Research Article

Digital Literacy as an Enabler of Circular Economy Adoption in SMEs: A Systematic Literature Review

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Abstract

Digitalization is increasingly recognized as a catalyst for sustainability, yet the specific role of digital literacy in enabling small and medium enterprises (SMEs) to adopt circular economy (CE) models remains poorly understood. This systematic literature review examines how digital literacy influences CE adoption among SMEs. Searches were conducted in Google Scholar using predefined Boolean queries, yielding forty records, of which five peer-reviewed journal articles met the inclusion criteria of focusing on SMEs, digital capability, and circular economy practices. Studies included quantitative, qualitative, and bibliometric designs and were appraised using the Joanna Briggs Institute (JBI) Critical Appraisal Tools. The synthesis shows that digital literacy functions as a strategic organizational capability operating across operational, innovation, and ecosystem pathways that shape SMEs' readiness and ability to implement CE. However, the evidence base remains fragmented, with digital literacy frequently measured indirectly through varied proxies such as fintech adoption, digital transformation readiness, or digital marketing capability. The small number of eligible studies and heterogeneity in conceptualization limit the generalizability of findings. Overall, the review highlights digital literacy as a foundational enabler of circular transitions in SMEs and underscores the need for clearer operational definitions, longitudinal evidence, and

comparative research to advance theory, policy, and practice in digital-circular transformation.

Keywords: digital literacy; circular economy; systematic literature review

INTRODUCTION

The accelerating digital transformation among small and medium enterprises (SMEs) is significantly reshaping business operations and aligning with global efforts to transition towards circular economy models. Information and Communication Technologies (ICT) have evolved from mere operational tools to strategic enablers of innovation and sustainability, facilitating the integration of circular economy practices within SMEs (Sivaiah & Vinodan, 2025). Digital technologies, such as blockchain for material traceability and platforms for asset sharing, are pivotal in optimizing resource use and extending product life cycles, thereby supporting circular economy objectives (Han et al., 2023). The integration of digital and circular economy strategies enhances innovation within SMEs, although the degree of digitalization required varies among enterprises (Arroyabe et al., 2024). Despite the potential of Industry 4.0 technologies to expedite circular transitions, SMEs often face challenges due to limited resources and a digital divide (Neri et al., 2023). A systematic literature review highlights the need for frameworks that address technological, financial, societal, and institutional influences on transitioning to circular business models, emphasizing the importance of a balanced approach to digital and circular economy integration (Kuik et al., 2023). The digital economy, characterized by the deep integration of data resources, plays a crucial role in transforming traditional sectors and optimizing resource allocation, which is essential for SMEs to remain competitive and sustainable (Philbin et al., 2022). However, SMEs still encounter barriers such as insufficient awareness and a lack of comprehensive implementation strategies for circular economy practices (Palombi et al., 2024). The transition to circular business models requires ongoing shifts in business management strategies, and digital technologies provide a structured path for SMEs to evolve towards circularity (Perotti et al., 2024). Moreover, the global shift towards more resilient and sustainable supply chains, driven by technological change and digitalization, presents both opportunities and challenges for SMEs, necessitating supportive policy environments to facilitate their integration into global value chains ("SMEs in more resilient, sustainable and...", 2023). Overall, the synergy between digital transformation and circular economy practices offers SMEs a pathway to enhance innovation, sustainability, and competitiveness in a rapidly evolving global market.

Digital literacy, encompassing the ability to effectively use, interpret, and integrate digital technologies, is crucial for organizations aiming to adopt circular economy practices. This competence enables firms to enhance resource efficiency, reduce waste, and innovate sustainably. Digital technologies such as IoT, AI, and blockchain are pivotal in transforming traditional linear economic models into circular ones by optimizing resource use and improving sustainability practices. The integration of these technologies into organizational processes facilitates the

transition to a circular economy, offering numerous benefits and opportunities for innovation.

Role of Digital Technologies in Circular Economy

Resource Optimization and Efficiency: Digital technologies enable organizations to optimize resource use, thereby increasing productivity and reducing waste. For instance, the adoption of digital platforms for asset sharing and product-as-a-service models can significantly enhance resource productivity, potentially increasing it by 15% by 2030 and reducing CO_2 emissions by 7.5% (Patwa et al., 2025).

