopus, SD, Wiley, Taylors & Francis, Springer	126
Rusch et al. (2023)	*Business Strategy and the Environment*	JP			Circular business model, circular supply chain, ReSOLVE, life cycle assessment	Internet of things, big data analytics, blockchain, artificial intelligence	N.A.	SCOPUS	186
Spaltini et al. (2023)	*Conference Proceedings*	CP			General	General	2011–2021	SCOPUS	25
Toth-Peter et al. (2023)	*Journal of Cleaner Production*	JP			Circular business model	General	Until August 2022	ABI/INFORM, EBSCO, SCOPUS	76

The table reports the following: general information (authors, year, journal, document type, i.e. JP: journal paper; CP: conference paper; BC: book chapter); context (geographical area, sector); content (circular economy aspects, digital technologies, years covered, database, # contributions reviewed).
Abbreviations: GS, Google Scholar; SD, Science Direct; WOK, Web of Knowledge; WOS, Web of Science.

Table 3. Content analysis of the analysed original contributions

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Bianchini et al. (2018)	*Conference Proceedings*	CP			General	General	C/E		Examples from the literature	
Bressanelli et al. (2018)	*Procedia CIRP*	CP			Circular business model	Internet of things, big data analytics	E		Case study ($N = 1$)	Italian household appliances manufacturer SME
Lopes de Sousa Jabbour et al. (2018)	*Annals of Operations Research*	JP			ReSOLVE	Cyber-physical system, cloud computing, Internet of things, additive manufacturing	C		–	
Makarova et al. (2018)	*Conference Proceedings*	CP		Automotive	Reverse logistics	Big data analytics, horizontal/vertical systems integration	C		–	
Neligan (2018)	*Intereconomics*	JP	Germany		Resource efficiency	General	E		Survey ($N = 600$)	German manufacturing firms
Cezarino et al. (2019)	*Management Decision*	JP	Emerging economies		General	General	C/E	Structuralist method		Brazil
Charnley et al. (2019)	*Sustainability*	JP	UK	Manufact.	Remanufacture	Simulation	E		Semi-structured interviews ($N = 5$); DES	Automotive
Chauhan et al. (2019)	*Benchmarking: An International Journal*	JP			Resource efficiency, recycle, reuse, re-manufacture, refurbish	Cloud computing, additive manufacturing, autonomous robots, big data analytics	C		SAP-LAP	
Ingemarsdotter et al. (2019)	*Sustainability*	JP			Circular business model, life cycle (thinking), reuse, resource efficiency, remanufacture	Internet of things	C/E		Secondary material ($N = 40$)	
Nascimento et al. (2019)	*Journal of Manufacturing Technology Management*	JP		Manufact.	Circular business model	Internet of things, additive manufacturing	C		Focus group	

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Pham et al. (2019)	*Sustainability*	JP			Circular business model	Internet of things, cloud computing, cyber-physical system	C/E		Case study (N = 1)	Taiwanese electric scooter manufacturer
Bag et al. (2020)	*Resources, Conservation & Recycling*	JP			Circular procurement	General	E	DCV	PLS-SEM (N = 112)	South Africa
De Marchi and Di Maria (2020)	*Book Chapter*	BC			Resource efficiency, recycle	Autonomous robots, additive manufacturing, Internet of things, big data analytics, cloud computing, augmented reality	E		Survey (N = 1229)	Italian manufacturing SMEs
Dev et al. (2020)	*Resources, Conservation & Recycling*	JP			Reverse logistics, ReSOLVE	General	C		Taguchi's experimental design framework	
Ingemarsdotter et al. (2020)	*Resources, Conservation & Recycle*	JP			Circular business model	Internet of things	E		Case study (N = 1)	Large European LED lighting manufacturer
Kintscher et al. (2020)	*Journal of Communications*	JP			Recycle	General	C			
Kouhizadeh et al. (2020)	*Production Planning & Control*	JP			ReSOLVE	Blockchain	C		Examples from the literature	
Kravchenko et al. (2020)	*Conference Proceedings*	CP			General	Additive manufacturing	C		Examples from the literature	
Kristoffersen et al. (2020)	*Journal of Business Research*	JP		Manufact.	General	Internet of things, big data analytics	C		Examples from the literature	
Rajput and Singh (2020)	*Journal of Cleaner Production*	JP			Resource efficiency	General	C		MILP	
Rocca et al. (2020)	*Sustainability*	JP			Disassembly	Simulation, augmented reality, autonomous robots	E		Application in Lab (N = 1)	
Rossi et al. (2020)	*Sustainability*	JP			Circular business model	General	C/E		Examples from the literature	
Uçar et al. (2020)	*Procedia CIRP*	CP			Reuse, remanufacture, recycle	Internet of things, big data analytics, cloud computing, artificial intelligence	E		Case Study (N = 3)	Europe
Awan et al. (2021b)	*Technology Forecasting and Social Change*	JP	Czech Republic	Manufact.	General	Big data analytics, business intelligence and analytics	C/E	KBV; Organisational Learning	PLS (N = 321)	Employees

(Continues)

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Bag et al. (2021b)	*Production Planning & Control*	JP	South Africa		Remanufacture	Big data analytics, Internet of things, cloud computing, artificial intelligence	E	RBV	Survey (N = 120)	
Bag et al. (2021c)	*International Journal of Production Economics*	JP	South Africa	Manufact.	10Rs	General	E	DCV; PBV	Survey (N = 124)	
Bag et al. (2021a)	*Technology Forecasting and Social Change*	JP	South Africa	Automotive	General	Big data analytics, artificial intelligence	C/E	RBV	Survey (N = 219)	
Bag et al. (2021d)	*Journal of Cleaner Production*	JP	South Africa	Manufact.	General	General	C/E	RBV	Survey (N = 230)	
Bag et al. (2021e)	*Production Planning & Control*	JP	Africa	Manufact.	General	General	C/E	OIPT	PLS-SEM (N = 200)	
Bekrar et al. (2021)	*Sustainability*	JP		Transportation	Reverse logistics	Blockchain	C		–	
Briechle and Lawrenz (2021)	*Conference Proceedings*	CP			Life cycle (thinking)	Artificial intelligence, simulation	C		–	
Ciliberto et al. (2021)	*Business Strategy and the Environment*	JP		Manufact.	General	General	C		–	
Del Vecchio et al. (2021)	*International Journal of Innovation and Technology Management*	JP	Italy		General	Digital platform	C/E		Case study (N = 1)	Italian circular economy stakeholder platform
Deng et al. (2021)	*Conference Proceedings*	CP		Manufact.	Life cycle (thinking), remanufacture	Digital thread	C	Level-up circularity protocol		
Gupta and Singh (2021)	*International Journal of Logistics Research and Applications*	JP	India	Logistic	General	General	C		BMW	
Järvenpää et al. (2021)	*Management and Production Engineering Review*	JP	Finland	Manufact.	Circular supply chain	General	E		Semi-structured interviews; case study (N = 3)	
Kamble and Gunasekaran (2021)	*Production Planning & Control*	JP	India	Manufact.	General	General	C/E		SEM (N = 238)	Practitioners
Kazancoglu et al. (2021)	*Production Planning & Control*	JP			General	General	C/E		MCDM; case study (N = 1)	Logistics sector; Turkey
Khan et al. (2021b)	*Business Strategy and the Environment*	JP	China, Pakistan		Circular procurement, circular design, recycle, remanufacture	Blockchain	C/E	EMT; PBV	PLS-SEM (N = 404)	

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Khan et al. (2021a)	*Business Strategy and Development*	JP	Malaysia		Circular procurement, circular design, recycle, remanufacture	Blockchain	C/E	PBV	PLS-SEM ($N=239$)	
Khan et al. (2021c)	*Sustainability*	JP	Ecuador	Manufact.	General	General	C/E		CB-SEM, EFA, CFA; Survey ($N=214$)	Large private firms; Ecuador
Kintscher et al. (2021)	*Procedia CIRP*	CP			Life cycle (thinking), recycle	General	C/E		Case study ($N=1$)	Electric Vehicle battery
Kristoffersen et al. (2021a)	*International Journal of Production Economics*	JP			General	Big data analytics	C/E	RBV; ROV	PLS-SEM ($N=125$)	European senior managers
Kristoffersen et al. (2021b)	*Technology Forecasting and Social Change*	JP			General	Big data analytics	C	RBV, ROV	Semi-structured interviews	
Kumar et al. (2021)	*Production Planning & Control*	JP	India	Automotive	Circular supply chain	General	C		DEMATEL	
Laskurain-Iturbe et al. (2021)	*Journal of Cleaner Production*	JP	Europe, Asia, Africa, America		Reuse, recover, recycle, resource efficiency	Additive Manufacturing, artificial intelligence, big data analytics, cybersecurity and blockchain, Internet of things, autonomous robots, augmented reality	E		Survey (120) and case study ($N=27$)	Project managers
Magrini et al. (2021)	*Sustainability*	JP	Italy	Electrical and Electronic Equipment	Life cycle (thinking), reuse, disassembly, repair, resource efficiency	Internet of things, blockchain	E	Business model canvas	Case study ($N=5$)	
Mastos et al. (2021)	*Journal of Cleaner Production*	JP	Greece	Waste Management	Circular supply chain	General	E	ReSOLVE	Case study ($N=1$)	
Nandi et al. (2021)	*Sustainable Production and Consumption*	JP		Manufact.	General	Blockchain	C			
Ranta et al. (2021)	*Resources, Conservation & Recycling*	JP	North Europe		Circular business model	General	E		Case study ($N=4$)	
Sharma et al. (2021b)	*Journal of Enterprise Information Management*	JP	India	Agricultural	Circular supply chain	Blockchain	C	ReSOLVE	ISM, DEMATEL	

(Continues)

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Shayganmehr et al. (2021)	*Journal of Cleaner Production*	JP	Iran	Textile	General	General	C		IVFS, AHP	
Spaltini et al. (2021)	*Procedia CIRP*	CP		Manufact.	Recycle, remanufacture, resource efficiency, redesign	Additive manufacturing, cloud computing	C		MOILP	
Agarwal et al. (2022)	*Industrial Robot*	JP	India	Manufact.	General	General	C/E		Survey (N=46)	Experts in rubber production
Aldrighetti et al. (2022)	*International Journal of Production Research*	JP	Italy	Manufact.	Circular supply chain, reuse, recycle	Internet of things, big data analytics, cloud computing, horizontal/vertical systems integration, cybersecurity, cyber-physical system, additive manufacturing, autonomous robots, augmented reality, artificial intelligence	C/E	TBL	PLS-SEM (N=96)	Northern Italian manufacturing firms
Assuad et al. (2022)	*Procedia CIRP*	CP			Refurbish	Additive manufacturing, cyber-physical system	E		Application in lab (N=1)	
Bag and Pretorius (2022)	*International Journal of Organisational Analysis*	JP		Manufact.	General	General	C			
Belhadi et al. (2022)	*International Journal of Production Economics*	JP			General	General	C/E	DCT	GTA; case study (N=4)	North African firms (3 large and 1 SME)
Bressanelli et al. (2022)	*Sustainability*	JP		Manufact.	Reduce, reuse, remanufacture, recycle, life cycle (thinking)	Internet of things, big data analytics, artificial intelligence, 3D printing, blockchain, augmented reality	C			
Caterino et al. (2022)	*Journal of Manufacturing Systems*	JP			Remanufacture	Cloud computing, Internet of things	C		Bees algorithm, tabu search	
Çetin et al. (2022)	*Resources, Conservation & Recycling Advances*	JP	The Netherlands	Building	General	General	E		Case study (N=3)	Social housing organisations
Chari et al. (2022)	*Business Strategy and the Environment*	JP		Manufact.	General	General	C	DCV	Semi-structured interviews	

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Chaudhuri et al. (2022)	*Journal of Business Research*	JP		Plastic waste	Circular business model	Blockchain, additive manufacturing	C/E	RBV; organisation ambidexterity	Case study (N=4)	SME using blockchain
Cherrafi et al. (2022)	*TQM Journal*	JP			Circular supply chain	General	C	DCV; RBV; TBL	Semi-structured interviews	
de Mattos Nascimento et al. (2022a)	*Journal of Manufacturing Technology Management*	JP		Automotive	Recycle, circular supply chain	Additive manufacturing	C		Focus group	
de Mattos Nascimento et al. (2022b)	*Sustainable Production and Consumption*	JP			Recycle, reuse, rethink, remanufacture	General	C/E	Constructivist theory	Focus group (N=16); example from a real-life case (N=1)	3D printing recycling factory (case).
Di Maria et al. (2022)	*Business Strategy and the Environment*	JP	Italy	Manufact.	General	General	C/E		PLS-SEM (N=189)	Northern Italian firms
Dwivedi and Paul (2022)	*Technology Forecasting and Social Change*	JP	Bangladesh	Footwear	General	General	C/E		DEMATEL; survey (N=72)	
Edwin Cheng et al. (2022)	*International Journal of Production Research*	JP	India	Manufact.	General	Big data analytics	C/E	DCV	PLS-SEM and bootstrap med. analysis (N=320)	Medium and large Indian manufacturing firms
Elghaish et al. (2022)	*Construction Innovation*	JP			Circular supply chain, life cycle assessment	Internet of things, blockchain, artificial intelligence	C			
Godinho Filho et al. (2022)	*Sustainability*	JP			General	General	C	ReSOLVE	ISM-MICMAC	
Hettiarachchi et al. (2022a)	*International Journal of Production Economics*	JP			General	Additive manufacturing	C		Causal loop diagram	
Hirota et al. (2022)	*Procedia CIRP*	CP			Reuse	Digital platform, Internet of things	E		Case study (N=1)	Manager supervising the reuse of containers
Huang et al. (2022)	*Sustainability*	JP			General	Big data analytics, simulation, Internet of things, additive manufacturing, cloud computing	E	RBV	SEM-PLS (N=189); ANN	Manufacturing SMEs in Malaysia
Huynh (2022)	*International Journal of Productivity and Performance Management*	JP	Norway	Fashion	Circular business model	Internet of things, big data analytics, additive manufacturing, cybersecurity and blockchain	E		Case study (N=10)	

(Continues)

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Dmitry et al. (2022)	*Transportation Research Part E: Logistics and Transportation Review*	JP			Circular supply chain	Cloud computing, digital platform, blockchain, Internet of things, artificial intelligence	C/E		Case study ($N=3$)	Firms using cloud for their supply chain
Kayikci et al. (2022a)	*Business Strategy and the Environment*	JP			Circular supply chain	Blockchain	C		FCM-FBWM	
Kayikci et al. (2022b)	*Journal of Business Research*	JP			Circular supply chain	Big data analytics, Internet of things, additive manufacturing, augmented reality, digital twin, autonomous robots, cyber-physical system, artificial intelligence, blockchain	C/E		Delphi method; case study ($N=4$)	SMEs in the textile industry in Turkey
Kazancoglu et al. (2022)	*Environmental Science and Pollution Research*	JP		Dairy supply chain	General	Internet of things, artificial intelligence, big data analytics, additive manufacturing, machine learning	C		SWARA, TOPSIS	
Khan et al. (2022c)	*Sustainability*	JP	Europe	Automotive	General	General	E	RBV	SEM ($N=213$)	Firms operating in Ukraine, Poland and Romania
Khan et al. (2022b)	*Operations Management Research*	JP	China, Pakistan		Circular supply chain, circular procurement, circular design	General	C/E		SEM-PLS ($N=290$)	SMEs operating in the China – Pakistan corridor
Khan et al. (2022d)	*International Journal of Logistics Research and Applications*	JP	China, Pakistan	Manufact.	Circular supply chain	Cybersecurity and blockchain	C/E		SEM; survey ($N=290$)	
Khan et al. (2022a)	*Kybernetes*	JP	United Arab Emirates	Third-party logistics	Reverse logistics and general	General	C		Delphi technique, ISM-MICMAC	
Liu et al. (2022)	*Business Strategy and the Environment*	JP			9Rs	Internet of things, big data analytics, artificial intelligence	C			
Lopes de Sousa Jabbour et al. (2022)	*International Journal of Production Economics*	JP			Circular business model	General	C/E	RBV; complementary theory	PLS-PM ($N=132$)	Supply chain managers working for firms having business in Brazil

