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Digital Concepts and Their Influence on Sustainability in Supply Chains

Completed Research Full Paper

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Abstract

Sustainability and digital transformation are both important and highly relevant megatrends. The convergence of digital transformation and sustainability transformation is referred to as the twin transformation. Digital transformation can serve as a catalyst to drive sustainability transformation. We categorize Supply Chain (SC) digital technologies into four Digital Concepts (DCs): Infrastructure, Engineering Technology, Data Technology, and Communication Technology. We conduct a systematic literature review, analyzing 43 full-text articles to identify the key DCs that impact SC sustainability based on the triple bottom line framework. We provide an in-depth analysis of the DCs and their role in shaping sustainability within the SC. By clustering relevant technologies into DCs, this study finds that most of these digital technologies have a positive overall impact on sustainability.

Keywords

Digital Concepts, Sustainability, Triple Bottom Line, Supply Chains.

Introduction

Digital transformation is a process initiated and driven by the emergence of digital technologies. Its impact on the value creation, strategy, and structural mechanisms of Supply Chains (SCs) is enormous (Feroz et al., 2023). At the same time, societal challenges ranging from poverty to climate change have sparked global movements that impact individuals, SCs, and society. As a result, organizations are beginning to recognize the need for SC sustainability transformation in parallel with digital transformation (Graf-Drasch et al., 2023). Sustainability and digital transformation, both important and highly relevant megatrends, are forming a convergence (Lingelbach & Feroz, 2024). Digital transformation can serve as a catalyst to drive sustainability transformation. The convergence of digital transformation and sustainability transformation in a joint approach is recently referred to as twin transformation (Meuser et al., 2024). Here, digital transformation can provide insights for sustainability transformation, while sustainability transformation can guide the design of digital transformation and create new value (Christmann et al., 2024).

Research on Industry 4.0 (I4.0) technologies emphasizes their role in advancing environmental sustainability. Birkel and Müller (2021) explore the connection between I4.0 and the triple bottom line (TBL) framework, which encompasses environmental, economic and social dimensions, highlighting both challenges and opportunities. Wang et al. (2023) review digital technologies in green SC practices, identifying gaps in their practical application. Sustainable practices not only improve SC performance but also align with consumer expectations (Chopra, 2019). However, sustainability must go beyond environmental concerns to address social equity, ethics, and long-term economic viability (Elkington, 2002). Managing technology and social organizations effectively can pave the way for sustainable economic growth (World Commission On Environment and Development, 2009). With increasing pressure on natural resources, a greater focus on sustainability in SC practices is essential (Chopra, 2019). This paper defines sustainability in SCs as the balance of environmental, social, and economic factors. The research field of digital technologies is extensive, particularly when combined with studies discussing sustainability or SCs. Various studies have been conducted by researchers reviewing these topics. While progress is being made, comprehensive reviews covering all aspects of the TBL remain scarce (Ejsmont et al., 2020). Chen et al. (2020) review the implications of digitalization on the dimension of environmental sustainability across various phases of manufacturing, including design, production, transportation, and customer services. Androod et al. (2024) provide an overview of the overall impact of digital technologies on SC sustainability. However, research should systematically map the impact of each digital technology on sustainability transformation (Androod et al., 2024; Chen et al., 2020). Considering twin transformation of SCs the following research questions (RQ) arise:

RQ1: How do digital concepts impact supply chain sustainability?

RQ2: What are the key digital concepts that have an impact?

To examine the role of digitalization in sustainable SCs, this study adopts the conceptual model proposed by Andres et al. (2024), which categorizes SC digital technologies into four digital concepts (DCs): Infrastructure, Engineering Technology, Data Technology, and Communication Technology. We deliberately use the term "digital concept" rather than "enabling technology" (Andres et al. 2024) to emphasize the targeted application of technologies and processes to achieve specific goals. This research aims to explore how DCs influence sustainability in SCs by identifying the key DCs with the most significant impact. A systematic literature review (SLR) is conducted following Denyer and Tranfield (2009) and Webster and Watson (2002), ensuring a comprehensive assessment of the role of DCs in SC sustainability.