Lifecycle Monitoring and Assessment: Technologies such as IoT and big data analytics allow for continuous monitoring and assessment of product lifecycles, ensuring efficient resource use and waste reduction. These tools provide insights into the entire value chain, facilitating better decision-making and enhancing sustainability practices (Emon & Khan, 2024).

Traceability and Transparency: Blockchain technology offers traceability and transparency in material flows, which is essential for closing material loops and ensuring the integrity of circular practices. This technology provides security and reliability, which are crucial for implementing effective circular economy strategies (Carlos et al., 2024).

Innovation in Product Design: Digital tools support the design of products that are easier to recycle, repair, and reuse, thus extending their lifecycle and reducing environmental impact. This innovation is critical for transitioning to a circular economy, as it aligns product design with sustainability goals (Suchek et al., 2021).

Challenges and Opportunities

Implementation Challenges: Despite the potential benefits, many organizations face challenges in effectively implementing digital technologies for circular economy practices. These include knowledge gaps and the need for new business models and management practices to support the transition (Leipziger et al., 2024).

Opportunities for Innovation: The integration of digital technologies presents opportunities for innovation in sustainable practices. By leveraging these technologies, organizations can develop new business models that align with circular economy principles, fostering sustainable growth and competitiveness (Țurcan et al., 2023).

While digital literacy is essential for adopting circular practices, it is also important to consider the broader context of organizational change and innovation. The transition to a circular economy requires not only technological integration but also a shift in organizational culture and strategy. Companies must be willing to adapt their business models and processes to fully realize the benefits of digital technologies in promoting sustainability. Additionally, collaboration between policymakers, businesses, and researchers is crucial to scale digital solutions and ensure long-term sustainability in a resource-conscious world (Roy, 2025).

The integration of digitalization into sustainability efforts, particularly within the framework of the circular economy, is increasingly recognized as a critical factor

for fostering sustainable business practices, yet the literature remains fragmented in its conceptualization of digital literacy and its empirical impact on small and medium enterprises (SMEs). Digital technologies such as blockchain, IoT, and AI are pivotal in enhancing traceability, efficiency, and resource optimization, thereby facilitating the transition from linear to circular economic models (Mamudu et al., 2024). However, the adoption of these technologies by SMEs is hindered by limited resources and a digital divide, which complicates their ability to fully leverage digital tools for circular economy practices (Neri et al., 2023). Empirical studies, such as those involving German manufacturing firms, suggest that a strong digital focus can significantly drive the implementation of circular business models, although this is not yet widespread among SMEs (Neligan et al., 2023). The role of digitalization extends beyond technical enablement; it acts as a catalyst for systemic change, influencing consumer behavior and policy reform, which are crucial for the adoption of circular economy principles (Bücker et al., 2025). Despite the potential of digital tools to support sustainability strategies, there is a notable gap in understanding how these technologies specifically advance SMEs' sustainability objectives, with existing research often overlooking the unique challenges faced by these enterprises (Alabi et al., 2025). Moreover, the relationship between digitalization and circular economy practices is still nascent, with empirical evidence sparse and fragmented, particularly concerning the moderating role of firm size in the adoption of digital technologies for sustainability (Hernández et al., 2024). The current literature underscores the need for a more integrated theoretical framework and targeted research to address these gaps, enabling SMEs to effectively harness digitalization for sustainable innovation and circular economy adoption (Sivaiah & Vinodan, 2025).

The nexus between digital literacy and the circular economy within the context of SMEs is a multifaceted topic that requires a comprehensive understanding of various empirical and conceptual insights. The systematic literature reviews conducted across multiple studies highlight the critical role of digital technologies in facilitating the transition to a circular economy (CE) by enabling data generation, processing, and analysis, which optimize production and reduce resource use (Cagno et al., 2021). However, SMEs face significant challenges in adopting these technologies due to limited resources and expertise, which are compounded by low digital literacy levels, particularly in rural areas (Ollerenshaw et al., 2021). The integration of local wisdom and pentahelix collaboration, involving government, academia, businesses, communities, and media, has been suggested as a strategy to enhance the competitiveness and sustainability of rural SMEs by improving digital literacy and fostering innovation (Dahmiri et al., 2023). Furthermore, the thematic reviews reveal that while the CE concept is gaining traction, its adoption among SMEs is hindered by economic and political barriers, such as a lack of financial resources and incentives (Ahmadov et al., 2025). The multi-level perspective (MLP) framework is proposed to address these challenges by considering factors at the micro, meso, and macro levels, thereby empowering SMEs and other stakeholders to effectively drive the CE transition (Ahmadov et al., 2025). Despite the growing body of literature, there remains a need for an integrated and holistic analysis of the relationships between digital technologies and CE practices, as well as empirical investigations into