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Lu et al. (2022)	*Production Planning & Control*	JP			3Rs, circular supply chain	Internet of things, cloud computing, big data analytics, smart factories and devices, automation	C	DCV		
Oyinlola et al. (2022)	*Africa Journal of Management*	JP	Africa	Plastic	General	General	C/E		Case study ($N=3$)	
Patil et al. (2022)	*Sustainable Materials and Technologies*	JP		Home automation e-waste	Disassembly, remanufacture, reuse, recycle	Cyber-physical system	C			
Pinheiro et al. (2022)	*Business Strategy and the Environment*	JP	Brazil	Electronics	Circular design	General	C/E	Stakeholder theory	PLS ($N=142$); case study ($N=1$)	
Plociennik et al. (2022b)	*Conference Proceedings*	CP			General	Digital product passport	E		Survey ($N=19$)	10 manufacturers and 9 end of life responsible
Plociennik et al. (2022a)	*Procedia CIRP*	CP			General	Digital product passport, cloud computing	E		Case study ($N=1$)	Electrical and electronic equipment sector
Psihoyos et al. (2022)	*IOP Conference Series: Earth and Environmental Science*	JP	–	–	9Rs	Additive manufacturing	E		Secondary material ($N=27$)	
Rizvi et al. (2022)	*Energy Sources, Part A: Recovery, Utilisation and Environmental Effects*	JP	India	Automotive	General	Blockchain	C/E		Best–worst method. Survey ($N=45$)	Automotive; India
Stavropoulos et al. (2022)	*Procedia CIRP*	CP		Automotive	Remanufacture	Autonomous robots, artificial intelligence, machine learning, augmented reality, simulation	C/E		Case study ($N=1$)	Electric vehicles micro factory
Talla and McIlwaine (2022)	*Smart & Sustainable Built Environment*	JP		Waste	recycle, recover, reuse	General	C		Semi-structured interviews	
Tang et al. (2022)	*Environmental Science and Pollution Research*	JP			Recycle, remanufacture, green manufacturing; circular design	Blockchain	C/E	EMT; PBV	PLS-SEM ($N=330$)	Indian businesses with supply chain operations

(Continues)

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Wilson et al. (2022)	*Management of Environmental Quality*	JP			Reverse logistics	Artificial intelligence	C			
Wynn and Jones (2022)	*Sustainability*	JP	Europe	Multiple	Reduce, recycle, reuse, circular business model, repair, refurbish, remanufacture	Big data analytics, Internet of things, artificial intelligence, additive manufacturing, autonomous robots, blockchain, cloud computing, information and communication technology	C		Semi-structured interviews	
Yaqot et al. (2022)	*Computer Aided Chemical Engineering*	BC		Mining	General	Cyber-physical system, autonomous robots, Internet of things, artificial intelligence, information and communication technology	C			
Yu et al. (2022)	*Business Strategy and the Environment*	JP	China	Automotive	Circular procurement, circular design, remanufacture, recycle	General	C/E		SEM ($N=286$)	
Ali and Johl (2023)	*Journal of Manufacturing Technology Management*	JP		SMEs	General	General	E	Institutional theory; RBV	PLS ($N=228$); MGA	Chinese manufacturing SMEs
Ertz and Gasteau (2023)	*Helyion*	JP		SMEs	Life cycle (thinking)	Additive manufacturing, big data analytics, Internet of things, artificial intelligence	E		Semi-structured interviews ($N=9$ firms)	Canadian manufacturing SMEs
Faisal (2023)	*Journal of Enterprise Information Management*	JP			Circular supply chain	General	C/E	DCV	ISM; PLS-SEM ($N=137$)	Electronics sector; India
Findik et al. (2023)	*Journal of Cleaner Production*	JP	Europe	SMEs	ReSOLVE	Artificial Intelligence, cloud computing, autonomous robots, Internet of things, big data analytics, blockchain	E		Analysis of a European dataset ($N=15{,}404$)	European SMEs
Han et al. (2023)	*Sustainability*	JP			Life cycle (thinking)	Internet of things, big data analytics, cloud computing, artificial intelligence	C/E		Example from a real-life case ($N=1$)	Bike-sharing
Hojnik et al. (2023)	*Journal of Cleaner Production*	JP			General	General	E		Semi-structured interviews ($N=10$)	

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
Neri et al. (2023b)	*Business Strategy and the Environment*	JP		Manufact.	Resource efficiency, circular supply chain, reduce, refurbish, recycle, remanufacture, reuse, circular business model	Internet of things, big data analytics, cloud computing, cybersecurity and blockchain, horizontal/vertical systems integration, simulation, augmented reality, autonomous robots, additive manufacturing	E		Semi-structured interviews ($N = 11$)	Italian manufacturing SMEs
Neri et al. (2023a)	*Business Strategy and the Environment*	JP		Manufact.	General	Internet of things, big data analytics, cloud computing, cybersecurity and blockchain, horizontal/vertical systems integration, simulation, augmented reality, autonomous robots, additive manufacturing	E	DCT	Case study ($N = 11$)	Northern Italian industrial firms
Okorie et al. (2023)	*Resources, Conservation & Recycling*	JP			General	General	E	RBV	Workshop	
Prakash and Ambedkar (2023)	*Journal of Advances in Management Research*	JP		Manufact.	Circular business model	Cloud computing, Internet of things, additive manufacturing, blockchain, artificial intelligence, big data analytics, digital twin, cyber-physical system, autonomous robots, augmented reality	E		DEMATEL; interviews ($N = 9$)	
Romagnoli et al. (2023)	*Logistics*	JP			Circular supply chain	Artificial intelligence, Internet of things, simulation, machine learning	E		SEM-PLS ($N = 157$)	
Schöggl et al. (2023)	*Sustainable Production and Consumption*	JP	Austria	Manufact.	General	Internet of things, artificial intelligence, blockchain, big data analytics	E	RBV; ROV	Survey ($N = 132$)	Managers or CEOs working in manufacturing firms
Sharma et al. (2023)	*Journal of Cleaner Production*	JP			Reduce, recycle, reuse, rethink, recover	Internet of things, big data analytics, cloud computing, additive manufacturing, artificial intelligence, autonomous robots	E		SEM-PLS ($N = 162$)	

(Continues)

Table 3. (Continued)

General information			Context		Content					
Authors	Journal	Document Type	Geographical area	Sector	Circular economy aspects	Digital technologies	Study type	Theory	Methodology	Context of investigation
van Eechoud and Ganzaroli (2023)	*Journal of Cleaner Production*	JP			Circular business model	General	E		Case study ($N=7$)	
Wiegand and Wynn (2023)	*Sustainability*	JP	Germany	Textile and clothing	General	General	E		Secondary material and survey ($N=29$)	Textile and clothing; Germany (plus one UK); SMEs
Yuan and Pan (2023)	*Journal of Environmental Management*	JP			General	General	E	DCV	Mediation model on data from database ($N=486$)	Chinese industrial firms

The table reports the following: general information (authors, year, journal, document type, i.e. JP: journal paper; CP: conference paper; BC: book chapter); context (geographical area, sector); content (circular economy aspects, digital technologies, document type, i.e. C: conceptual; E: empirical; C/E: conceptual and empirical research, theory, methodology, investigation context).
Theory: DCV, dynamic capabilities view; DCT, dynamic capabilities theory; EMT, ecological modernisation theory; KVB, knowledge-based view; OIPT, organisational information processing theory; PBV, practice-based view; RBV, resource-based view; ROV, resource orchestration view; TBL, triple bottom line.
Methodology: AHP, analytic hierarchy process; ANN, artificial neural network; BMW, best–worst method; CFA, confirmatory factor analysis; DEMATEL, Decision-Making Trial and Evaluation Laboratory; DES, discrete event simulation; EFA, exploratory factor analysis; GTA, graph theoretic approach; IVFS, interval-valued fuzzy sets; ISM, interpretive structural modelling; MCDM, multiple-criteria decision making; MGA, multi-group analysis; MICMAC, cross-impact matrix multiplication applied to classification: MILP, mixed integer linear programming; MOILP, multi-objective integer linear programming; PLS, partial least squares; SEM, structural equation modelling; SWARA, stepwise weight assessment ratio analysis; TOPSIS, technique for order preference by similarity to ideal solution.
Context of investigation: SMEs, small- and medium-sized enterprises.

conference papers (15%; $n = 25$) and book chapters (about 2%; $n = 3$), namely De Marchi and Di Maria (2020), Okorie et al. (2021), Yaqot et al. (2022). Regarding the source of journal papers (Figure 3), the largest shares are in *Sustainability* ($n = 24$), *Business Strategy and the Environment* ($n = 14$), *Journal of Cleaner Production* ($n = 13$) and *Production Planning and Control* ($n = 8$). Therefore, the topic has been mainly addressed at the intersection of *Business, Management and Accounting* and *Environmental Science* subject areas (https://www.scimagojr.com). However, recently the topic has also started to be studied from more technical sources such as *Computer Networks* or *Computers and Industrial Engineering*, so from the perspective of the *Computer Science* subject area.

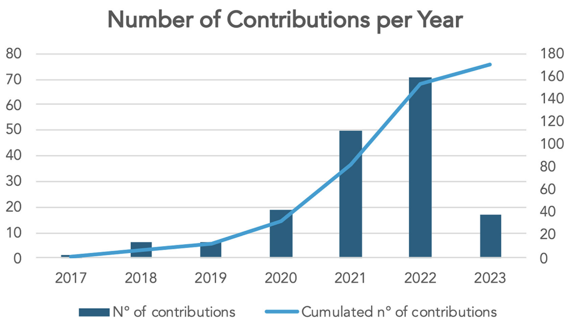

Figure 2. Temporal distribution of reviewed contributions.

3.2. Context

Most contributions (about 75%; $n = 129$) do not focus on a specific geographical region. However, there is a significant focus on Asia ($n = 14$), particularly India ($n = 7$) (e.g. Kamble and Gunasekaran, 2021; Agarwal et al., 2022), China and Pakistan ($n = 3$) (e.g. Khan and Yu, 2021; Khan et al., 2022b), Bangladesh, China, Malaysia, United Arab Emirates ($n = 1$, each) respectively, Dwivedi and Paul (2022), Yu et al. (2022), Khan et al. (2021c, 2022a) and towards Europe ($n = 15$), especially Italy ($n = 4$) (e.g. Del Vecchio et al., 2021; Magrini et al., 2021), Germany ($n = 2$), namely Neligan (2018) and Wiegand and Wynn (2023), Austria, Czech Republic, Finland, Greece, Norway, The Netherlands ($n = 1$, each), respectively, Schöggl et al. (2023), Awan et al. (2021b), Järvenpää et al. (2021), Mastos et al. (2021), Huynh (2022), Çetin et al. (2022). The manufacturing sector is addressed from a general perspective ($n = 34$) or with a focus on specific subsectors, such as automotive ($n = 8$) (e.g. Makarova et al., 2018; de Mattos Nascimento et al., 2022a), textile ($n = 4$) (e.g. Shayganmehr et al., 2021; Wiegand and Wynn, 2023) and food ($n = 2$), namely Lopes de Sousa Jabbour et al. (2021) and Sharma et al. (2021b). As for size, almost all contributions do not have a specific target, but a few studies specifically address small- and medium-sized enterprises (SMEs) ($n = 9$) (e.g. Ali and Johl, 2023; Findik et al., 2023), large ones ($n = 1$) (Ingemarsdotter et al., 2020) or medium and large ones ($n = 1$) (Edwin Cheng et al., 2022).

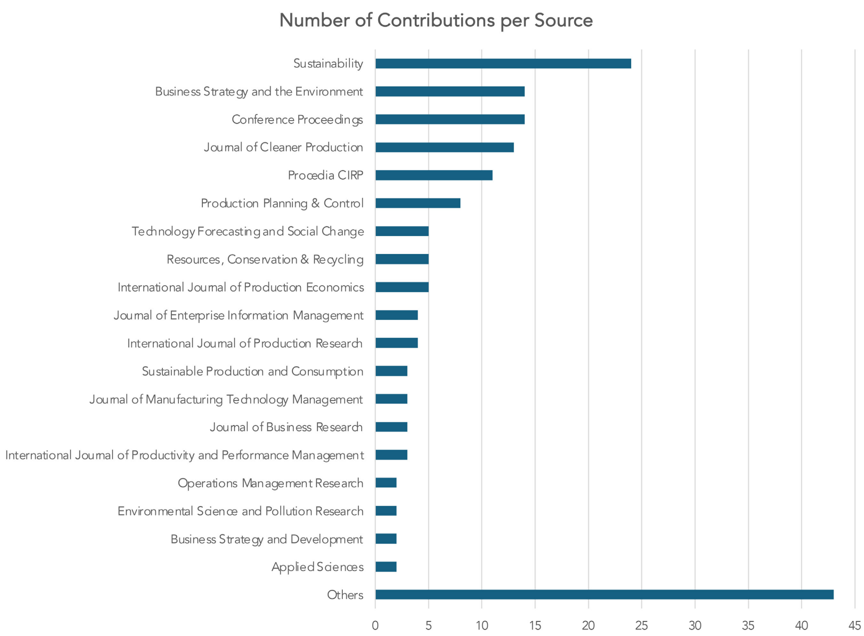

Figure 3. Distribution of the reviewed contributions according to their source.

3.3. Content

3.3.1. Digital technologies and circular economy

A consistent portion of contributions (46%; $n=78$) does not draw attention to specific digital technologies; rather, they address the topic from a general perspective. The most addressed digital technologies are the Internet of things ($n=49$) (e.g. Nascimento et al., 2019; Ingemarsdotter et al., 2020), big data and analytics ($n=42$) (e.g. Makarova et al., 2018; Edwin Cheng et al., 2022), artificial intelligence ($n=30$) (e.g. Briechle and Lawrenz, 2021; Wilson et al., 2022) and cybersecurity and blockchain, mainly regarding the blockchain ($n=25$) (e.g. Bekrar et al., 2021; Nandi et al., 2021). The result aligns with previous insights (Lei et al., 2022; Hettiarachchi et al., 2022b; Taddei et al., 2022). An overview of the digital technologies considered and their occurrence in the reviewed contributions is offered in Figure 4, while details are available in Tables 2 and 3.

A large share of contributions (45%; $n=77$) addresses circular economy from a general perspective. The mainly investigated aspects relate to remanufacturing ($n=24$) (e.g. Charnley et al., 2019; Caterino et al., 2022), recycling ($n=23$) (e.g. Kintscher et al., 2020, 2021), circular business models and circular supply chains ($n=22$, each) (e.g. Ranta et al., 2021; Dmitry et al., 2022; Prakash and Ambedkar, 2023; Romagnoli et al., 2023) and reuse ($n=20$) (e.g. Uçar et al., 2020; Hirota et al., 2022). The findings support Lei et al. (2022) and Taddei et al. (2022). An overview of the aspects of the circular economy considered and their occurrence in the reviewed contributions is offered in Figure 5, while details are available in Tables 2 and 3.

Focusing on the combination of digital technologies and circular economy aspects addressed, interesting insights emerge (Table 4). The combination 'General–General' shows the highest occurrence in the revised literature ($n=47$). Big data analytics ($n=13$), Internet of things ($n=12$), artificial intelligence, additive manufacturing, cybersecurity and blockchain ($n=6$, each) are largely considered in discussions involving a general focus on circular economy, e.g. respectively, Edwin Cheng et al. (2022), Kazancoglu et al. (2022), Bag and Pretorius (2022), Hettiarachchi et al. (2022a) and Nandi et al. (2021). On the other hand, recycling ($n=7$), circular business model ($n=8$) and circular supply chain ($n=6$) are the circular economy aspects more often coupled with a general focus on digital technologies, e.g. respectively, Kintscher et al. (2020), Rossi et al. (2020) and Faisal (2023). Combinations seem to mostly consider circular supply chain, remanufacture, recycling, reuse and resource efficiency, with the Internet of things, big data analytics, cybersecurity and blockchain, artificial intelligence, additive manufacturing and cloud computing (e.g. Ingemarsdotter et al., 2019; Khan and Yu, 2021; de Mattos Nascimento et al., 2022a). However, most combinations remained uncovered

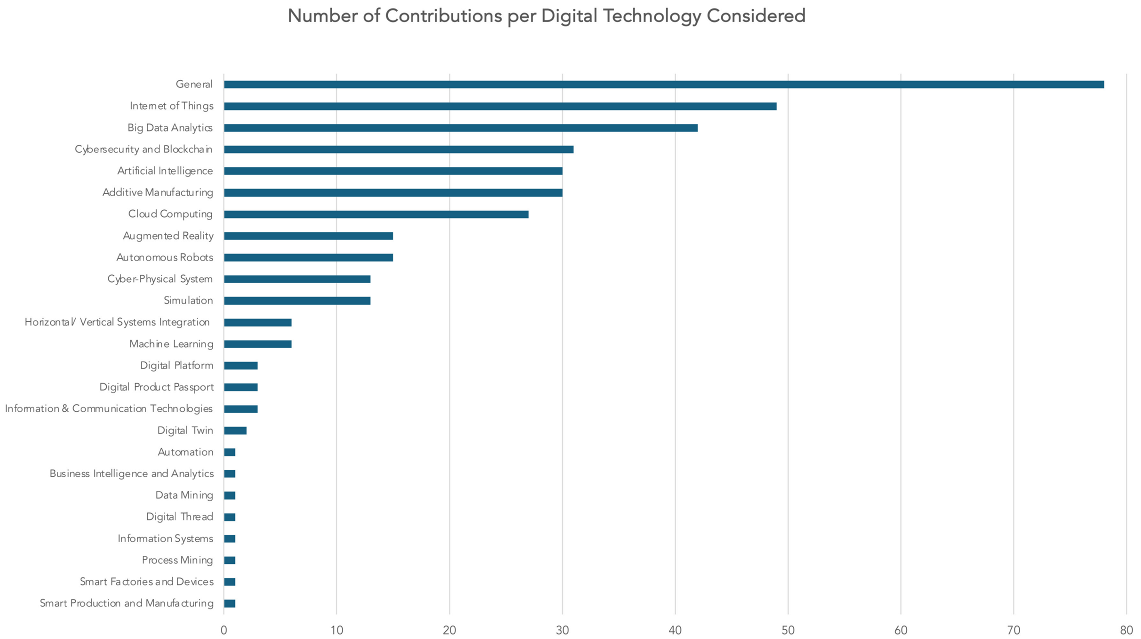

Figure 4. Distribution of the reviewed contributions according to the digital technologies considered.