Digital Concepts for Sustainable Supply Chains

In traditional supply chain management (SCM), companies focus on the economic aspect of the SC, but in sustainable SCM, in addition to economic aspects, social and environmental aspects should also be considered. In line with the TBL approach, sustainability in this paper is defined as environmental, social and economic sustainability. Based on the TBL concept, the focus of sustainable SCM can be defined as the economic, social, and environmental aspects of SCM. It means that the SC processes should be managed in such a way that profitability and social welfare are increased while their negative impact on the environment is reduced (Karmaker et al., 2023). Several DCs show great potential for improving the sustainability of SCs. The goal of this study is to explore how DCs influence sustainability in SCs. The reviewed DCs in this paper are based on the conceptual model by Andres et al. (2024). Notably, they base their model on the framework outlined by Ivanov et al. (2021), who analyzed the current state of research and future opportunities for research on I4.0 in relation to operations management. However, our SLR considers the entire SC and the technologies affecting sustainability. Therefore, the conceptual model by Andres et al. (2024) is expanded to include key technologies deemed relevant for this research, which were reviewed in other literature reviews. These technologies include, e.g., simulations, additive manufacturing, 3D printing or cyber-physical systems (Chen et al., 2020; Garay-Rondero et al., 2019; Pyun & Rha, 2021). Table 1 shows the DCs and technologies relevant for this paper.

Research Methodology

In this study, we followed the structured approach outlined by Denyer and Tranfield (2009) and Webster and Watson (2002) to conduct a SLR. To build a strong foundation for our research, we conducted a keyword-based search across four well-established academic databases: SCOPUS, Web of Science (WoS), EBSCO, and the AIS Electronic Library. The keywords, detailed in Table 2, were grouped into clusters, using "OR" within clusters and "AND" between them to refine the search results. To keep the focus on the most relevant literature, we limited our search to article titles, abstracts, and keywords, applying filters to include only journal articles and conference proceedings. Since databases function differently, we used the "all fields" filter for the AIS Electronic Library. Our search, conducted in July 2024, followed the inclusion and exclusion criteria outlined in Table 3. Our initial search retrieved 3,412 records. After removing 1,562 duplicates, we were left with 1,850 articles. We then screened the titles and abstracts, which led to the exclusion of 1,749 papers.