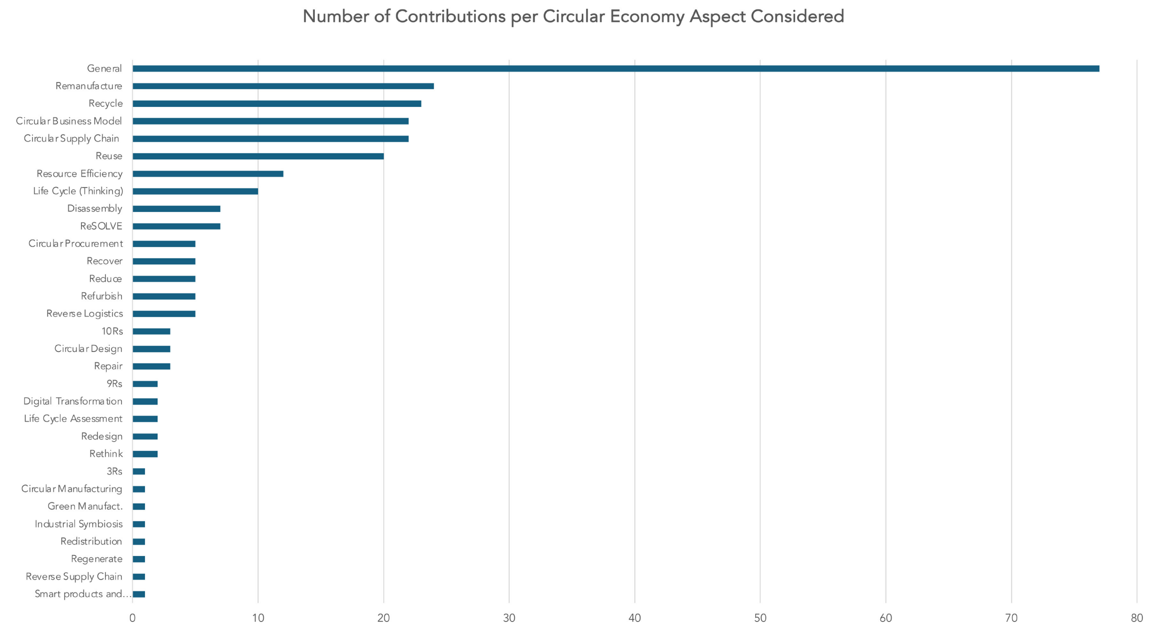

Figure 5. Distribution of the reviewed contributions according to the circular economy aspect considered.

by the existing literature (Table 4), leaving room for future contributions to the knowledge.

3.3.2. Types of relationship

Most of the revised contributions (85%; $n=144$) focus on a direct relationship and do not hint at possible moderators. A limited set (9%; $n=13$) considers a direct relationship influenced by the presence of moderators (e.g. Awan et al., 2021a; Oyinlola et al., 2022; Rejeb et al., 2022). A small set depicting a non-direct relationship focuses on the presence of mediators (6%; $n=10$) (e.g. Ranta et al., 2021; Di Maria et al., 2022; Gebhardt et al., 2022). Among this latter set, the digital-enabled dynamic capabilities seem to play an important role ($n=4$) (Kristoffersen et al., 2021b; Chari et al., 2022; Neri et al., 2023a; Yuan and Pan, 2023). Only one contribution considers the relationship as simultaneously moderated and mediated (Sharma et al., 2023). Details on the relationship considered by each contribution are reported in Appendices A and B.

3.3.3. Types of studies and methodologies used

Most contributions (56%) are theoretical, meaning both literature reviews ($n=54$) and conceptual contributions ($n=40$), aligned with Cagno et al. (2021). The remaining contributions are equally divided between pure empirical research ($n=38$) and conceptual/empirical research ($n=38$), that is, proposing a conceptual model or framework and then testing or validating it empirically (Murillo-Luna et al., 2011; Neri et al., 2018).

Qualitative and quantitative methods are employed. Focusing on the former ($n=44$), most contributions employ the case study method ($n=22$) (e.g. Bressanelli et al., 2018; Ranta et al., 2021), with limited use of other methods, such as the semi-structured interviews ($n=7$) (e.g. Cherrafi et al., 2022; Hojnik et al., 2023). Contributions applying a quantitative method ($n=47$) are mainly based on surveys ($n=11$) (e.g. Neligan, 2018; Bag et al., 2021b) and partial least squares regression ($n=21$) (e.g. Bag et al., 2020; Tang et al., 2022). A few contributions rely on mixed methods ($n=7$), such as a survey and case study (Laskurain-Iturbe et al., 2021) or partial least squares regression and case study (Pinheiro et al., 2022) or semi-structured interviews and discrete events analysis (Charnley et al., 2019). Results contrast Cagno et al. (2021), and two explanations are possible. On the one hand, research might have moved from an exploratory to a more descriptive domain as the topic became increasingly central in the current debate; on the other hand, the COVID-19 emergency could have made the case studies less practicable, possibly favouring the increase in the number of surveys. Focusing on the sample size, the average survey sample is 241 shreds of evidence, ranging from 19 (Plociennik et al., 2022b) to 1,229 (De Marchi and Di Maria, 2020). In contrast, the average partial least squares regression sample is around 219 pieces of evidence, ranging from 96 (Aldrighetti et al., 2022) to 404 (Khan et al., 2021b). As for contributions based on case studies, alone or in combination with other methods ($n=25$), almost half of them rely only on

Table 4. Combinations of digital technologies and circular economy aspects as emerged from the revised literature, with the details of their occurrence

		Digital technologies									
		General	Internet of things	Big data analytics	Cybersecurity and blockchain	Artificial intelligence	Additive manufacturing	Cloud computing	Augmented reality	Autonomous robots	Cyber-Physical system
Circular economy aspects	General	47	12	13	7	7	7	6	3	3	3
	Remanufacture	4	11	10	7	7	8	10	4	5	2
	Recycle	7	12	12	10	7	11	10	6	7	3
	Circular business model	8	14	9	9	4	7	6	4	5	3
	Circular supply chain	6	12	10	11	7	8	8	5	5	5
	Reuse	4	13	11	6	7	10	10	5	6	2
	Resource efficiency	2	9	8	4	2	7	4	4	4	
	Life cycle (thinking)	1	6	5	3	5	4	2	2	1	
	Disassembly		3	2	2	1	3	1	1	3	1
	ReSOLVE	1	6	5	5	3	3	4	2	3	2
	Circular procurement	4			2						
	Recover	2	3	3	2	3	3	2	1	1	1
	Reduce	1	4	4	3	3	4	3	2	3	
	Refurbish	1	3	4	3	2	5	4	1	3	2
	Reverse logistics	2		1	1	1					
	10Rs	1	2	2	2		2	2	2	2	2
	Circular design	3			3	1					
	Repair		3	2	3	2	2	2		1	1
	9Rs		1	1		1	1				
	Digital transformation	1	1	1	1		1	1	1	1	
	Life cycle assessment		2	1	2	2					
	Redesign	1					1	1			
	Rethink	1	1	1		1	1	1		1	
	3Rs		1	1				1			
	Circular manufacturing										
	Green manufacturing				1						
	Industrial symbiosis	1									
	Regenerate		1	1	1	1	1	1			1
	Reversed supply chain	1									
	Smart products and services, servitisation		1	1	1		1	1	1	1	

Darkest blue: more than 15 occurrences; dark blue: between 11 and 15 occurrences (included); medium blue: between 6 and 10 occurrences (included); light blue: between 2 and 5 occurrences (included); lightest blue: 1 occurrence.

a single case study ($n=11$) (e.g. Pham et al., 2019; Plociennik et al., 2022a), whereas few contributions conducted between 5 and 10 case studies ($n=3$) (Magrini et al., 2021; Huynh, 2022; van Eechoud and Ganzaroli, 2023) and more than 10 case studies ($n=2$) (Laskurain-Iturbe et al., 2021; Neri et al., 2023a). The average number of case studies conducted is 4.

4. Emerging themes

This section presents the principal themes that have emerged from the literature review. The literature has mostly analysed the relationship as a direct one, yet it also yielded interesting insights into the conceptualisation of a non-direct relationship and of possible mediators. The section provides an overview of the relationship between digital technologies and the circular economy, demonstrating how the former can support the implementation of the latter (Section 4.1). Previous contributions primarily focused on the role of individual digital technologies in facilitating the implementation of circular economy principles (Section 4.1.1). However, insights can also be gained from examining the potential synergies resulting from concurrently adopting multiple digital technologies (Section 4.1.2). The section then examines the role of moderators and mediators,

Simulation	Horizontal/vertical systems integration	Machine learning	Digital platform	Digital product passport	Information & communication technology	Digital twin	Automation	Business intelligence and analytics	Data mining	Digital thread	Information systems	Process mining	Smart factories and devices	Smart production and manufacturing
3	2	2	1	3	2			1						
5	2	2			1					1		1		
3	3	1			1							1		
3	2	1			1	1								
5	3	3	1			1	1					1	1	
2	3		1		1									
2	2													
2	1									1				
3	1													
2	2				2									
1		1										1		
1	1				1									
2	1	1			1							1		
	1													
2	2				1				1					1
1		1			1							1		
1	1													
		1					1						1	
											1			
1		1										1		
1	1													

moving from a discussion of both direct and indirect relationships (Section 4.2).

4.1. The relationship between digital technology adoption and circular economy implementation

4.1.1. Single digital technologies

Digital technologies have proved to support the effective implementation of a circular economy; see also Chauhan et al. (2022) and Dmitry et al. (2022). A set of main contributing digital technologies can be identified, namely the Internet of things, big data analytics, additive manufacturing and artificial intelligence (Lei et al., 2022; Taddei et al., 2022; Wynn and Jones, 2022). The main circular economy aspects relate to efficiency in resource use, remanufacture and circular design (Khan et al., 2021c, 2022b, 2022c; Pinheiro et al., 2022). The review suggests that efforts primarily focus on resource efficiency, as noted previously (Elia et al., 2020; Mura et al., 2020; Nudurupati et al., 2022). The most effective digital technologies for implementing a circular economy in manufacturing align with previous research. The Internet of things is recognised for its versatility (Atzori et al., 2017), and it is commonly integrated with artificial intelligence and big data analytics, allowing for automated control (Marcon et al., 2022). Additive manufacturing, while still limitedly adopted, has been shown to support various aspects of the circular economy, such as production management, resource use and design (Despeisse et al., 2017; Kamble and Gunasekaran, 2021; Neri et al., 2023b).

Digital technologies can strongly support the manufacturing sector's transition towards a circular economy in different sub-sectors (Neri et al., 2023b), such as electronics (De Felice and Petrillo, 2021; Magrini et al., 2021; Pinheiro et al., 2022), electric vehicles and battery manufacture (Kintscher et al., 2021; Stavropoulos et al., 2022) and textile (Kayikci et al., 2022b; Wiegand and Wynn, 2023). Table 5 reports the support offered by single digital technology to implement circular economy aspects, as emerged from the review.

4.1.2. *Concurrent adoption of digital technologies*

The concurrent adoption of various digital technologies can offer relevant support as well. It is indeed recommended to implement multiple digital technologies simultaneously rather than using them individually (Rusch et al., 2023).

Integrating digital technologies in digital ecosystems is valuable support for defining circular business models (Abideen et al., 2021; Elghaish et al., 2022), especially in the context of the supply chain (Ertz et al., 2022). Cyber-physical systems that integrate digital technologies can effectively manage the end of life of e-waste, supporting aspects related to remanufacturing, reuse, recycling and disassembly (Okorie et al., 2021; Patil et al., 2022).

The adoption of additive manufacturing, big data analytics, the Internet of things, artificial intelligence and automated robots can significantly enhance process efficiency by collecting and analysing real-time data (Ghoreishi and Happonen, 2022; Patyal et al., 2022). This is particularly true in the early stages of a product's life cycle, which can promote the development of a circular product (Rusch et al., 2023).

Integrating the Internet of things and artificial intelligence can improve resource efficiency and enhance product usage. The integration can also favour the disassembly and remanufacturing processes, thanks to learning techniques and big data processing (Agrawal et al., 2022b). Furthermore, it enables traceability (Abideen et al., 2021). Artificial intelligence and big data analytics support process innovation by analysing collected data (Liu et al., 2022) and providing solutions for various recycling paths (Bag et al., 2021a). The adoption of big data analytics, simulation and digital twin technology can aid in end-of-life management, specifically regarding recycling, reusing and remanufacturing, by assessing the evolution of product behaviours and characteristics (Briechle and Lawrenz, 2021; Tiwari et al., 2021; Edwin Cheng et al., 2022). Artificial intelligence and autonomous robots can optimise recycling operations (Elghaish et al., 2022). Additionally, their combination with simulation can support remanufacturing activities (Stavropoulos et al., 2022).

The combined adoption of the Internet of things and blockchain facilitates a transparent information flow throughout the product life cycle, promoting activities such as reuse, repair and recycling (Magrini et al., 2021; Huynh, 2022) and waste reduction (Neri et al., 2023b). Integrating cybersecurity and blockchain with other digital technologies or platforms is useful to enable secure data sharing among different stakeholders in the supply chain (Caterino et al., 2022; Dmitry et al., 2022).

4.2. *Moderators and mediators of the relationship*

4.2.1. *Moderators*

Organisational, technological and social factors moderate the relationship between adopting digital technologies and implementing a circular economy (Gupta and Singh, 2021; Kumar et al., 2021; Shayganmehr et al., 2021). The moderators identified include top management commitment (Kazancoglu et al., 2021), culture, training and educational activities (Bag et al., 2021c; Mastos et al., 2021), competencies such as digital (Rejeb et al., 2022), analytical (Kazancoglu et al., 2021), technical (Shayganmehr et al., 2021), and digitalisation (Sahu et al., 2022) skills. Another emerging moderator is the involvement of stakeholders, such as governments, customers and suppliers, already at the stage of strategy definition and decision making (Awan et al., 2021a; Hettiarachchi et al., 2022a; Sahu et al., 2022). Among stakeholders, multinational corporations can play a key role in fostering the relationship between digital technologies and circular economy in third-party enterprises, particularly start-ups and SMEs (Oyinlola et al., 2022). Research institutes and universities provide essential support by facilitating the adoption of digital technologies (Bag et al., 2021c).

The turbulent environment in which a firm operates, also referred to as 'industry dynamism' (Bag et al., 2021a), proved to moderate the effects of the concurrent adoption of big data analytics and artificial intelligence and circular economy implementation (Bag et al., 2021a). Also, the firm's size emerged as a significant moderator (Huang et al., 2022), as

Table 5. Support offered by single digital technologies to the implementation of specific circular economy aspects, as emerged from the review

		Digital technologies									
		Artificial intelligence	Additive manufacturing	Augmented reality	Big data analytics	Cloud computing	Blockchain	Horizontal/vertical systems integration	Internet of things	Autonomous robots	Simulation
Circular economy aspect	Circular design	[4] [18]	[5] [18] [31] [39]		[29]		[11] [21] [42]		[32]		
	Circular procurement	[13]					[22] [43]				
	Digital transformation – dematerialisation							[16] [41]			
	Digital transformation – servitisation								[5] [32]		
	Digital transformation – virtualisation			[5]							
	Disassembly			[18]	[3]			[1]		[18] [22] [40]	[36]
	End of life	[12] [13] [38]			[12]		[8]	[7]	[34]		[36]
	Life cycle (thinking)	[4] [18]	[14]		[2][15]		[19]				
	Optimisation of processes	[7] [29] [33] [35] [44]									
	Recovery		[23]						[23] [32]	[23]	
	Recycle		[17] [28] [31] [37]	[27]	[12]		[12] [13]	[1]	[10] [23] [33] [37]	[23] [25]	
	Refurbish						[12] [13] [14] [26] [45]				
	Remanufacture		[17] [28] [31] [37]		[2]				[10] [33] [37]		[40]
	Repair		[17] [28] [31] [37]				[14] [26] [45]		[10] [33] [37]	[47]	
	Resource efficiency	[23]	[9] [23]	[27]	[2] [15] [23]	[12]	[43]		[3] [5] [15] [23] [24]		
	Reuse		[17] [23] [28] [31] [37]		[12]		[14] [26] [45]		[10] [23] [33] [37]		
	Reverse logistics	[46]									
	Traceability					[30]					
	Waste management	[23]	[6] [23]	[23]			[8] [20]			[42]	

For each identified relationship, main supporting references are offered, specifically: [1] Acerbi and Taisch (2021), [2] Agarwal et al. (2022), [3] Awan et al. (2021b), [4] Awan et al. (2022), [5] Bressanelli et al. (2022), [6] Burmaoglu et al. (2022), [7] Chauhan et al. (2022), [8] De Felice and Petrillo (2021), [9] de Mattos Nascimento et al. (2022a), [10] de Oliveira Neto et al. (2022), [11] Elghaish et al. (2022), [12] Halliouі et al. (2022), [13] Hennemann Hilario da Silva and Sehnem (2022), [14] Hettiarachchi et al. (2021), [15] Hettiarachchi et al. (2022b), [16] Hirota et al. (2022), [17] Huynh (2022), [18] Kayikci et al. (2022b), [19] Kayikci et al. (2022a), [20] Khan et al. (2021c), [21] Khan et al. (2021b), [22] Kintscher et al. (2021), [23] Laskurain-Iturbe et al. (2021), [24] Lopes de Sousa Jabbour et al. (2021), [25] Lopes de Sousa Jabbour et al. (2022), [26] Nandi et al. (2021), [27] Oyinlola et al. (2022), [28] Patyal et al. (2022), [29] Pinheiro et al. (2022), [30] Plociennik et al. (2022b), [31] Ponis et al. (2021), [32] Rejeb et al. (2022), [33] Rizvi et al. (2021), [34] Rusch et al. (2023), [35] Khan et al. (2022d), [36] Sassanelli et al. (2021), [37] Spaltini et al. (2021), [38] Talla and McIlwaine (2022), [39] Tavares-Lehmann and Varum (2021), [40] Tiwari et al. (2021), [41] Trevisan et al. (2021a), [42] Trevisan et al. (2021b), [43] Upadhyay et al. (2021), [44] Voulgaridis et al. (2022), [45] Walden et al. (2021), [46] Wilson et al. (2022), [48] Wynn and Jones (2022).

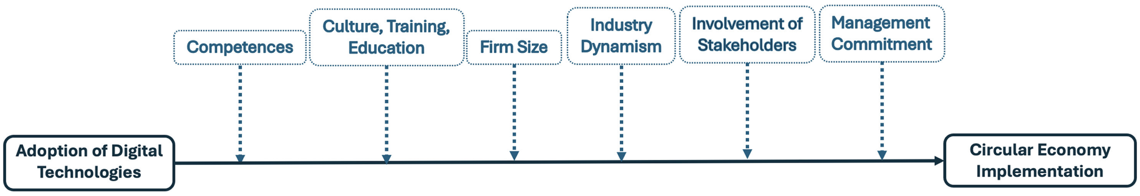

Figure 6. Moderators of the relationship between digital technologies and circular economy, identified according to the literature review. The moderators are reported in alphabetical order; the order does not indicate the relevance of the moderators.

larger firms possess greater resources to adopt digital technologies and are more likely to prioritise circular economy strategies (Ali and Johl, 2023). Figure 6 provides a snapshot of the identified moderators.

4.2.2. Mediators

Recent contributions explored the non-direct relationship between adopting digital technologies and implementing a circular economy, observing the presence of 'transitivity paths' (Godinho Filho et al., 2022) or mediators.

Di Maria et al. (2022) highlight the role of supply chain integration in mediating the relationship between smart manufacturing technologies, such as autonomous robots, additive manufacturing and augmented reality and implementing a circular economy through enhanced collaborations within and between companies. Yuan and Pan (2023) define this as 'supply chain dynamic capabilities'. According to Gebhardt et al. (2022), adopting digital technologies for information exchange and traceability can support collaboration among different partners, which is considered crucial for the circular economy. Additionally, Ranta et al. (2021) suggest that the adoption of digital technologies can increase efficiency, improve collaboration and optimise processes, thereby facilitating the implementation of circular business models. Sharma et al. (2023) propose that adopting digital technologies can enhance the implementation of a circular economy, with green logistics meant as sustainable transportation, promoting sustainable packaging and sharing of environmental information across the network, serving as a mediator.

Faisal (2023) asserts that adopting digital technologies can support dynamic capabilities related to servitisation, coopetition and knowledge and skills that, in turn, can enhance the circular economy performance of the supply chain. According to Kristoffersen et al. (2021a, 2021b), implementing a circular economy is mediated by the capability of business analytics, which emphasises the non-direct nature of the relationship with big data analytics. Similarly, Chari et al. (2022) and Neri et al. (2023a) suggest that digital technologies are essential for generating digital-enabled dynamic capabilities that ultimately lead to implementing circular economy practices.

The role of digital-enabled dynamic capabilities as a mediator emerged thus as a promising and important topic that requires further exploration and understanding (Kamble and Gunasekaran, 2021; Cherrafi et al., 2022; Okorie et al., 2023). Kristoffersen et al. (2021b) assert that big data analytics is crucial to developing a business analytics capability to implement the circular economy. According to Kristoffersen et al. (2021b), research has so far primarily concentrated on identifying the resources necessary for implementing big data analytics, not deepening the comprehension of how to cultivate the corresponding capability, which is indeed what facilitates the conversion of data into actionable insights. Kristoffersen et al. (2021a) further note that the business analytics capability is optional for implementing a circular economy. Still, it can help enterprises understand how to impact their investments in the circular economy significantly. Bag et al. (2021c) assert that dynamic capabilities are essential for implementing the 10Rs model. They further note that the mere presence of a resource is insufficient to influence an enterprise's performance; instead, how the practices are implemented has a more significant impact. Bag et al. (2021e) suggest that dynamic remanufacturing capabilities can be achieved through improved information flow and strategic control. This can result in enhanced visibility for better management of customer demand, increased agility and optimised processes, all of which can positively impact remanufacturing. Chari et al. (2022) argue that digital technologies can enable dynamic capabilities for communication, resources, technology and collaboration, all enabling the circular economy. Neri et al. (2023a) explore the potential of digital-enabled dynamic capabilities to facilitate the implementation of a circular economy through business transformations. Their study examines the sensing, seizing and transforming dynamic capabilities and offers insights into their micro-foundations.

Figure 7 provides a snapshot of the identified moderators.

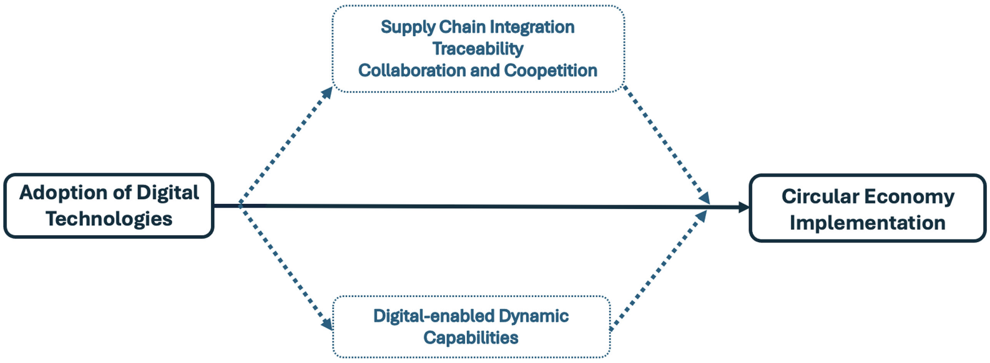

Figure 7. Mediators of the relationship between digital technologies and circular economy, identified according to the literature review.

5. Summary and future research directions

Based on the performed review, reflecting on current trends in research and practice, we identify and discuss current limitations and future research streams to investigate the relationship between digital technologies adoption and circular economy implementation.

While research has investigated the connection between digital technologies and the circular economy, a knowledge gap persists. Existing studies often adopt a general perspective, treating both digital technologies and circular economy practices as broad concepts (Table 4). This approach, while valuable for providing a foundational understanding, has limitations. It hinders our ability to explore how particular digital technologies can uniquely support specific circular economy practices and the requirements for successfully adopting these technologies or practices. Although recent efforts have addressed the earlier issues (Aldrighetti et al., 2022; Wynn and Jones, 2022; Sharma et al., 2023), additional holistic research is needed (Lei et al., 2022). Future research should investigate synergistic interactions between digital technologies and circular economy practices (Ertz et al., 2022; Hettiarachchi et al., 2022b). This focus on synergies can provide valuable insights to accelerate the transition towards a more circular economy through proper exploitation of innovation. Indeed, the simultaneous adoption of digital technologies also offers several potentials to foster the transition of companies towards the Industry 4.0 paradigm (Facchini et al., 2022); on the other hand, further efforts should simultaneously consider different aspects of the circular economy (Schöggl et al., 2023). Previous literature underlined the need for such a holistic approach (Chaudhuri et al., 2022; Dmitry et al., 2022; Tang et al., 2022). We therefore make the following suggestion for future research:

Future direction No. 1. Conduct a holistic investigation of the role of digital technologies in supporting the transition of the manufacturing sector to a circular economy.

The relationship between digital technologies and the circular economy is mainly addressed directly, with a limited focus on moderators. Furthermore, the non-direct relationship, particularly the role of mediators, must be more widely addressed. As Kamble and Gunasekaran (2021) suggested, further efforts should be focused on comprehensively understanding the factors that may influence the relationship.

Concerning moderators, the reviewed contributions consider the relevance of internal and external stakeholders (Awan et al., 2021a; Hettiarachchi et al., 2021) and competencies (Kazancoglu et al., 2021). However, the role of 'climates' as moderators is largely emphasised in the literature but not in the existing knowledge on the relationship between digital technologies and the circular economy. A climate is a shared perception of policies, practices and procedures characterising an organisation (Jiang and Probst, 2015). Several climates can be derived from the literature, such as the sustainability climate, which represents possible approaches to sustainability (Neri et al., 2021, 2022). Thus, it is possible that the digital and circular economy climate could moderate the relationship between digital technologies' adoption and circular economy implementation in manufacturing firms. Therefore, we make the following suggestion for future research:

Future direction No. 2. Identify the moderators of the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector and understand their influence.

In particular:

Future direction No. 2a. Understand the role of stakeholders in moderating the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector.

Future direction No. 2b. Understand the role of competencies in moderating the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector.

Future direction No. 2c. Identify the climates moderating the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector and understand their influence.

Regarding mediators, the reviewed contributions offered a limited investigation, focusing mainly on collaboration (Di Maria et al., 2022; Yuan and Pan, 2023), skills and procedures (Ranta et al., 2021; Sharma et al., 2023) and green logistics (Sharma et al., 2023). However, mediators must be identified to properly harness digital technologies' potential to support a circular economy, as suggested by Kamble and Gunasekaran (2021). We therefore make the following suggestion for future research:

Future direction No. 3. Identify the mediators of the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector and understand their influence.

Among the proposed mediators, digital-enabled dynamic capabilities play a relevant role (Awan et al., 2022; Chari et al., 2022). Dynamic capabilities allow enterprises to constantly reconfigure and renew operational capabilities (Ambrosini et al., 2009; Protogerou et al., 2012) to keep pace with a constantly evolving scenario. Internal and external organisational skills are adapted, integrated and reconfigured (Teece et al., 1997) through technological, organisational and strategic innovation (Helfat et al., 2007). Dynamic capabilities have been studied for quite some time (Winter, 2003; Teece, 2007; Ambrosini et al., 2009), but only recently have they been acknowledged as a driver for circular economy in the industry (Bag et al., 2021c; Köhler et al., 2022; Coppola et al., 2023). The discussion recently focused on how digital technologies can lead to digital-enabled dynamic capabilities (Teece, 2018; Roscoe et al., 2019; Yaqot et al., 2022). Khan et al. (2020a) and Santa-Maria et al. (2022) report on the impact of both technological upgrading and research and development on dynamic capabilities, and similar insights are provided by Khan et al. (2020b) and Belhadi et al. (2022). Considering the review's findings, the literature recognises the relationship between digital-enabled dynamic capabilities and circular economy implementation (Okorie et al., 2023). Despite the growing interest, the evidence currently available is scattered and fragmented. Contributions focus on selected digital technologies that enable a limited set of dynamic capabilities, such as Kristoffersen et al. (2021a, 2021b), or are based on the study of a limited context, such as Neri et al. (2023a). Consequently, there is a lack of clear guidance, especially for practitioners. Such guidance is needed to understand the most promising digital technologies in business transformation, allowing practitioners to allocate resources effectively. This is especially true in a scenario where enterprises, particularly SMEs, may be characterised by limited resources such as time, staff and money to dedicate to adopting digital technologies and implementing the circular economy (Ali and Johl, 2023). The categorisation of digital-enabled dynamic capabilities, their microfoundations and the mechanisms for their generation have not been extensively developed. Furthermore, the role of digital-enabled dynamic capabilities in influencing circular economy implementation has not been thoroughly explored. However, with further research and analysis, a clear and organised discussion can be developed. We therefore offer the following suggestion for future research:

Future direction No. 4. Investigate the role of digital-enabled dynamic capabilities as mediators of the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector.

As widely recognised (Bressanelli et al., 2022), collaboration with upstream, downstream, cross-industry and government stakeholders can be of support for both the adoption of digital technologies (Kayikci et al., 2022a) and the implementation of a circular economy (Negri et al., 2021; Cagno et al., 2023). However, the knowledge on this specific aspect is still limited, as also noted by Di Maria et al. (2022) and Oyinlola et al. (2022), calling for further research. Furthermore, drawing on Kristoffersen et al. (2021b), stakeholders' engagement in a transparent and collaborative environment is crucial to support enterprises in developing digital-enabled dynamic capabilities. Hence, stakeholders' involvement may influence the adoption of digital technologies and the generation of digital-enabled dynamic capabilities. We therefore offer the following suggestion for future research:

Future direction No. 5a. Investigate the role of stakeholders' engagement in the adoption of digital technologies.

Future direction No. 5b. Investigate the role of stakeholders' engagement in generating digital-enabled dynamic capabilities.

Empirical research is strongly recommended to explore all the above future directions, as it is generally lacking in the existing literature. Contributions dealing with the relationship between digital technologies and the circular economy are largely conceptual, such as Elghaish et al. (2022) and de Mattos Nascimento et al. (2022a): for this reason, many of these contributions call for empirical applications (see Skalli et al., 2022; Wynn and Jones, 2022; Rusch et al., 2023). Qualitative empirical research has been called for Yaqot et al. (2022), for which semi-structured interviews or case studies seem the preferred methods (Gupta and Singh, 2021; Aldrighetti et al., 2022). The need for additional quantitative empirical applications is also highlighted (Laskurain-Iturbe et al., 2021; Sahu et al., 2022), especially to obtain statistical validation (Bag and Pretorius, 2022). Among the possible methods, partial least squares regression emerges as promising (Khan et al., 2021a; Sharma et al., 2021a). We therefore make the following suggestion for future research:

Future direction No. 6: *Conduct qualitative and quantitative empirical investigations to deepen our understanding of the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector.*

The role of contextual factors should be considered when considering all the previous suggestions (Neri et al., 2021; Lopes de Sousa Jabbour et al., 2022). Contextual factors can influence the overall strategies of enterprises (Choudhury, 2016). The list of possible contextual factors is quite extensive. Still, for simplicity, it is possible to refer to the classification proposed by Sousa and Voss (2008), which considers four main factors: national context and culture, firm size, strategic context and other organisational variables, such as the specific sector in which the firm operates. Contextual factors should be duly considered to characterise the context studied (Aldrighetti et al., 2022; Huynh, 2022) and the existing literature offers suggestions for studying different countries and sectors (Bag et al., 2021e; Pinheiro et al., 2022) or the size (Çetin et al., 2022; Huang et al., 2022). We therefore make the following suggestion for future research:

Future direction No. 7. Understand the role of contextual factors in influencing the relationship between adopting digital technologies and implementing a circular economy in the manufacturing sector.

Figure 8 proposes a visualisation of the suggested future directions.

6. Conclusions

The article critically reviewed the extant knowledge on the relationship between adopting digital technologies and implementing a circular economy in manufacturing firms. The findings provide insights into the proper exploitation of innovation, in the form of Industry 4.0's digital technologies, to improve the industry's environmental impact in the circular economy.

We provided an overview of the current knowledge base, allowing for a comprehensive list of axes

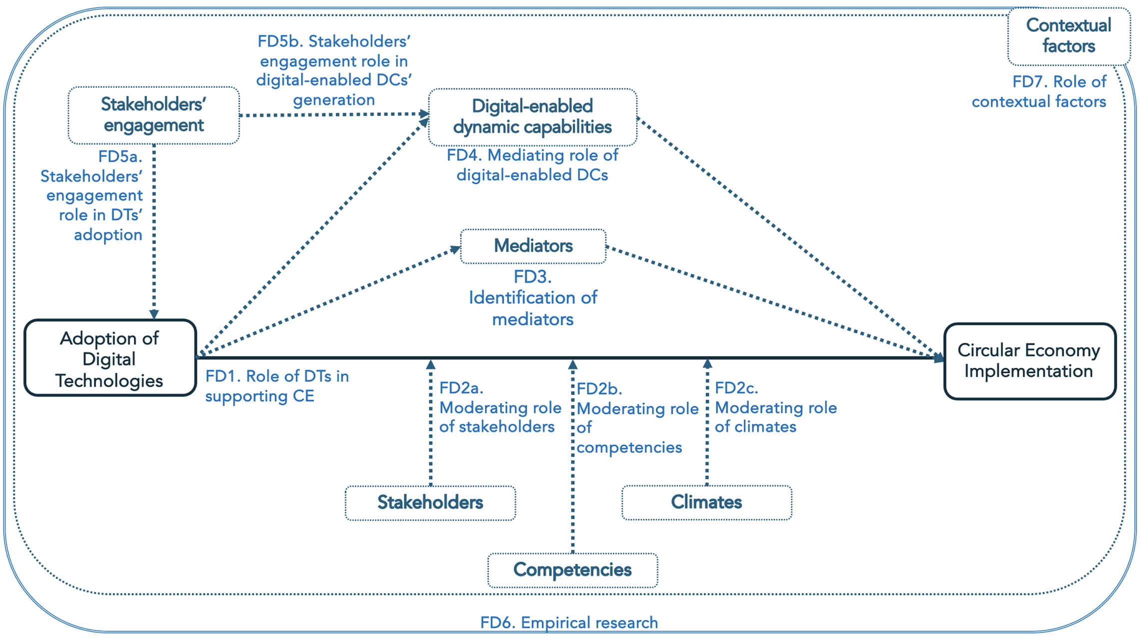

Figure 8. The suggested future directions.

for the analysis; such axes could be useful for academics and practitioners alike as a reference guide to continue exploring the topic, especially concerning moderators and mediators. As digital-enabled dynamic capabilities emerged as a relevant mediator, we recommend future studies to understand how adopting digital technologies helps adapt, integrate and reconfigure operational capabilities for supporting circular economy implementation.