Infrastructure	
Internet of Things (IoT)	The IoT enables information transparency and real-time data sharing across the SC, using smart components to facilitate communication across processes (Chen et al., 2020; Lu et al., 2018). IoT is used in asset-intensive industries and requires more specialized systems while integrating fewer devices (Holtschulte, 2022).
Cyber-Physical Systems	Cyber-physical systems establish a production network and increase transparency by enhancing communication (Chen et al., 2020).
Engineering Technology	
Augmented/ Virtual Reality	Augmented reality enhances physical processes by overlaying digital contents such as 3D models or videos. This can be used in training or repair processes (Andres et al., 2024; Rüßmann et al., 2015). Virtual reality addresses the user directly and provides a digital experience with simulations (Andres et al., 2024).
Digital Twins	Digital twins use sensor data to build a virtual replica of the real world, such as machines or various processes. This enables testing of activities and assessing the possibility for errors or accidents that could occur in the real process (Andres et al., 2024; Holtschulte, 2022).
Collaborative Robots	Collaborative Robots are devices that can handle objects and process steps, while working next to or with humans without additional safety barriers (Andres et al., 2024).
Sensors	Sensors can monitor and processes their environment and translate the gathered data into digital information (Holtschulte, 2022).
Additive Manufacturing/ 3D printing	Additive manufacturing as a technology of I4.0 can be used to design or manufacture prototypes, spare parts or customized products, and components. This can be achieved with, for instance, 3D printing (Chen et al., 2020; Rüßmann et al., 2015).
Others	Other engineering technologies that cannot be classified in the categories could be robotics or autonomous robotics for assembly (ASCM, 2024; Garay-Rondero et al., 2019; Rüßmann et al., 2015).
Data Technology	
Business Intelligence	Business intelligences are methods, practices, or tools with focus on generating information to improve decision making in companies (Andres et al., 2024).
Big Data Analytics	Big data analytics can store, process, and analyze large volumes of data from diverse sources and with varying characteristics (Andres et al., 2024).
Artificial Intelligence	Artificial intelligence technologies use a diverse range of techniques and models to learn, analyze data, make decisions, or provide services that other technologies or humans cannot process (Andres et al., 2024; Ayoubi et al., 2023).
Machine Learning	Machine learning is a variance of artificial intelligence and uses computers for predictions and decisions, thereby detecting patterns in data and learning on their own without previous programming of scenarios (Andres et al., 2024; ASCM, 2024).
Mathematical Programming Models	Mathematical programming is applied to model and solve problems in SC processes, using heuristics and information provided by users, as well as optimization techniques and algorithms (Andres et al., 2024).
Hybrid Intelligence	Hybrid intelligence integrates human abilities and artificial intelligence, resulting in improved outcomes and continuous enhancement of each of their results (Andres et al., 2024).
Others	Other data technologies relevant from literature could be simulations that mirror the real world, e.g. machine activities (Garay-Rondero et al., 2019; Rüßmann et al., 2015).
Communication Technology	
Blockchain	Blockchain is decentralized and records data from every transaction in the SC in blocks with time stamps and organizes them chronologically (Andres et al., 2024; Yasanur, 2021).
Cloud/ Edge Computing	Cloud or edge computing is customer-oriented and serves as an infrastructure for storing data without the need for hardware. It uses technical interfaces to provide services such as platforms, software, or information infrastructure (Andres et al., 2024; Holtschulte, 2022).
Platforms	Platforms enable centralization of data and communication across the SC in addition to sharing information internal or with customers (Perano et al., 2023; Pyun & Rha, 2021).
Real-time Information Systems/ RFID Tracking	RFID tags can be used to track materials or products across the SC and provide data. They also can be utilized as an identification tool (Andres et al., 2024; Holtschulte, 2022). Real-time information systems are a broader technology also providing end-to-end visibility in processes (Pyun & Rha, 2021).
Others	Other communication technologies could be information and communication technologies, that encompass a broad spectrum of technologies for communication (Barreto et al., 2017; Pradhan et al., 2020).

Table 1. Digital Concepts and Reviewed Technologies

After assessing 101 full-text articles, 29 were identified as potentially relevant (Figure 1). To make sure we didn't miss important studies, we conducted a backward and forward search, as per Webster and Watson (2002). The backward search, which involved checking the references of the selected papers, added four more studies. Meanwhile, the forward search, conducted via SCOPUS, identified 10 additional relevant papers by tracking citations of the selected articles. This brought our final number of included studies to 43. Figure 1 provides a visual breakdown of our selection process, illustrating how we refined our search at each stage. By following this systematic approach, we ensured that our review covers a wide range of high-quality research, forming a strong and reliable foundation for our study.

Supply Chain	Sustainability	Digital Concepts	Influence
"supply chain*" OR SCM OR logistic*	"triple bottom line" OR sustainab* OR green	smart OR digital*	impact* OR influenc* OR performance

Table 2. Keywords for Database Search

Inclusion Criteria	**Exclusion Criteria**
- English language - Studies with focus on digital technologies or concepts - Studies with focus on the SC or logistic - Studies examining the implications for sustainability (environmental, social, economic) - Studies from 2018 to 2024	- Studies that are not peer-reviewed or with low quality (no clear citation, etc.) - Non-academic papers - Literature review or bibliometric analysis - Mathematical models and frameworks with estimations/ statements and no empirical data to support the statements

Table 3. Inclusion and Exclusion Criteria

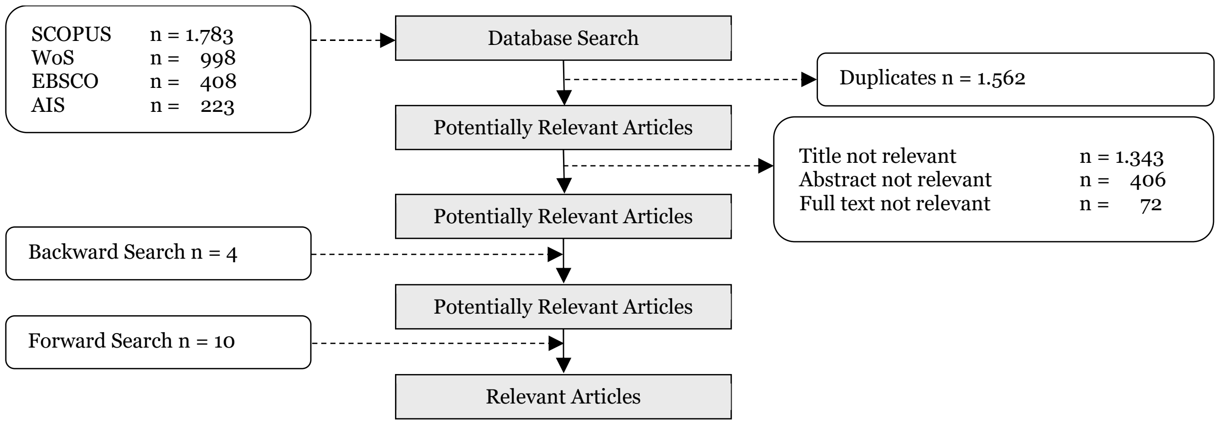

Figure 1. Results of the Selection and Evaluation Process

Results

This SLR employs a concept-centric approach to analyze the impact of digital technologies. The reviewed studies focus on four key DCs: Infrastructure, Engineering Technology, Data Technology, and Communication Technology. Table 4 shows that among digital technologies, communication technology is the most extensively studied (n=52), covering cloud and edge computing (n=16), blockchain (n=15), real-time information systems and RFID tracking (n=11), and digital platforms (n=7). Engineering technologies rank second (n=47), with particular focus on sensors (n=15) and additive manufacturing or 3D printing (n=10). Other topics include digital twins (n=4), augmented and virtual reality (n=3), and collaborative robots (n=2). Data technologies are also ranked second (n=47), particularly big data analytics (n=25) and artificial intelligence (n=15), while machine learning (n=1) and other data-related fields (n=6) remain underexplored. Notably, business intelligence, mathematical models, and hybrid intelligence, initially outlined by Andres et al. (2024), are absent from the reviewed publications. Infrastructure technologies rank fourth (n=31), with an emphasis on the Industrial Internet of Things (n=23) and cyber-physical systems (n=8).

Table 5 shows that environmental sustainability is the most frequently explored dimension (n=39), while economic (n=30) and social (n=24) sustainability receive comparatively less attention. A small number of studies (n=3) consider sustainability impacts without specifying a particular dimension.

Key examples of DC's impacts, differentiated by the sustainability dimension, are listed in the following. Please note that a detailed overview of the number of papers per impact can be found in our Digital Appendix. Environmental sustainability focuses on reducing resource consumption and improving efficiency. Many studies highlight efforts to minimize the use of natural resources (n=18) and hazardous materials (n=7). Reducing energy requirements and consumption is also widely explored (n=16). Additionally, research examines the adoption of renewable energy sources (n=4) and waste reduction strategies (n=21), including recycling and responsible waste management (n=9). Emissions-related factors, such as lowering greenhouse gas emissions (n=12) and reducing fuel consumption (n=2), play a crucial role in environmental sustainability. Other considerations include land use, pollution control, and preventing environmental accidents (n=5).