We suggested seven streams for future research that we deem necessary to deepen the understanding of the relationship between digital technologies and the circular economy. We thus offer an interesting base for explanatory and descriptive qualitative research to properly assess the provided suggestions against applications characterised by different features and conduct quantitative research to provide a stronger generalisation of the results. While we think all the proposed research directions need investigation, it would not be feasible nor appropriate to tackle them together. We thus suggest first performing exploratory studies to understand better the possible relevance of the different factors in determining the relationship, moving then to explanatory or descriptive studies, and also providing statistical generalisability of the impact of moderators and mediators. After studying the dynamics taking place within a single firm (micro level), we suggest research to focus on supply chains and networks (meso level), to understand if said moderators and mediators still apply.

From a managerial standpoint, the study allows professionals to exploit digital technologies better to implement the circular economy. Practitioners can hint at how to properly configure the firm in which they operate to better exploit said relationship, favouring the presence of supporting moderators and mediators and the adoption of those digital technologies showing more potential for supporting the circular economy and enabling the most relevant dynamic capabilities.

We conducted our analysis following principles of ethics, quality and accuracy. Nonetheless, limitations should be highlighted. We employed only Scopus as the scientific research database and different findings might be obtained using other databases. The topic addressed is a current hot one in the managerial and academic debate, we expect the number of related contributions to constantly increase, and the specific time frame we used could have excluded some relevant recent contributions. Mediators and moderators were identified only through the analysis of the literature, they might not represent all the possible ones. Future research should tackle the above-mentioned limitations while also investigating the evolution of the topic and the proposed research streams.

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Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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APPENDIX A

Analysis of the literature reviews reviewed according to the following axes: motivation and contribution, findings, limitations, future research, type of relationship, mediators and moderators, details on dynamic capabilities

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Pagoropoulos et al. (2017)	Understand how digital technologies can support circular business models	Digital technologies support the circular economy transition by optimising material flow Overall, there is a dearth of empirical evidence	Limitations related to the method used	Provide empirical evidence	Direct	–	–
Okorie et al. (2018)	Understand the role of digital technologies in the transition towards circular economy	Proposal of a framework for integrating circular economy and digital technologies based on the technology life cycle	Limitations related to the method used	Focus more on the role of big data analytics. Investigate the role of stakeholders	Direct	–	–
Cioffi et al. (2020)	Understand what digital technologies can support circular business models	Innovative technologies enable circular economy, but a conscious innovation path is needed; despite the benefits, investments return times are long. Circular economy adoption needs managerial and legislative changes and can be eased by digital innovations	Limitations related to the method used	Consider the evolution of the academic interest on the topic	Direct	–	–
Cwiklicki and Wojnarowska (2020)	Understand the relationship between circular economy and Industry 4.0	Industry 4.0 can support the implementation of circular economy, especially regarding recycle and reuse strategies The most impacting digital technologies are Internet of things and big data analytics	Limitations related to blurred concepts of Industry 4.0 and circular economy	Understand the relationship at a supply chain level	Direct	–	–

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Demestichas and Daskalakis (2020)	Understand how digital technologies can pave the way for circular economy	The most popular digital technologies are those allowing data collection analysis (Internet of things, cybersecurity and blockchain, artificial intelligence) Barriers to the adoption of digital technologies for circular economy relate to consumer, costs, lack of education on circular economy, familiarisation with technologies	Limitations related to the method used	Focus on metrics to prioritise circular economy efforts	Direct	–	–
Ghoreishi and Happonen (2020)	Understand how artificial intelligence can accelerate the circular product design	Artificial intelligence can enhance business models that support circular economy, which are pivotal for the growth and competitiveness of the industries	Limitations related to the method used	Analyse the artificial intelligence's impact on different circular economy aspects Understand barriers to the adoption of Industry 4.0 and related benefits	Direct	–	–
Piscitelli et al. (2020)	Understand how digital technologies can unlock the circularity of resources	Circular economy and Industry 4.0 are closely linked. Technologies support circular economy in the ability to have more knowledge and in the monitoring of processes and products	Limitations related to the method used	N.A.	Direct	–	–
Poschmann et al. (2020)	Understand how autonomous robots can support disassembly process	Pre-defined processes and flexible automation are main research streams Ample possibilities for integrating the disassembly processes into a superordinate circular economy information system	Limitations related to the method used	Focus on the information processes and system concepts towards an autonomous disassembly system	Direct	–	–

(Continues)

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Rosa et al. (2020)	Understand the relationship between digital technologies and circular economy, focusing on the overlaps	Digital technologies positively impact the life cycle management of products and specific insights are dependent on the digital technologies considered	Limitations related to the method used	Provide empirical evidence	Direct	–	–
Abideen et al. (2021)	Understand how technologies are applied in current supply chains how they can support the creation of circular business model to gain a competitive advantage	The integration and implementation of different digital technologies have a direct and positive impact on the definition of circular business models. The main barriers for the implementation of circular business models are the weak collaboration among actors of the supply chain and lack of market governance	Only one database. Limitations related to keywords	Focus on machine learning algorithms for allowing the integration of digital technologies for circular supply chains	Direct	–	–
Acerbi et al. (2021)	Investigate how artificial intelligence is used to support the adoption of circular manufacturing strategies at the different scales of adoption (i.e. micro, meso, macro)	Artificial intelligence allows for tracking, analysing and using huge amount of data tailored to situations; the availability of data stimulates firms towards the implementation of circular manufacturing strategies. Artificial intelligence‘s benefits are identified as for micro, meso and macro levels	No distinction among different types of artificial intelligence	Explore synergies among firms Explore more in detail different circular manufacturing strategies	Direct	–	–
Acerbi and Taisch (2021)	Understand the role of different information systems in supporting the adoption of circular manufacturing	Available information systems contribute differently to the implementation of circular manufacturing. Three new generation information systems are identified by the study, whose integration with traditional information systems favour reuse, recycling and remanufacturing activities	Lack of empirical evidence	Tackle the mentioned limitations	Direct	–	–

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Atif et al. (2021)	Understand the role of digital technologies in the implementation of circular economy, being particularly concerned in the domain of servitisation business models	Digital technologies and circular economy enable each other's, for different aspects. As circular economy aims at extending the product life cycle and servitisation facilitates such purpose, coupling these two aspects can facilitate the sought transition	Few papers considered	Investigate factors enabling firms to grasp opportunities coming from digital technologies adoption, so to ease the barriers hindering the transition	Direct	–	–
Awan et al. (2021a)	Understand the support that Internet of things can bring for addressing circular economy challenges and supporting the adoption of circular economy practices	Leveraging on Internet of things, the data coming from the customer can support informed decisions and the identification of the best end-of-life strategy, leading to circular economy enhancement. Stakeholders' cooperation is a prerequisite	Only few digital technologies and circular economy practices are considered	Identify strategies to operationalise circular economy	Direct	Moderator: stakeholder collaboration	–
Cagno et al. (2021)	Need for a holistic view linking digital technologies to circular economy aspects for operationalisation purposes. Understand what has been addressed about the linkage digital technologies – circular economy – so to pave the way for future investigations, shaping the analysis around the ReSOLVE framework	Confirmation of the relevant role of digital technologies in enabling and supporting the circular economy transition. It may not be possible to adopt a digital technology without at least a partial presence of another one	Limitations on databases. Limitations related to timeframe	Empirical analysis (case studies) Characterise the relationship between digital technologies and circular economy	Direct	–	–

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APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
De Felice and Petrillo (2021)	Understand to what extent digital technologies can enable circular economy practices, how and in which areas they should be applied	Internet of things and cybersecurity and blockchain are the main technologies tackling waste and end-of-life management, while additive manufacturing favours the use of lower environmental impact products	Limited set of digital technologies considered	Investigate the evolution of supercomputers applications	Direct	–	–
Hettiarachchi et al. (2021)	Understand the intersection between Industry 4.0, circular economy, supply chain management and quantitative methods to provide insights into current trends and dynamics	Digital technologies foster the implementation of circular economy and the creation of sustainable supply chain	Query not provided	Not provided	Direct	–	–
Lopes de Sousa Jabbour et al. (2021)	Understand the state of art of circular economy practices adoption in supply chains (food loss) considering the adoption of digital technologies	Link between digital technologies adoption and ReSOLVE framework, highlighting the role that digital technologies could have in collecting information on the movement of goods in real time	Limitations related to the method used	Provide conceptual and empirical contributions on the reduction of food waste through circular economy practices	Direct	–	–
Massaro et al. (2021)	Understand how digital technologies can be exploited to foster circular economy in firms	Digital technologies support firms in creating new production models, introducing reuse and recycling actions. The main digital technology identified is the Internet of things	Low depth of analysis for both professional and scientific realities	Empirical analysis (case studies) to connect academic and practitioners' perspectives	Direct	–	–

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Okorie et al. (2021)	Understand the interactions between refurbishing and remanufacturing – two strategies for keeping resources in the loop and digital technologies	Cyber-physical systems, cloud computing, Internet of things and additive manufacturing are main enablers for refurbishment and remanufacturing strategies. Cyber-physical systems support cleaning, disassembly and inspection operations in remanufacturing	Limitations related to the method used	Identify the proper digital technologies for support refurbishment and remanufacturing activities	Direct	–	–
Ponis et al. (2021)	Understand the contribution of additive manufacturing in linear manufacturing paradigm to reach circular business models	Recycling, reuse, remanufacturing and repair can be performed through the help of additive manufacturing. Additive manufacturing can allow the configuration of closed loop supply chains	Limited number of papers considered	Focus on different digital technologies to understand how they assist supply chain operation	Direct	–	–
Rizvi et al. (2021)	Analysis of reverse logistics in the context of circular economy in terms of potential growth and development deriving from digital technologies application	The introduction of circular economy in companies' affairs needs an adequate support from big data analytics and the Internet of things to effectively perform the activities of data collection, data analysis and data integration	Limitations related to the method used	Understand the moderators of the relationship	Direct	–	–
Sassanelli et al. (2021)	Understand how simulation is used to facilitate disassembly processes with the aim of implementing circular economy strategies	Identification of eight areas as for the supporting role of simulation to circular economy-driven disassembly purposes	Limitations related to the method used	Adopt a sector-independent approach, focusing on different life cycle stages of goods	Direct	–	–

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APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Tavares-Lehmann and Varum (2021)	Understand the link between digital technologies, circular economy and sustainability	Focus on the effect that big data analytics, cloud computing, artificial intelligence and the Internet of things have on circular economy practices at different stages of the product life cycle	Limitations related to the method used	Need for a large dataset on the implementation of digital technologies and circular economy practices Consider the influence of policymakers	Direct	–	–
Tiwari et al. (2021)	Understand how to develop a circular economy capability, focusing on the need for proper end-of-life management in the electric motors' sector, also understand the role of digital technologies	Digital technologies can foster recovery value activities	Limitations on the process for digital technologies selection	Deepen the understanding of the support offered by digital technologies	Direct	–	–
Trevisan et al. (2021b)	Understand main research streams connecting digital technologies and circular economy practices, suggesting future research	The research streams identified are Industry 4.0, business and sustainability. The digital technologies considered are Internet of things, autonomous robots, big data analytics and cybersecurity and blockchain	Limited set of digital technologies considered	Focus on coordination between companies and stakeholders to design circular solutions Include the social pillars in circular business models	Direct	–	–

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Trevisan et al. (2021a)	Understand what circular economy practices are adopted in business ecosystems using the Internet of things and big data analytics	Identification of eight cases of business environments adopting circular economy practices through the help of digital technologies. Identification of four levels of adoption of circular economy actions according to the degree of dependence on digital technologies	Limited set of digital technologies considered	Focus on other digital technologies	Direct	–	–
Upadhyay et al. (2021)	Understand the effect of cybersecurity and blockchain on sustainability and social responsibility	Cybersecurity and blockchain allows waste reduction and efficiency, reducing the carbon footprint. Cybersecurity and blockchain facilitates the implementation of other digital technologies as the Internet of things, 3D printing and additive manufacturing and allows stakeholders to share and co-create data in a transparent manner	Lack of empirical analysis	Provide quantitative evidence on the link Focus on developing countries	Direct	–	–
Walden et al. (2021)	Understand the role of digital technologies and digital product passport in enabling circular economy practices	Digital technologies are enablers for circular economy and for upscaling the circular economy. Cybersecurity and blockchain, the Internet of things and digital twins are crucial for tracking and tracing components and products, useful to foster reuse, repair and refurbishment activities	Limitations related to the method used	Understand the impact of digital product passport on digital circular economy, including the entire value chain and the main stakeholders	Direct	–	–

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Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Agrawal et al. (2022b)	Development of a research framework for smart and circular supply chains for integrating digital technologies and circular economy practices	Digital technologies integrated in logistics activities can improve remanufacturing capabilities. The role of industrial practitioners and relevant stakeholders is investigated to foster the implementation of circular economy initiatives	A deep understanding of the integration between Industry 4.0 and circular economy misses	–	Direct	–	–
Agrawal et al. (2022a)	Understand the potentialities offered by circular economy as for sustainable business performance in the era of digitalisation	The adoption of digital technologies can foster the implementation of different circular economy practices, with a positive effect on the sustainable business performance, and develop business models with reuse and recycling activities	Lack of supporting framework	Develop the framework	Direct	–	–
Awan et al. (2022)	Understand the integration between Industry 4.0 and circular economy under the perspective of value chain activities design and management	Classification of supporting activities for circular business models. Stakeholder collaboration can lead to the development of capabilities to create more sustainable products and services. Infrastructure must be upgraded so to manage new information flows and resources correctly	Only two databases. Limitations related to keywords	Understand the possible role as mediators of the relationship between infrastructure planning and circular economy Examine stakeholders' role in embracing circular business models	Direct	–	–
Burmaoglu et al. (2022)	Identification of four areas at the intersection between digitalisation and circular economy, explored in detail as per their impact in the manufacturing scenario	Identification of four areas at the intersection of digital technologies and circular economy: sharing economy, additive manufacturing, digital business models; industrial ecology and remanufacturing	Limitations on databases. Limitations related to keywords	Empirical analysis using case studies	Direct	–	–

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Chauhan et al. (2022)	Development of a framework to understand how digital technologies operationalise the shift towards circular economy	Digital technologies can support circular economy mainly thanks to the massive quantity of data that are generated and processed; digital technologies adoption can be fostered or guided thanks to institutional pressures	Limitations on databases	Tackle the limitations	Direct	–	–
Ertz et al. (2022)	Understand how different digital technologies can extend the product lifetime, focusing on the characteristics of digital technologies for product lifetime extension	Emerging technologies allows product lifetime extension in every stage of the life cycle of goods. Digital technologies are currently more adopted in the middle stages of the product life cycle, while they are less adopted in the design and recovery parts	Only the Internet of things, big data analytics, artificial intelligence and additive manufacturing are cited for the product lifetime extension	Focus on the role of additive manufacturing, cyber-physical systems and the Internet of things in product design and recovery, understanding how digital technologies can contribute to product lifetime extension	Direct	–	–
Gebhardt et al. (2022)	Understand the current knowledge concerning the support that digital technologies provide in the collaboration mechanism of circular supply chains	Identification of three archetypes of Industry 4.0-enabled circular supply chain collaboration: digitally enabled circular supply chain information sharing system; digital circular supply chain collaboration platforms; digitally enabled system for collaborative circular flow decision	No empirical validation of the framework proposed	Circular supply chain collaboration mechanisms and digital technologies should be addressed for assessing their relative importance and interconnectedness	Non-direct	Mediators: collaboration	-

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Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Ghoreishi and Happonen (2022)	Understand the role of digital technologies (especially the Internet of things) in enabling circularity to maximise the product value in the fashion industry	The Internet of things is fundamental to adopt circular economy practices. The integration of the Internet of things with other digital technologies (especially big data analytics and artificial intelligence) is fundamental to support the decision making about circularity	Lack of a conceptual framework. Lack of empirical validation	Investigate the barriers hindering the implementation of digital technologies for circular economy	Direct	–	–
Hallioui et al. (2022)	Understand how digital technologies and circular economy are investigated in the extant literature from a contemporary business management perspective	Analysis of four digital technologies (cybersecurity and blockchain, cloud computing, artificial intelligence and big data analytics) as for their impact of circular economy implementation	No detail investigation of circular economy aspects	Perform empirical studies leveraging on artificial intelligence, cybersecurity and blockchain, cloud computing and big data analytics as enablers of circular economy	Direct	–	–
Happonen and Ghoreishi (2022)	Understand the digitalisation opportunities for the textile industry, particularly focusing on digital technologies that can accelerate and promote the necessary closing of the loop sought by circular economy	Digital technologies and circular economy in the textile sector are still far from being implemented	No identification of the relationship between digital technologies and circular economy	Properly characterised the relationship between digital technologies and circular economy	Direct	–	–