Economic sustainability factors revolve around financial performance and cost efficiency. Studies explore the impact of sustainability on product pricing (n=2), market access (n=1), and revenue growth (n=11). Cost reductions in operations, procurement, and logistics are commonly reviewed (n=8). Additionally, optimizing asset utilization (n=2) and improving customer satisfaction and brand reputation (n=3) contribute to economic stability. Some studies highlight the financial benefits of sustainable practices, e.g., lower insurance premiums and reduced waste disposal costs (n=3). Social sustainability covers workplace safety, employee well-being, and community impact. Research evaluates improvements in working conditions (n=10), accident prevention (n=7), and health and safety (n=3). Employee satisfaction, job security, and professional development opportunities are also considered (n=4).

Some studies address sustainability benefits without specifying a dimension (n=3). These include waste reduction, and energy efficiency. Overall, sustainability research provides valuable insights into balancing environmental responsibility, economic growth, and social well-being.

Infrastructure	Internet of Things	Al-Khatib (2023); Bhatti et al. (2023); Chiarini (2021); De Vass et al. (2021); Ghadge et al. (2022); Hmamed et al. (2024); Joshi & Sharma, (2022); Karmaker et al. (2023); Kayikci (2018); Kumar et al. (2024); Li et al. (2020); Lopes De Sousa Jabbour et al. (2022); Ma et al. (2023); Metwally et al. (2024); Nara et al. (2021); Ojo et al. (2019); Padidar et al. (2022); Prapinit et al. (2024); Sahoo & Upadhyay (2024); Shee et al. (2021); Umar et al. (2022a); Umar et al. (2022b); Wynn & Jones (2022)	n=23
	Cyber-Physical Systems	Bhatti et al. (2023); Bortolotti et al. (2023); Braccini & Margherita (2018); Ghadge et al. (2022); Kermanshah et al. (2020); Nara et al. (2021); Ojo et al. (2019); Umar et al. (2022b)	n=8
Engineering Technology	Augmented / Virtual Reality	Chiarini (2021); Kayikci (2018); Sahoo & Upadhyay (2024)	n=3
	Digital Twins	Kim et al. (2021); Metwally et al. (2024); Singh et al. (2023); Wynn & Jones (2022)	n=4
	Collaborative Robots	Chiarini (2021); Nara et al. (2021)	n=2
	Sensors	Ahmad Amouei et al. (2023); Al-Khatib (2023); Bortolotti et al. (2023); Chiarini (2021); Hernández et al. (2024); Hemmati et al. (2022); Kayikci (2018); Lopes De Sousa Jabbour et al. (2022); Mastos et al. (2020); Nara et al. (2021); Ojo et al. (2019); Padidar et al. (2022); Sahoo & Upadhyay (2024); Shee et al. (2021); Tao & Chao (2024)	n=15
	Additive Manufacturing/ 3D Printing	Bhatti et al. (2023); Chiarini (2021); Ghadge et al. (2022); Joshi & Sharma (2022); Kayikci (2018); Kumar et al. (2024); Lopes De Sousa Jabbour et al. (2022); Nara et al. (2021); Sahoo & Upadhyay (2024); Wynn & Jones (2022)	n=10
	Others	Bhatti et al. (2023); Braccini & Margherita (2018); Chiarini (2021); Ghadge et al. (2022); Hemmati et al. (2022); Junge & Straube (2020); Karmaker et al. (2023); Kayikci (2018); Kumar et al. (2024); Nantee & Sureeyatanapas (2021); Ojo et al. (2019); Padidar et al. (2022); Wynn & Jones (2022)	n=13
Data Technology	Big Data Analytics	Ahmad Amouei et al. (2023); Bhatti et al. (2023); Chiarini (2021); Chienwattanasook et al. (2022); Gallo et al. (2023); Ghadge et al. (2022); Hemmati et al. (2022); Hernández et al. (2024); Hmamed et al. (2024); Joshi & Sharma (2022); Karmaker et al. (2023); Kayikci (2018); Khan et al. (2022); Kumar et al. (2024); Li et al. (2020); Lopes De Sousa Jabbour et al. (2022); Ma et al. (2023); Metwally et al. (2024); Nara et al. (2021); Ojo et al. (2019); Sahoo & Upadhyay (2024); Tao & Chao (2024); Umar et al. (2022a); Umar et al. (2022b); Wynn & Jones (2022)	n=25
	Artificial Intelligence	Bhatti et al. (2023); Chiarini (2021); Gallo et al. (2023); Hemmati et al. (2022); Hernández et al. (2024); Hmamed et al. (2024); Joshi & Sharma (2022); Karmaker et al. (2023); Khan et al. (2022); Kumar et al. (2024); Ma et al. (2023); Ojo et al. (2019); Sahoo & Upadhyay (2024); Umar et al. (2022b); Wynn & Jones (2022)	n=15
	Machine Learning	Sahoo & Upadhyay (2024)	n=1
	Others	Braccini & Margherita (2018); Chiarini (2021); Junge & Straube (2020); Lopes De Sousa Jabbour et al. (2022); Nantee & Sureeyatanapas (2021); Padidar et al. (2022)	n=6
Communication Technology	Blockchain	Bhatti et al. (2023); Camel et al. (2024); Ghadge et al. (2022); Hernández et al. (2024); Hmamed et al. (2024); Jasrotia et al. (2024); Karmaker et al. (2023); Khan et al. (2022); Ma et al. (2023); Metwally et al. (2024); Rehman Khan et al. (2022); Umar et al. (2022a, 2023); Umar et al. (2022b); Wynn & Jones (2022)	n=15
	Cloud/Edge Computing	Bhatti et al. (2023); Chiarini (2021); Ghadge et al. (2022); Hernández et al. (2024); Joshi & Sharma (2022); Junge & Straube (2020); Kayikci (2018); Li et al. (2020); Ma et al. (2023); Mastos et al. (2020); Metwally et al. (2024); Nara et al. (2021); Ojo et al. (2019); Sahoo & Upadhyay (2024); Umar et al. (2022a); Wynn & Jones (2022)	n=16
	Platforms	Ahmad Amouei et al. (2023); Camel et al. (2024); Li et al. (2020); Mastos et al. (2020); Padidar et al. (2022); Sahoo & Upadhyay (2024); Wynn & Jones (2022)	n=7
	Real-Time Information Systems/ RFID Tracking	Al-Khatib (2023); Chiarini (2021); Efimova & Saini (2023); Kermanshah et al. (2020); Kim et al. (2021); Lopes De Sousa Jabbour et al. (2022); Mastos et al. (2020); Ojo et al. (2019); Padidar et al. (2022); Prapinit et al. (2024); Shee et al. (2021)	n=11
	Others	Efimova & Saini (2023); Junge & Straube (2020); Shee et al. (2021)	n=3

Table 4. DC by Technology – Classifying the Reviewed Articles

Discussion of Impacts

To address the second RQ, this section explores how various DCs impact environmental, social, and economic dimensions. DCs are widely implemented across SCs. Among infrastructure, the Internet of Things (IoT) and cyber-physical systems are crucial DCs that enhance collaboration, productivity, and visibility in SCs (De Vass et al., 2021; Ma et al., 2023). IoT positively impacts all sustainability dimensions, though its primary effects are environmental and economic (Ghadge et al., 2022; Kumar et al., 2024; Li et al., 2020). When combined with other digital solutions and green practices, its impact is even more substantial (Chiarini, 2021; Karmaker et al., 2023). Cyber-physical systems facilitate real-time monitoring and operational flexibility in smart manufacturing, especially when integrated with sustainable production strategies (Bortolotti et al., 2023; Braccini & Margherita, 2018). However, social impact has received limited research (Ghadge et al., 2022).