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Hennemann Hilario da Silva and Sehnem (2022)	Understand opportunities in terms of adoption digital technologies for circular economy	The creation of cyber-physical environment, using different digital technologies, allows the collection and analysis of real-time data, improving the decision-making process, favouring the transition from linear to circular model	Limitation related to the method used	Investigate the relationship between Industry 4.0 and clean production in manufacturing Examine the role of cybersecurity and blockchain, big data analytics and additive manufacturing in supporting optimisation of supply chain and circular economy activities	Direct	–	–
Hettiarachchi et al. (2022b)	Understand the current knowledge at the intersection of digital technologies and circular economy	Additive manufacturing, big data analytics and the Internet of things are the most discussed digital technologies: big data analytics mostly in relation to closed loop supply chains; additive manufacturing with LCA and spare parts topics; the Internet of things mainly with waste management	Limitations on database	Explore more the relationship between least discussed digital technologies and circular economy	Direct	–	–

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APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Lei et al. (2022)	Social network analysis combining digital technologies with circular economy practices, highlighting their link considering a single digital technology or the integration of multiple technologies	The most implemented digital technologies and circular economy practices are mentioned. The Internet of things, additive manufacturing, big data analytics and artificial intelligence are defined as the basic digital technologies to enable the most adopted circular economy practices. A consideration on the investment needed to implement digital technologies is made, focusing on the possible difficulties that small- and medium-sized enterprises could have	Limitations related to the method used	Perform empirical research to enable a quantification of the impacts of the relationships. Understand how to integrate different digital technologies	Direct	–	–
de Oliveira Neto et al. (2022)	Analysis of the impact of each digital technologies' adoption on circular economy and eco-efficiency targets	The Internet of things and horizontal/vertical systems integration are the most used digital technologies. Circular economy practices such as reuse, recycling and remanufacturing can benefit from the adoption of the Internet of things, with further improvements if coupled with artificial intelligence	Limited set of circular economy practices considered	Include both developed and developing countries in the analysis; include different industrial sectors	Direct	–	–
Patyal et al. (2022)	Understand the linkages between digital technologies, circular economy practices and sustainable development goals	Digital technologies support the objective of the ReSOLVE model leading to the adoption of circular economy practices. Big data analytics and the Internet of things help in collecting and managing real-time data of specific operations. Additive manufacturing allows to exploit its remanufacturing potentialities	Limitations on database Lack of empirical analysis	Tackle the limitations. Support the presented framework with surveys and case studies	Direct	–	–

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Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Rejeb and Appolloni (2022)	Understand the role of digital technologies in the transition towards circular procurement	Digital technologies act as a catalyst for circular procurement. The following seem to play a relevant role: big data analytics; blockchain; the Internet of things; simulation; cloud computing; additive manufacturing; artificial intelligence; cyber-physical systems	Limitations related to the method used	Understand the implication at a supply chain level Investigate the effect of digital maturity	Direct		Digital technologies can offer adaptive and flexible capability, benefitting the procurement function
Rejeb et al. (2022)	Understand how the Internet of things can support the transition towards circular economy. Development of a framework for strategies allowed by the Internet of things	Four possible dimensions for explaining the Internet of things – circular economy link: the Internet of things-related technologies in the circular economy context; enablers of the Internet of things for the circular economy; barriers to the Internet of things adoption in the circular economy; impact of the Internet of things on sustainable circular economy	Limitations related to the method used	Investigate the impact of the Internet of things adoption's antecedents on the circular transition. Combine the Internet of things with digital technologies to ensure product maintenance, repair and upgradability	Direct	Moderator: digital competencies	–

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APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Sahu et al. (2022)	Understand the integration between digital technologies and circular economy practices	Digitalisation is necessary to foster circular economy activities, also through the integration among manufacturers, suppliers and end-consumer to support recovery and recycling activities	Limitations related to the method used Limited sectorial analysis Lack of empirical analysis	Develop quantitative models for statistical approaches	Direct	Moderators: digitalisation; system integration; continuous improvement; reliability and stability; technological roadmap; government policy and regulation; preventive and predictive maintenance; collaborative manufacturing	–
Skalli et al. (2022)	Provide an overview of the relationships between Industry 4.0, circular economy and supply chain management, understanding the impact of digital technologies on the other two	The support of digital technologies to circular economy is confirmed. Research should move towards the investigation of barriers and drivers	Limitations related to the method used	Provide empirical applications to the several conceptual frameworks provided in the literature	Direct	–	–
Taddei et al. (2022)	Systematisation of digital technologies, circular economy and supply chains relationships from a unique perspective	The Internet of things, big data analytics, cloud computing, autonomous robots and additive manufacturing bring most benefits to circular supply chains. 3Rs, waste management, energy efficiency, material efficiency and circular design are the most addressed circular economy aspects	Consideration of only meso and macro levels	Provide empirical investigation Identify the fit digital technologies and business models to successfully adopt circular supply chains	Direct	–	–

APPENDIX A (Continued)

Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Voulgaridis et al. (2022)	Understand the Internet of things' role, protocols and communication routes to link it with circular economy	Identification of challenges at the nexus between digital technologies and circular economy. New business models needed for data sharing and integration	Limited set of digital technologies considered	Provide empirical evidence (case studies)	Direct	–	–
Atif (2023)	Evaluate the role of digital technologies in supporting the transition towards product-service systems	Digital technologies can support product-service systems. Yet, additional efforts are necessary for (i) conducting empirical research on the relationship, while also understanding the role of policies and legislations; (ii) redesign the operating model; iii) understand how to keep a healthy relationship with stakeholders; (iv) study barriers and drivers; (v) frame the relationship within the resource management	Limitations related to the method used	Address the open issues emerged from the literature	Direct	–	–
Rusch et al. (2023)	Understand the role of digital technologies in supporting sustainable product management	Characterisation of the effect that digital technologies have on sustainable product management Identification of benefits brought by digital technologies on the product life cycle Main barriers to circular economy are lack of knowledge about digital technologies and lack of coordination and information exchange about the products' life cycle	Limitations related to the method used No consideration of social perspective	Provide empirical investigation	Direct	–	–

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Authors and year	Motivation and main contribution	Main findings	Main limitations	Main future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Spaltini et al. (2023)	Understand if digital technologies can represent a driver for circular economy, by also overcoming barriers	Most of the barriers experienced by firms when embracing circular economy can be solved or reduced thanks to digital technologies	Limitations related to the method used	Understand the influence of different manufacturing processes	Direct	–	–
Toth-Peter et al. (2023)	Understand the transition process to circular business models and the enabling role of Industry 4.0	Many factors emerged as inter-related, thus worthy of being addressed holistically rather than in a separated manner. The transition takes place also beyond the firm's boundaries. A transition framework is provided	Limitations related to the method used	Expand the systematic literature review to also include meso and macro levels Provide empirical investigation in different contexts Investigate the relevance of specific technologies, as blockchain Investigate the entrepreneurial process that allows the implementation of circular economy	Direct	–	–

APPENDIX B

Analysis of the original contributions reviewed according to the following axes: motivation and contribution, findings, limitations, future research, type of relationship, mediators and moderators, details on dynamic capabilities

Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Bianchini et al. (2018)	Understand how digital technologies can solve issues faced in implementing circular economy	Description of how the application of the Internet of things and big data analytics can support circular business models during the entire product life cycle	Limitations related to the methodology used	Investigate the supply chain level	Direct	–	–
Bressanelli et al. (2018)	Understand of the role of digital technologies in enabling product-service systems	The Internet of things and big data analytics are relevant and help firms overcoming challenges, through digitally enabled functionalities	Limited sample investigated	Provide additional empirical evidence	Direct	–	–
Lopes de Sousa Jabbour et al. (2018)	Understand the link between Industry 4.0 and circular economy	Proposal of a roadmap to enhance the application of circular economy principles in firms through Industry 4.0	Lack of empirical application	Provide empirical application of the roadmap, preferably case studies	Direct	–	–
Makarova et al. (2018)	Understand how digital technologies can support reverse logistics	Proposal for a framework allowing the planning and organisation of processes, minimising raw materials' consumption and reduce negative environmental impacts	N.A.	Provide empirical application of the framework	Direct	–	–
Neligan (2018)	Understand the relevance of digitalisation to improve material efficiency in the German industry	Opportunities deriving from digital technologies are limitedly exploited and addressed primarily to improve efficiency in the manufacturing process	Limited context investigated	Evaluate barriers and drivers to the circular transition	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Cezarino et al. (2019)	Investigate the relationships between Industry 4.0 and circular economy and the limitations for their adoption	The relationship is explored from political, economic, social and technological perspectives	Limited context investigated	Provide additional empirical evidence	Direct	–	–
Charnley et al. (2019)	Understand how simulation informed by Industry 4.0 and the Internet of things can accelerate the implementation of circular economy	The analysis of data can influence decisions on remanufacture and can lead to significant cost, material and resource savings	Limited context investigated	Provide additional empirical evidence	Direct	–	–
Chauhan et al. (2019)	Analyse the role of digital technologies in realising circular economy	The Internet of things and cybersecurity and blockchain are pivotal for supporting circular economy transition The important role of top managers is also underlined	Limitations related to the methodology used	Provide empirical application of the roadmap, preferably case studies	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Ingemarsdotter et al. (2019)	Analysis on how companies implement the Internet of things for circular economy strategies	The Internet of things entails capabilities as tracking, monitoring, control and optimisation Current implementations of the Internet of things enabled circular economy mainly target efficiency in use and product life extension	Limitations related to the methodology used	Provide empirical application of the roadmap, preferably case studies	Direct	–	The Internet of things entails capabilities as tracking, monitoring, control, optimisation – not specified if they are intended as dynamic
Nascimento et al. (2019)	Explore how digital technologies can enable circular business models focused on the reuse/recycle of material	Proposal of a framework of recommendations for circular business models to reuse scraps	Limited context and sample investigated Limitations related to the methodology used	N.A.	Direct	–	–
Pham et al. (2019)	Understand how digital technologies can accelerate the sharing economy	Industry 4.0 is an enabler for sharing economy, specifically it can help overcoming barriers to circular economy adoption	Limited context and sample investigated	Approach circular economy through a policy-oriented approach	Direct	–	–
Bag et al. (2020)	Investigation of the relationships between procurement 4.0 and digital technologies, within the circular economy context	Firms with a strong procurement strategy and effective procurement 4.0 processes attain enhanced circular economy performance	Limited context investigated	Provide additional empirical evidence Further evaluate the effect of moderators	Direct	Moderator: information processing capabilities	Information processing capabilities are introduced as deriving from the introduction of Industry 4.0 in the procurement process

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
De Marchi and Di Maria (2020)	Understand of the connections between Industry 4.0 and circular economy strategies	Positive relationship between Industry 4.0 and circular economy adopters, with digital technologies acting as both enablers and amplifiers of circular economy	Limited context investigated	Provide additional empirical evidence	Direct	–	–
Dev et al. (2020)	Proposal for a roadmap for sustainable reverse supply chain/logistics by implementing Industry 4.0 and circular economy	Insights for full circularity adoption for sustainable operations management are provided	Limited context investigated	Increase circular economy awareness among industrial decision makers	Direct	–	–
Ingemarsdotter et al. (2020)	Understand how to leverage on the Internet of things for the implementations of circular economy strategies	The Internet of things supports: servitised business models; tracking of products; conditions monitoring and predictive maintenance; estimations of remaining lifetime; design decisions to improve durability	Limitations related to the methodology used	Provide additional empirical evidence Investigate the role of data management	Direct	–	The Internet of things capabilities are introduced – not specified if they are intended as dynamic
Kintscher et al. (2020)	Proposal for an approach to integrate Industry 4.0 in recycling processes	Information sharing is pivotal for enabling an efficient recycling process	Limitations related to the methodology used	Provide additional empirical evidence	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Kouhizadeh et al. (2020)	Understanding of cybersecurity and blockchain can be of use to implement the ReSOLVE framework	Blockchain allows transparent, decentralised, secure transaction processes and positively impacts on the overall sustainability Blockchain adoption suffers from infrastructure challenges	Limitations related to the methodology used	Provide empirical evidence Provide application at a supply chain level	Direct	–	Cybersecurity and blockchain capabilities are introduced in terms of transparency and traceability – not specified if they are intended as dynamic
Kravchenko et al. (2020)	Understand how additive manufacturing can enable circular economy, with the identification of the main sustainability aspects to be considered	Additive manufacturing supports several circular economy strategies and circular business models Sustainability aspects must be considered at a planning and design stage	Lack of a link between sustainability aspects and circular economy strategies	Provide empirical application in different contexts	Direct	–	–
Kristoffersen et al. (2020)	Proposal of a framework for smart circular economy	Digital technologies hold potentials for improved efficiency and productivity	Lack of empirical evidence	Provide empirical application of the framework Analyse the role of business analytics capability using the research-based view theory	Direct	–	Business analytics capability is introduced – not specified if they are intended as dynamic. The capability is also introduced as a possible mediator, but the aspect is not explored

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Rajput and Singh (2020)	Proposal for a model for Industry 4.0 set-up to achieve circular economy and cleaner production, through the optimisation of products machine allocation	The proposed model optimises trade-offs between energy consumption and machine processing cost	Limitations related to the methodology used	Address the limitations	Direct	–	–
Rocca et al. (2020)	Presentation of a laboratory application case, to foster the rethink of business strategies in view of digital technologies and circular economy	Digital technologies allow better use of resources, increased production sustainability and benefits along the product life cycle	Limitations related to the empirical validation	N.A.	Direct	–	–
Rossi et al. (2020)	Analysis of the application of an assessment tool for understanding how Industry 4.0 can support circular economy	Proposal of a systematised framework considering circular business models enhanced by intelligent assets	Limitations related to the empirical validation	Provide empirical application of the framework	Direct	–	–
Uçar et al. (2020)	Understand the role of the Internet of things, big data analytics and artificial intelligence in supporting circular economy	Digital technologies can act as enablers or triggers for circular economy	Limitations related to the methodology used	Perform additional empirical investigation Investigate other contexts	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Awan et al. (2021b)	Understand the relationship between big data analytics and circular economy performance in manufacturing companies working in developing countries	Big data analytics influences circular economy performance and it is associated with data-driven insights enhancing the decision-making process	Limited context considered	Need for generalise findings Focus on the mediating role of circular economy performance between big data analytics capability and environmental and innovation performance	Direct	–	–
Bag et al. (2021b)	Analysis of the resources influencing procurement 4.0, leading companies to increase productivity in remanufacturing operations and circular economy aspects	Three resources positively influence the implementation of procurement 4.0 that shows a direct relationship with remanufacturing	Limited sample size and context investigated	Focus on developed countries Understand the relationship between procurement 4.0 and supply chain risk	Direct	–	–
Bag et al. (2021c)	Understand the effect of digital technologies on 10Rs manufacturing capabilities	A higher use of leads to higher levels of 10Rs advanced manufacturing capabilities. Delivery system moderates the relationship	Limited sample size and context investigated	Understand how to manage human resources to fit in the Industry 4.0 setup Analyse the role of artificial intelligence in enabling 10Rs	Direct	Moderators: delivery system – top management support; training and project resources; support of research institutes and universities	Need for dynamic capabilities for running 10Rs based advanced manufacturing operations effectively. These dynamic capabilities can anticipate threats on the market and lead the transformation and penetration in newer markets

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Bag et al. (2021a)	Understand how companies belonging to the automotive sector adopt big data analytics – artificial intelligence technologies and the connection with circular economy capabilities	Big data analytics – artificial intelligence enhance the life cycle of resources, increasing the efficiency of processes and providing more recycling options. Organisational flexibility and industry dynamism moderated the relationship	Limited context investigated	Generalise the results by considering different countries	Direct	Moderators: organisational flexibility; industry dynamism	–
Bag et al. (2021d)	Provision of a theoretical model where resources needed to drive the technological process to develop circular economy capabilities are highlighted	Identification of 35 resources divided in 9 factors that can enable Industry 4.0 adoption. Information technology and big data analytics are considered fundamental	Limitations related to the sample investigated	Generalise the results by considering different industries	Direct	–	
Bag et al. (2021e)	Provision of a conceptual framework showing that digital technologies can reduce resource consumption, waste and pollution	Digital technologies influence circular economy performance indicator, which positively affects dynamic remanufacturing capability	Limited sample size and context considered	Investigate the moderating effect of information processing capability	Direct	–	
Bekrar et al. (2021)	Identification of relationships and opportunities at the intersection between transportation, reverse logistics and cybersecurity and blockchain	Cybersecurity and blockchain's adoption in the context of transportation and reverse logistics presents barriers, removable involving multiple parties (governments, suppliers, consumers, universities, communities) and entities to develop partnerships	The topic remains quite abstract	Provide empirical evidence Understand how to overcome barriers	Direct	–	––