Engineering technologies, including augmented reality, digital twins, and collaborative robotics, mainly enhance manufacturing and logistics sustainability. Augmented reality improves economic outcomes but has mixed environmental effects due to limited adoption and knowledge gaps (Chiarini, 2021; Kayikci, 2018). Digital twins optimize production efficiency and reduce waste, reinforcing circular economy initiatives (Kim et al., 2021; Singh et al., 2023). Collaborative robotics improve productivity and safety, yet their energy consumption raises concerns about their environmental footprint (Chiarini, 2021; Nara et al., 2021). Sensors and automation technologies are widely used to enhance efficiency, though their direct social impacts remain underexplored (Lopes De Sousa Jabbour et al., 2022; Tao & Chao, 2024).

Data technologies, particularly big data analytics and artificial intelligence (AI), are extensively studied. Big data analytics and AI significantly contribute to sustainability by improving data collection, predictive analytics, and decision-making (Chiarini, 2021; Sahoo & Upadhyay, 2024). AI supports green SC collaboration, particularly when integrated with circular economy initiatives (Gallo et al., 2023; Kumar et al., 2024). However, some companies hesitate to implement AI due to uncertainty about its sustainability impact (Chiarini, 2021).

	Sustainability				Digital Concepts			
	Not specified	Environmental	Social	Economic	Infrastructure	Engineering Technology	Data Technology	Communication Technology
Braccini & Margherita (2018)		•	•	•	•	•	•	
Kayikci (2018)		•	•	•	•	•	•	•
Ojo et al. (2019)		•	•	•	•	•	•	•
Junge & Straube (2020)		•	•			•	•	•
Kermanshah et al. (2020)		•	•	•	•			•
Li et al. (2020)		•		•	•		•	•
Mastos et al. (2020)		•	•	•		•		•
Chiarini (2021)		•			•	•	•	•
De Vass et al. (2021)		•	•	•	•			
Kim et al. (2021)		•	•	•		•		•
Nantee & Sureeyatanapas (2021)		•	•	•		•	•	
Nara et al. (2021)		•	•	•	•	•	•	•
Shee et al. (2021)		•	•	•	•	•		•
Chienwattanasook et al. (2022)	•						•	
Ghadge et al. (2022)		•		•	•	•	•	•
Hemmati et al. (2022)		•	•	•		•		•
Joshi & Sharma (2022)		•	•	•	•	•	•	•
Khan et al. (2022)		•		•			•	•
Lopes De Sousa Jabbour et al. (2022)		•	•	•	•	•	•	•
Padidar et al. (2022)		•			•	•	•	•
Rehman Khan et al. (2022)		•		•				•
Umar et al. (2022a)		•		•	•		•	•
Umar et al. (2022b)		•	•	•	•		•	•
Wynn & Jones (2022)	•				•	•	•	•
Al-Khatib (2023)		•	•	•	•	•		•
Ahmad Amouei et al. (2023)		•	•	•		•	•	•
Bhatti et al. (2023)		•			•	•	•	•
Bortolotti et al. (2023)		•	•	•	•	•		
Efimova & Saini (2023)		•						•
Gallo et al. (2023)		•					•	
Karmaker et al. (2023)		•	•	•	•	•	•	•
Ma et al. (2023)		•	•	•	•		•	•
Singh et al. (2023)		•				•		
Umar et al. (2023)			•	•				•
Camel et al. (2024)		•		•				•
Hernández et al. (2024)		•				•	•	•
Hmamed et al. (2024)		•	•	•	•		•	•
Jasrotia et al. (2024)		•						•
Kumar et al. (2024)		•		•	•	•	•	
Metwally et al. (2024)		•			•	•	•	•
Prapinit et al. (2024)	•				•			•
Sahoo & Upadhyay (2024)		•	•	•	•	•	•	•
Tao & Chao (2024)		•	•	•		•	•	
n=	3	39	24	30	26	27	28	34

Table 5. Concept Matrix

Communication technology is the most extensively studied DC. Communication technologies enable monitoring and communication across the SC, facilitating interactions within processes or plants and across borders, both upstream and downstream. Blockchain, cloud computing, and real-time tracking systems facilitate SC transparency and efficiency. Blockchain enhances trust and sustainability by providing secure data sharing (Camel et al., 2024; Hernández et al., 2024), while cloud computing centralizes information, improving productivity and reducing resource use (Ojo et al., 2019; Sahoo & Upadhyay, 2024). A variety of studies indicate that this DC should be combined with or support other DCs to leverage their effects and have an impact on environmental or all sustainability dimensions (e.g., Chiarini, 2021; Nara et al., 2021). RFID tracking and real-time information systems further optimize logistics, minimizing carbon emissions through better route planning (Al-Khatib, 2023; Efimova & Saini, 2023). In summary, digital technologies offer significant potential to enhance sustainability in SCs. However, their effectiveness often depends on integration with complementary technologies.

Conclusion, Limitations and Outlook

Sustainability has become an increasingly important focus in recent years, especially with the growing integration of digital technologies into SC processes. These advancements have highlighted their implications across environmental, social, and economic dimensions of sustainability. This review contributes significantly to the research field in several ways. First, it provides an in-depth analysis of DCs and their role in shaping sustainability within the SC. By clustering relevant technologies into DCs, this study finds that most of these technologies have a generally positive impact on sustainability. However, some concerns persist regarding potential negative effects, with studies showing mixed findings. Notably, firms adopting circular economy principles or green practices tend to enhance the sustainability benefits of these technologies.

Second, this review identifies the key DCs that influence sustainability. Among them, big data analytics emerges as the most impactful technology, driving data-driven decision-making. The IoT serves as a crucial infrastructure technology, while cloud and edge computing offer extensive communication capabilities. Additionally, sensors play a critical role in engineering applications. Each of these technologies presents unique value for both researchers and industry professionals. Third, this review uncovers opportunities for further enhancing sustainability. Technologies such as augmented and virtual reality can improve social sustainability by enhancing employee training, risk assessments, and knowledge-intensive tasks. Digital twin technology also holds promise beyond manufacturing, particularly when integrated with blockchain, AI, and sensors. This integration can optimize processes, improve efficiency, and drive environmental and economic benefits. Furthermore, collaborative robotics can enhance workplace safety and product quality, while greater emphasis on social sustainability, whether through company initiatives or targeted technology adoption, can yield broader benefits. However, our study shows that the impact of DCs on social sustainability remains understudied. Therefore, future research should focus on the impact of digitalization on social sustainability.

Despite the potential benefits, it is essential to consider the risks associated with DCs. Concerns include increased energy consumption due to data centers supporting these technologies, lifecycle costs, and potential rebound effects. One of the most common concerns is energy consumption, for example in data centers (Chen et al., 2020a; Chiarini, 2021; Umar et al., 2023). However, the electricity mix used needs to be considered when quantifying. In the current literature, no attention has been paid to the possibility of privacy disruption for employees when reviewing the social factors analyzed. Privacy concerns arise with tracking technologies, as employees may perceive monitoring efforts as intrusive. Furthermore, the disruptions to the labor market caused by digitalization (e.g., job losses and the need for new skills) have not been considered in the literature reviewed. Future research should explore how change management strategies can mitigate these concerns and foster acceptance.

Several limitations of this study should be acknowledged. While measures were taken to minimize bias, some may persist due to the exclusion of grey literature, reports, and books. Additionally, certain technologies were underrepresented in the reviewed literature, raising questions about their relevance or omission from the database search. Future research should investigate the collaborative effects in SCs of different technologies within and across DCs. Thereby, researchers and practitioners can expand their understanding of sustainable technology implementation and its potential to enhance environmental, social, and economic outcomes across the SC.

Link to Our Digital Appendix

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