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Briechle and Lawrenz (2021)	Provision of a framework for processing process and product data to favour better decision-making process to implement circular economy	The framework proposed helps firms in understanding the right path among recycling, repair/reuse, refurbishment/remanufacture	Barriers to the acceptance of circular products by customers are not considered	Create an economically sustainable circular business model	Direct	–	–
Ciliberto et al. (2021)	Provision of a framework connecting the concepts of lean production, Industry 4.0, reverse logistic, sustainable production and circular economy	Digital technologies improve the closed loop production. Reverse logistics can integrate the principles of circular economy into the supply chain, allowing the recovery of wastes and their reintroduction in the cycle	Lack of empirical investigation The role of stakeholders in the chain is not considered	Provide empirical investigation Understand the role of different stakeholders	Direct	–	–
Del Vecchio et al. (2021)	Analysis of the case of the Italian Circular Economy Stakeholder Platform (ICESP) through the Quantuple Helix model	Five categories of stakeholders are analysed. The digital passport provided by ICESP allows the creation of a virtual environment for different stakeholders to share knowledge and collaborate in a circular economy perspective	Limited sample considered	Include more digital technologies in the analysis	Direct	–	–
Deng et al. (2021)	Understand how digital thread can be applied for extending the useful life of goods	The extension of the useful life of goods requires the involvement of different stakeholders, as they could have knowledge and expertise related to specific technologies and activities	Limited sample considered	Perform additional empirical investigation Include further sectors	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Gupta and Singh (2021)	Identification of critical success factors for adopting circular economy practices through the usage of digital technologies for the logistics sector in developing countries	Identification of different organisational, technological and social critical success factors for adopting digital technologies to achieve circular economy practices	Limitations related to the method used Limited context investigated	Perform additional empirical investigation Include further countries	Direct	Moderators: organisational, technological and social critical success factors	–
Järvenpää et al. (2021)	Understand how digital technologies can increase efficiency of waste and by-product flows among different firms and the challenges for industrial symbiosis	Identification of the need for better information on material and forecast availability; the Internet of things and big data analytics play a fundamental role	Limited sample considered	Focus on the entire supply chain	Direct	–	–
Kamble and Gunasekaran (2021)	Understand of how digital technologies can enable circular economy practices and of dynamic capabilities needed to improve sustainability	Digital technologies have a direct effect on sustainability related performance. Circular economy is a mediator between Industry 4.0 and sustainability related performance	Limited context considered	Identify additional mediators, while also focusing on moderators	Direct	–	Digital technologies generate dynamic capabilities that enable sustainability as a strategic core competence of an organisation
Kazancoglu et al. (2021)	Identification of the main risks related to the implementation of circular economy, addressable through digital technologies	Management knowledge, expertise and skills for digital technologies are needed for increasing efficiency and effectiveness of circular economy initiatives	Limited sample and context considered Limitations related to the method used	Investigate other contexts Apply other methodologies for ranking the risks' relevance	Direct	Moderators: management knowledge; expertise; analytical skills for using the digital technologies	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Khan et al. (2021b)	Analysis of the role of cybersecurity and blockchain in favouring the adoption of circular economy and its impact on firms' organisational and environmental performance	Cybersecurity and blockchain has a strong correlation with circular procurement, circular design, recycling and remanufacturing activities. Discussion on the main barriers hindering the implementation of digital technologies in small- and medium-sized enterprises	Limited context considered Limited set of digital technologies considered	Include more digital technologies in the analysis Investigate other countries	Direct	–	–
Khan et al. (2021a)	Investigation of the relationship between cybersecurity and blockchain, circular economy practices and firms' performance	Cybersecurity and blockchain in fundamental for successfully implement circular procurement, circular design, recycling and remanufacturing	Limited context considered	Investigate other contexts Use a mathematical model for validate the results	Direct	–	
Khan et al. (2021c)	Investigation of the relationship between digital technologies, institutional regulation, COVID-19 and circular economy in a developing country	Digital technologies have a direct enabling role on circular economy practices; the important role of institutions is underlined	Limited context considered	Investigate other contexts	Direct	–	–
Kintscher et al. (2021)	Provision of a technical framework indicating how to make the recycling process more efficient by including digital technologies	The framework proposed different levels of analysis according to specific digital technologies	No investigation of all the phases of the product life cycle	Consider other phases of the product life cycle	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Kristoffersen et al. (2021a)	Test of the validity of Kristoffersen et al. (2021b)'s conceptual model	Business analytics capability has a positive impact on circular economy implementation and recourse orchestration, in turn positively impacting firms' performance	Limited context considered Limitations related to the method used	Perform additional empirical investigation Include different perspectives from the same firm	Non-direct	Mediators: degree of circular economy implementation; resource orchestration capabilities	
Kristoffersen et al. (2021b)	Provision of a conceptual framework to understand how business analytics can be structured, bundled and leveraged to achieve competitive advantage	A correct management of business analytics resources (tangible resources, intangible resources and human skills) will be central for firms when navigating the circular economy transition	Limited set of digital technologies considered	Perform additional empirical investigation Perform quantitative analysis	Non-direct	Mediator: business analytics capability	–
Kumar et al. (2021)	Identify critical success factors for integrating digital technologies and circular supply chains	Identification of organisational critical success factors and the extent to which they favour the applicability of digital technologies and circular economy practices in supply chains	Consideration of only organisational critical success factors Limited context considered	Provide empirical investigation Investigate other contexts	Direct	Moderators: organisational critical success factors	–
Laskurain-Iturbe et al. (2021)	Investigation of the mutual interdependences among eight digital technologies and five circular economy	Analysis of the effect of digital technologies on recovery, recycling, reuse, reduce input consumption and reduce waste emission, understanding the extent of the effect	Limitations related to the method used	Perform quantitative analysis Need for considering the integration of digital technologies. Investigate other contexts	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Magrini et al. (2021)	Investigation of the role of digital technologies in increasing circularity in Italian firms operating in the electronic equipment sector	Provision of solution for integrating cybersecurity and blockchain and the Internet of things to enable repair, reuse and recycling	Limited context considered	Need for investigating the impact on social aspects	Direct	–	–
Mastos et al. (2021)	Identification of the added value provided by digital technologies in enabling circular economy practices through three real-world applications in the waste-to-energy sector	The proposed technological solution includes first an online bidding process tool and cybersecurity and blockchain	Limited sample considered Lack of consideration of social aspect	Investigate other contexts. Need for investigating the impact on social and environmental aspects	Direct	–	–
Nandi et al. (2021)	Provision of a framework linking localisation, agility and digitalisation, considering the impact of cybersecurity and blockchain on them and circular economy practices	The link between localisation, agility and digitisation and the enabling role of cybersecurity and blockchain for circular economy practices is described in a framework, descending this link to the case of COVID-19	Focus only on the last tier of supply chain	Perform quantitative analysis Focus on the entire supply chain	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Ranta et al. (2021)	Analysis of different forerunners based in Northern Europe focusing on their adoption of digital technologies to enable circular business models	Data collection technologies (the Internet of things mainly) allow for incremental innovation; data collection and analysis technologies (artificial intelligence mainly) allow for radical innovation	Limited sample considered	Perform additional empirical investigation	Non-direct	Mediators: skills and procedures – not further specified	–
Sharma et al. (2021b)	Understanding of the consequences of adopting cybersecurity and blockchain for circularity in agriculture supply chains, identifying key enablers	Identification of factors enabling the adoption of cybersecurity and blockchain, that is fundamental for assuring traceability and transparency, with a positive impact on circular economy	Limited context considered Limitations related to the method used	Investigate other contexts Perform additional quantitative analysis	Direct	–	–
Shayganmehr et al. (2021)	Provision of a framework to evaluate the relevance of digital technologies enablers for implementing circular procurement	Identification of 27 digital technologies enablers, organised in six categories. The most relevant category is 'technical capability'	Lack of empirical research Limited context considered No consideration of interrelationships among digital technologies	Provide empirical investigation	Direct	Moderators: the identified enablers	–
Spaltini et al. (2021)	Provision of a conceptual framework studying how digital technologies impacts circular economy practices – especially recycling, remanufacturing, reduce and redesign	The Internet of things connects different stakeholders within the supply chain; cloud computing supports virtualisation; additive manufacturing is mainly considered in remanufacturing activities	No consideration of social perspective	Include the social perspective	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Agarwal et al. (2022)	Development of a framework based on the rubber industry in India, identifying challenges hindering circular economy implementation and possible solutions through digital technologies	The main challenges identified are (i) information disruptions among the supply chain members due to multiple channels; (ii) manpower inability to handle the toxic materials	Challenges identified by a limited sample of experts	Adopt other multi-criteria decision methods, combining different fuzzy set theories as well	Direct	–	–
Aldrighetti et al. (2022)	Identification of the most adopted digital technologies and relative closed loop supply chain activities according to firms' size	Reuse and recycle are the most implemented strategies in different manufacturing sub-sectors. The necessity to jointly adopt digital technologies and relative closed loop supply chain practices to positively impact firms' performance is underlined	Limited sample size. Lack of consideration of macro-economic aspects	Replicate the in-study different contexts Perform case studies	Direct	–	–
Assuad et al. (2022)	Develop a framework for the adoption of big data analytics powered artificial intelligence to develop sustainable manufacturing and circular economy capabilities	Big data analytics – artificial intelligence adoption is still at early stages in small- and medium-sized enterprises. Thanks to institutional pressures, firms can deploy digital technologies and workforce skills, ultimately leading to circular economy capabilities	Limitations related to the method used	Statistically validate the framework	Direct	–	–
Bag and Pretorius (2022)	Understand how to integrate digital technologies in reconditioning process, usually performed manually	Additive manufacturing together with cyber-physical systems can support the realisation of reconditioning operations	Limited empirical evidence	–	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Belhadi et al. (2022)	Provision of a theoretical framework grouping together some of the most important Industry 4.0–circular economy practices, under the lens of dynamic capabilities	Eight high-order dynamic capabilities can derive from the Industry 4.0–circular economy integration	Limited set of digital technologies considered No consideration of the impact on sustainable performance	Link circular economy–Industry 4.0 and sustainable performance indicators	Direct	–	Dynamic capabilities are considered as possibly enabled by the integration of circular economy–Industry 4.0., allowing firms to embrace sustainability
Bressanelli et al. (2022)	Analysis of the inter-relations between digital technologies and circular economy, with the proposal of the smart circular economy paradigm concept	Identification of the possible applications of digital technologies in the different products' life-cycle phases, focusing on the Internet of things, big data analytics, artificial intelligence, additive manufacturing and augmented reality	Limited set of digital technologies considered Limitations related to the method used	Consider whole industrial ecosystems including stakeholders	Direct	–	–
Caterino et al. (2022)	Provision of a framework for distributed manufacturing system that is the CRMfg	CRMfg allows the centralisation of the remanufacturing process. Each actor can share data as for resources and capabilities. The exchange of data is supported by cybersecurity and blockchain	Limited sample size and context considered	Include further countries Perform additional case studies	Direct	–	–
Çetin et al. (2022)	Provide an empirical investigation of Dutch social housing organisations' implementation of digital technologies to introduce the concept of circularity for their buildings	Digital platforms allow the exchange of information among stakeholders belonging to the building industry fostering the reuse or recycle of products and materials	Limited sample considered	Consider small- and medium-sized social housing organisations and include additional stakeholders	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Chari et al. (2022)	Identification of dynamic capabilities to allow to shift to circular economy. Provision of a conceptual framework connecting dynamic capabilities, circular economy, Industry 4.0 and resilience for reaching sustainability targets	Adopting circular economy practices introduces complexity and uncertainty as well as it requires to rethink and restructure leadership, mindset, business models, product design, service and distribution processes. Circular economy requires the collaboration with both internal and external stakeholders	The role of dynamic capabilities generated by digital technologies to foster circular economy practices is partially described	Need to prioritise dynamic capabilities to structure a resilient and circular supply chain. Provide an empirical test of the propositions suggested	Non-direct	Mediator: dynamic capabilities	Digital technologies create dynamic capabilities that allow to directly adopt circular economy practices. The dynamic capabilities are categorised in communication, resources, organisation, technology and collaboration
Chaudhuri et al. (2022)	Analysis of resources and capabilities needed to implement 3D printing and cybersecurity and blockchain to favour circular business models in small- and medium-sized enterprises	To provide value to customers, firms need to combine resources with capabilities. Adaptive, explorative and exploitative capabilities are considered	Limited set of digital technologies and circular economy practices considered Limited sample considered	Consider other digital technologies and circular economy practices Investigate the role of contextual factors	Direct	–	Explorative, exploitive and adaptive dynamic capabilities are needed to properly adopt digital technologies
Cherrafi et al. (2022)	Provision of a framework depicting the effect that digital technologies have on circular economy practices, supply chain resilience and sustainability	Digital technologies allow to sense threats and opportunities, mobilise resources to face them and to transform, redefining the assets of the organisation for improved supply chain resilience and sustainability Circular economy contributes as well to improved supply chain resilience and sustainability	Limited sample considered. Limitations related to the method used	Provide empirical validation Investigate how to restore manufacturing capabilities in turbulent scenarios	Direct	–	Digital technologies are recognised as enablers of dynamic capabilities (sensing, seizing, transforming) for fostering supply chain sustainability and resilience

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
de Mattos Nascimento et al. (2022a)	Understand additive manufacturing can favour some circular economy activities along the supply chain, focusing on the automotive industry	Additive manufacturing can support the life cycle management of goods by reintroducing in the loop recycled materials and enabling remanufacturing activities. 3D printing needs 3D CAD systems to work properly	Exclusion of some specific process Lack of economic evaluation	Provide empirical investigation	Direct	–	–
de Mattos Nascimento et al. (2022b)	Understand how Industry 4.0 can be combined with lean management (via value stream mapping) to achieve circular economy	Creation of a circular value stream mapping 4.0	Empirical results might be influenced by the specific context	Investigate other contexts	Direct	–	–
Di Maria et al. (2022)	Analysis of the mediating role of supply chain integration on the relationship between digital technologies and circular economy performance	Smart manufacturing technologies have both a direct and indirect effects on circular economy performance Processing technologies have only a direct effect on circular economy performance	Subjective measurement of circular economy performance. Limited context considered	Include further countries Measure circular economy performance in an objective manner Explore the role played by different stakeholders	Non-direct	Mediator: supply chain integration	–
Dwivedi and Paul (2022)	Definition of the most important challenges hindering the Industry 4.0–circular economy adoption for sustainable footwear production in Bangladesh	Lack of competence about digital technologies and circular economy is the most relevant challenge hindering the implementation of sustainable footwear production	Circular economy and digital technologies are addressed from a general perspective	Perform additional empirical investigation	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Edwin Cheng et al. (2022)	Analysis of the relationships among big data analytics, circular economy practices and sustainable supply chain flexibility	Circular economy practices and sustainable supply chain flexibility mediate the relationship between big data analytics capabilities and sustainable supply chain performance	Limited context considered The theory frame used might prevent identifying all the dynamics	Provide both qualitative and quantitative empirical investigation Include further sectors	Direct	–	–
Elghaish et al. (2022)	Provision of a conceptual framework resuming the main uses of digital technologies to favour the implementation of circular economy practices	Artificial intelligence, the Internet of things, cybersecurity and blockchain and digital twin enable circular economy Definition of a digital ecosystem, integrating these technologies, to collect, store, analyse data and share data among stakeholders	Lack of empirical analysis	Provide empirical investigation	Direct	–	–
Godinho Filho et al. (2022)	Identification of the relationships between digital technologies and circular economy	Identification of 17 constructs, identifying main digital technologies and highlighting the benefits of their integration	Limited set of digital technologies considered. Limitations related to the method used	Include further sectors	Non-direct	Not further explored	–
Hettiarachchi et al. (2022a)	Understand the relationship between additive manufacturing and circular economy and conceptualisation through causal loop diagram	The text highlights the relevance of technology maturity in customers for implementing reduce and recycling practices. The organisational structure needs to include the integration with customers and other actors of the supply chain while implementing circular economy practices	Limited set of digital technologies and circular economy practices considered Limitations related to the method used	Provide empirical investigation Consideration of policy's influence	Direct	Moderator: supply chain stakeholders	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Hirota et al. (2022)	Identification of the functions digital platforms should have to properly manage the relationship among multiple stakeholders in the context of circular economy	Digital platforms foster data sharing among stakeholders. Integrating other digital technologies like the Internet of things with the platform increases efficiency and customer satisfaction	Limited sample considered	Perform additional empirical investigation	Direct	–	–
Huang et al. (2022)	Analysis of the role of quality 4.0 in promoting circular economy in manufacturing firms. Quality 4.0 is intended as a part of Industry 4.0 aimed at enhancing quality thanks to efficient technologies and advanced analytics – yet it also includes the integration of people, process and technologies	Quality 4.0's technical factors and Industry 4.0 have a positive relationship with circular economy	Limited context investigated Limitations related to the methodology used	Investigate other contexts Investigate the role of internal and external factors in shaping the relationship Understand the moderating role of firm's size	Direct	Digital technologies are tested as a mediator between Quality 4.0 and circular economy, but the hypothesis is rejected	–
Huynh (2022)	Understand the use of different digital technologies to enable circular business models in the fashion industry	Identification of three different circular business models based on digital technologies	Limited context considered	Investigate other contexts	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Ivanov et al. (2022)	Investigation of the concept of cloud supply chains	Digital passport and cybersecurity and blockchain, assure collaboration and visibility along the supply chain, while artificial intelligence and the Internet of things connect products and systems to foster the optimisation	Limited set of digital technologies considered	Include more digital technologies in the analysis	Direct	–	–
Kayikci et al. (2022a)	Identification of critical success factors for the adoption of cybersecurity and blockchain-based circular supply chains	Network collaboration is the most relevant critical success factor. Cooperative stakeholders can exploit cybersecurity and blockchain to work together along the different phases of the life cycle of products, starting from the designing phase	No investigation of relationships among critical success factors	Investigate barriers to the adoption of cybersecurity and blockchain Evaluate the impact of critical success factors on firm performance Analyse interactions among critical success factors	Direct	–	–
Kayikci et al. (2022b)	Provision of a conceptual framework to measure the maturity and readiness of small- and medium-sized enterprises in the adoption of digital technologies and implementation of circular economy practices	The readiness of Turkey small- and medium-sized enterprises operating in the textile industry is depicted by the framework. The adoption of digital technologies and implementation of circular economy practices is strongly connected to collaboration with firms capable to influence other stakeholders of the supply chain	Limited sample and context considered Lack of investigation of the reasons for low readiness and maturity	Perform additional empirical investigation Investigate other contexts	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Kazancoglu et al. (2022)	Identification and ranking of the critical success factors deriving from the adoption of the Internet of things for circular diary supply chains	Six critical success factors for the Internet of things enabled circular diary supply chains are identified in general and related to each stage of production	Limited context considered	Investigate other contexts	Direct	–	–
Khan et al. (2022c)	Investigation of the relationship between digital technologies and circular economy practices and their effect on organisational performance in the automotive sector	The Internet of things and big data analytics are fundamental for favouring recycling activities and better solutions for the management of the life cycle of goods	Limited sample considered	Perform qualitative empirical investigation Investigate other contexts	Direct	–	–
Khan et al. (2022b)	Investigation of the role of digital technologies in enabling circular economy practices in small- and medium-sized enterprises	The Internet of things and artificial intelligence are fundamental to enable the implementation and definition of circular business models, leading to redesign and recycle activities	Limited context considered. Limited set of circular economy practices considered	Investigate other contexts Include more circular economy practices in the analysis	Direct	–	–
Khan et al. (2022d)	Examine the adoption of cybersecurity and blockchain in supply chains and the consequent impact on circular economy practices and performance	Cybersecurity and blockchain impacts circular economy aspects of companies, including green design, green manufacturing, recycling and remanufacturing	Limited set of digital technologies considered. Limited context considered	Include more digital technologies in the analysis Investigate other contexts	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Khan et al. (2022a)	Identification of critical success factors deriving from digital technologies and linked to reverse logistics	Identification of managerial implications related to 15 critical success factors	Lack of operationalisation	Provide empirical investigation	Direct	–	–
Liu et al. (2022)	Identification of digital functions helpful to improve circular economy	Explanation of main functions of digital technologies (the Internet of things, big data analytics, artificial intelligence) for circular economy are provided in a heatmap that enables to identify the most promising ones, according to the different digital technologies Identification of mechanisms for the integration of digital functions supporting and enhancing circular economy strategies	Limited set of digital technologies considered	Include more digital technologies in the analysis	Direct	Moderators: digital functions	–
Lopes de Sousa Jabbour et al. (2022)	Investigation of the effect of the joint application digital technologies and circular economy practices on organisational performance	The adoption robots and sensors can improve and optimise the recycling process Digital technologies adoption facilitates the connection between supply chain's actors, favouring the close the loop activities	Limitations related to the method used	Need for assessing the role that contextual factors	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Lu et al. (2022)	Identification of drivers and barriers for developing supply chain management. Provision of a conceptual framework linking digital technologies, circular economy and dynamic capabilities	Systemic change is recognised as an important driver determining an enhanced understanding of digitalisation opportunities, leading to innovation and integration	Limitations related to the method used	Understand the mechanisms shaping the relationship between digital technologies and circular economy	Direct	–	Dynamic capabilities are needed for incorporating sustainability in supply chain management; dynamic capabilities are enabled by both digital technologies and circular economy
Oyinlola et al. (2022)	Analysis of the circular plastic economy in Africa through three case studies and provision of a research framework for digital innovation	The adoption of a multi-sided platform allows to connect different actors along the chain, favouring the collection of the recycling activities	Limited context considered	Need for involving different supply chain's stakeholders	Direct	Moderators: presence of a market, entrepreneurs and multi-national companies	–
Patil et al. (2022)	Provision of scenarios for cyber-physical systems implementation for printed circuit boards and mechatronics products' end of life	Cyber-physical systems supports remanufacturing, reusing, recycling and disassembly Cyber-physical systems framework removes most of the barriers associated to the end-of-life management of e-waste	Limited set of digital technologies considered	Include more digital technologies in the analysis	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Pinheiro et al. (2022)	Quantitative model for the relationship between digital technologies, stakeholders, circular product design and company performance, considering Brazilian companies operating in the electronic equipment sector	Digital technologies have a direct connection with circular product design. Artificial intelligence is identified as the most relevant digital technology in favouring circular product design	Limited context considered	Investigate other contexts	Direct	–	–
Plociennik et al. (2022b)	Identification of systematic requirements analysis for the digital product passport, with the aim of favouring circular economy	The use of digital product passport technology provides transparency, collaboration, trust and traceability, improving the management of the end of life	Limited sample considered	Perform additional empirical investigation Investigate the prerequisite of data handling system for digital product passport	Direct	–	–
Plociennik et al. (2022a)	Proposal for a digital life cycle passport that can be written and read by various stakeholders along the full product life cycle	The digital life cycle passport favours the communication among different actors of the supply chain, able to share information, helping actors at the end of life to apply the best circular economy practice to the products	Limited sample considered	Perform additional empirical investigation Investigate other contexts	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Psihoyos et al. (2022)	Analysis of the contribution offered by different 3D printing methods to circular economy	Different 3D printing methods offered support to circular economy. Repair and refurbish are the most prominent circular strategies; reuse repurpose and recover are absent. Most of the collected evidence still take place at a laboratory level	Evidence based on secondary material	Need for additional case studies	Direct	–	–
Rizvi et al. (2022)	Understand stakeholders' perception on cybersecurity and blockchain's effect on sustainability and circularity	Cybersecurity and blockchain provides coordination of activities to the stakeholders operating in the automotive supply chain. Reuse emerged as the main circular economy practice enabled by cybersecurity and blockchain in the sector	Limited sample and context considered	Investigate other contexts	Direct	–	–
Stavropoulos et al. (2022)	Provision of a framework to recognise and evaluate the acceptance for remanufacturing operations of damaged from impacts parts	Machine learning and simulation are needed to develop a virtual representation of the part to assess its adherence to remanufacturing criteria	Limited sample considered	Provide additional empirical investigation	Direct	–	–
Talla and McIlwaine (2022)	Analyses of the role of different digital technologies in reducing construction waste and enhancing the ability of firms to recycle, reuse and recover	Additive manufacturing and autonomous robots can optimise the design phase, reducing the consumption of materials. Machine learning analyses components, assessing whether they can be reused or they should be targeted for other circular economy practices	Limitations related to the method used Lack of quantitative investigation	Provide quantitative empirical investigation	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Tang et al. (2022)	Investigation of how digital technologies impact circular economy practices, integrating it with performance improvements	Cybersecurity and blockchain impacts circular economy in terms of green manufacturing, green design, recycling and remanufacturing	Limited set of digital technologies considered	Include more digital technologies and circular economy practices in the analysis Investigate other contexts	Direct	–	–
Wilson et al. (2022)	Analysis of the impact that artificial intelligence has on each of the phases identified for activating the reverse flow and closing the supply chain	Artificial intelligence offers many opportunities for reverse logistics, particularly for collection and processing activities	Lack of analysis of the challenges for artificial intelligence adoption	Perform a more systemic analysis	Direct	–	–
Wynn and Jones (2022)	Investigation on the role of digital technologies in promoting circular economy transition	Reduce and recycling are the most adopted circular economy practices, while practices requiring collaboration with other stakeholders are the least implemented	Limitations related to the method used	Provide additional empirical investigation (case studies or survey)	Direct – though the relationship did not emerge clearly from the investigation	–	–
Yaqot et al. (2022)	Identification of the role of digital technologies in modifying the way operations are conducted in the context of circular economy	Jointly adopting digital technologies allows to develop 'I4 capabilities' to sense, optimise and actuating the process of stockpiling to conveyor belt	No clear investigation of the relationships among digital technologies, capabilities and circular economy	Provide additional empirical investigation, as semi-structured interviews	Direct	–	Digital technologies enable capabilities

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Yu et al. (2022)	Analysis of the impact of digital technologies on circular economy and supply chain capabilities	Digital technologies positively affect supply chain capabilities, meant as the capability of firm to assimilate, utilise and identify both external and internal information/ resources to facilitate the entire supply chain activities	Limited context considered	Investigate other contexts Understand the implication on performance	Direct	–	–
Ali and Johl (2023)	Analysis of the role of institutional pressures and organisational resources to promote Industry 4.0 and sustainability	Institutional pressure has a positive effect on organisational resources, which can orchestrate digital technologies effectively. In turn, digital technologies have a positive effect on sustainability practices and circular economy capabilities	Limited context investigated	Frame the analysis within contingency theory Perform multi-respondents or longitudinal studies Investigate other contexts	Direct	Moderator: firm size (small and medium)	–
Ertz and Gasteau (2023)	Analysis of how digital technologies support organisation in implementing product lifetime extension and thus circular economy	The study provides concrete impacts of digital technologies on product lifetime extension. Digital technologies support (i) research and development activities, especially as for the improvement and validation of prototypes; (ii) smart production; (iii) automation of processes; (iv) decision making	Limited sample size and context considered	Perform additional empirical investigation Perform quantitative investigation Include more digital technologies in the analysis	Direct	–-	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Faisal (2023)	Investigation of the role that digital technologies play in the implementation of circular economy practices in supply chains	Identification of driver variables that, through the implementation of digital technologies, can support servitisation, coopetition and knowledge and skills, all fundamental elements to enhance circular performance of supply chains and are considered dynamic capabilities	Limitations related to the method used Limited context investigated	Perform additional empirical investigation	Non-direct	Mediators: coopetition, servitisation, knowledge and skills	Coopetition and servitisation are recognised as dynamic capabilities influencing circular performance in a supply chain
Findik et al. (2023)	Analysis of the support that digital technologies can offer to circular economy in European small- and medium-sized enterprises	Digital technologies support environmental strategies. Policy priority should be focused on spread Industry 4.0 to improve the implementation of circular economy in small- and medium-sized enterprises	Dynamic interactions between digital technologies and circular economy were not observed Limited aspects of circular economy considered	Address the limitations	Direct	–	It is suggested to study the relationship using a dynamic capabilities lens, to put at the centre the concept of adaptation, necessary to exploit the digital technologies
Han et al. (2023)	Selected digital technologies are assessed against their role in each of the life cycle stages, considering their potential impact on performance objectives of circular economy	The studied digital technologies facilitate the transition to circular economy	Limited sample size and context considered	Perform additional empirical investigation Evaluate the degree and scope of digital technologies	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Hojnik et al. (2023)	Analysis of the impact of digitalisation and demographic changes on eco-innovation and how these impacts, enable and develop circular economy	Digitalisation allows firms to create new product and optimise existing ones, by increasing control, transparency and manageability of processes	Limited sample size.	Perform additional empirical investigation	Direct	–	–
Neri et al. (2023b)	Investigation of role that digital technologies may have in supporting the implementation of circular economy practices by industrial small- and medium-sized enterprises	Among digital technologies, the Internet of things, big data analytics and autonomous robots emerge as the most promising digital technologies, strongly supporting the implementation of a variety of circular economy practices The integration among the Internet of things, big data analytics, horizontal/vertical systems integration, cloud computing and autonomous robots is of great interest to foster the circular transition	Limited sample and context considered	Provide additional empirical investigation Investigate other contexts and evaluate the impact of contextual factors Understand the mediators of the relationship between digital technologies and circular economy	Direct	–	–
Neri et al. (2023a)	Investigation of the digital-enabled dynamic capabilities in supporting the implementation of circular economy	The relationship between digital technologies and circular economy might not be only direct but appears mediated by digital-enabled dynamic capabilities The dynamic capabilities appeared enabled by several digital technologies, alone or in combination	Limited context investigated Lack of measurement of the strength of the dynamic capabilities	Address the limitations Perform a quantitative analysis to explore correlation among the different variables Evaluate barriers and drivers impacting on the presence of digital-enabled dynamic capabilities	Non-direct	Mediator: digital-enabled dynamic capabilities	Dynamic capabilities are identified in terms of sensing, seizing and transforming. The most interesting ones are evaluated in terms of increasing knowledge, traceability and changes in process

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Okorie et al. (2023)	Explore the role of digital technologies in the cultivation of firm's competitive advantage and the deployment of internal resources and competencies to achieve net zero and circular economy	Twenty-one digital technologies are categorised in terms of the competitive advantages they can bring Four scenarios are offered as pathways for digital technologies adoption	Limitations related to the method used	Perform additional empirical investigation	Direct		Digital resources and capabilities are identified; they can support a digital-enable circular economy and the achievement of new competitive advantage
Prakash and Ambedkar (2023)	Analysis of digital technologies enabling key aspects of circular economy, their relative importance and the casual relationship between the two	Digital technologies can be grouped into two technological subsets: one that facilitates circular economy data acquisition (the Internet of things) and one that facilitates the analysis (big data analytics, cloud computing, artificial intelligence) of the collected data. These relations can be exploited to ultimately create optimised material, energy and waste circular flow loops of remanufacturing, repair, reuse, redistribution and recycling	Limitations related to the method used	Perform additional empirical investigation Examine circular economy user interactions for servitisation	Direct	–	–
Romagnoli et al. (2023)	Understand if sustainable practices implementation and digital technologies adoption play a role in the creation and management of circular supply chains	Both sustainable practices and digital technologies play a role, although the role of the former is stronger. Simulation appears as an interesting digital technology	Limited set of digital technologies considered	Focus on other digital technologies Investigate the effect of disruptive events in influencing the relationship	Direct	–	–

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Schöggl et al. (2023)	Investigation of the level of adoption of four digital technologies in different manufacturing industries and their influence on the circular economy implementation	The level of implementation of digital technologies depends on the size of the firm and its resources. The adoption of digital technologies alone is not enough to implement circular economy strategy, rather a clear value proposition and proper internal capabilities are necessary	Limited sample and context considered	Explore the relationship between digital technologies and circular economy in small- and medium-sized enterprises Consider all circular economy practices	Direct	–	–
Sharma et al. (2023)	Understand how green logistics affects circular economy adoption in the era of Industry 4.0 by analysing the relationship among the three concepts	Firms can enhance circular economy adoption driven by digital technologies with green logistics as a mediator. Digital technologies have a significant effect on circular economy adoption; the mediation of green logistics practices is significant	Limited sample size and context considered	Perform additional empirical investigation Expand the role of firm's size and circular economy implementation level	Direct and Indirect	Mediator: green logistics. Moderators: institutional pressure, supply chain flexibility	––
van Eechoud and Ganzaroli (2023)	Understand the dynamic capabilities involved in the digitally enabled transition from linear to circular economy	Proposal of a framework on the role of dynamic capabilities in digital circular business models Dynamic capabilities for circular business models and/or digitalisation are combined to find commonalities and possibilities for exploitation	Limitations related to the method used Lack of consideration of different circular business models and different nature of innovation	Address the limitations Evaluate the contribution of dynamic capabilities on final outcomes (e.g. environmental or economic)	Direct	–	The dynamic capabilities considered are those for circular business models innovation and for digital technologies adoption; they are addressed together in a synergic manner

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Authors	Motivation and contribution	Findings	Limitations	Future research	Type of relationship	Mediators and moderators	Details on dynamic capabilities
Wiegand and Wynn (2023)	Investigation of how the industry is moving towards sustainability and circular economy; analysis of the role of digital technologies in the transition	Firms are at a turning point as for the use of digital technologies for the implementation of sustainability and circular economy-related activities, especially, the transition has not been directly driven by digital technologies. Additionally, circular economy is not approached holistically and there is the need to understand how digital technologies contribute to value creation Provision of an operational framework	Limited context investigated Limitations related to the method used	Investigate additional countries Examine the role of external market influences	Direct	–	–
Yuan and Pan (2023)	Understand how digital technologies influence circular economy capabilities through supply chain management	Digital technologies application and supply chain management influence the circular economy capabilities. Overall, digital technologies enable circular economy not only gaining advantages from individual enterprises, but also from dynamics among different enterprises of the supply chain	Limited context investigated	Investigate other contexts	Indirect	Mediators: supply chain dynamic capabilities (supply chain risk management, collaboration and integration)	The dynamic capabilities considered are: (i) supply chain dynamic capabilities; (ii) dynamic circular economy capabilities