decision-making processes and specific CE practices (Cagno et al., 2021). The development of a theoretical framework that articulates these elements could serve as a basis for SMEs, translating the transition to a CE as a path of sustainable organizational growth (Fontoura et al., 2024). Overall, enhancing digital literacy and fostering a paradigm shift in circular thinking at the micro level are essential for SMEs to fully realize the potential of CE practices and contribute to a more sustainable future (Ibrahim & Aduah, 2025).

Digital literacy plays a pivotal role in the adoption of circular economy (CE) business models among micro, small, and medium enterprises (MSMEs) by facilitating the integration of digital technologies that enhance operational efficiency and sustainability. The intersection of digitalization and CE is crucial, as digital technologies optimize processes, foster innovation, and improve the sustainability of circular practices, thereby having a positive impact on both economic and environmental aspects (Turcan et al., 2023). Despite the potential of digital technologies like Industry 4.0 to expedite CE transformation, MSMEs often face challenges due to limited resources and a digital divide, which hinders comprehensive implementation strategies (Neri et al., 2023). Digital literacy is essential for MSMEs to navigate the digital marketplace effectively, as it enables them to leverage technological advancements for economic growth and sustainability (Ibrahim & Aduah, 2025). In Indonesia, for instance, digital economic literacy has been shown to significantly increase revenues for SMEs, yet a substantial portion of these enterprises still struggle with basic digital marketing capabilities (Al-Shami et al., 2024). The adoption of digital technologies in circular business practices is further supported by structured pathways that guide MSMEs through their transition to circularity, highlighting the importance of digital tools in shaping and refining circular products and processes (Perotti et al., 2024). However, the relationship between digital transformation and CE is complex, as digital technologies can act as both facilitators and barriers, depending on how they are integrated into business models (Försterling et al., 2023). Therefore, enhancing digital literacy among MSMEs is critical to overcoming these barriers and enabling the successful adoption of CE practices, which in turn contributes to a more sustainable future (Mishra et al., 2024). Overall, digital literacy not only empowers MSMEs to adopt circular economy models but also ensures their long-term viability and competitiveness in the digital era.

The integration of digital capabilities within Small and Medium-sized Enterprises (SMEs) is increasingly recognized as a critical factor in advancing circular economy (CE) practices, which aim to promote sustainable development by optimizing resource use and minimizing waste. Several studies highlight the role of digital technologies, such as cloud computing, 3D printing, and blockchain, in enabling SMEs to implement CE principles effectively. For instance, cloud computing facilitates sustainable business processes by supporting the Circular Approach to Business Practices (CABP), thereby enhancing the competitive advantage of SMEs through improved resource management and operational efficiency (Natrajan et al., 2024). Similarly, digitalization in the agrifood sector, exemplified by digitized closed-loop hydroponic cultivation, optimizes resource use and minimizes waste, demonstrating the potential of digital technologies to drive CE adoption (Farace &

Tarabella, 2024). Furthermore, the integration of digital and CE strategies is shown to catalyze innovation within SMEs, with those achieving a balanced integration more likely to innovate and improve their environmental impact (Arroyabe et al., 2024). The resource-based view combined with ambidexterity perspectives suggests that SMEs need specific digital and circular resources and capabilities to provide value to customers, highlighting the importance of adaptive and exploratory capabilities in leveraging digital technologies for CE initiatives (Chaudhuri et al., 2022). Despite these advancements, challenges remain, such as the need for empirical testing of CE frameworks and the integration of digital technologies across different sectors to fully realize system-wide benefits. Additionally, the variability in digital and CE integration among SMEs suggests that tailored strategies are necessary to address the unique needs and capabilities of different enterprises (Arroyabe et al., 2024). Overall, the synthesis of these studies underscores the transformative potential of digital capabilities in enhancing CE practices among SMEs, while also identifying areas for further research and development to overcome existing barriers and optimize the benefits of digital-CE integration.

The synthesis of frameworks, terminologies, and empirical findings from the provided papers reveals a conceptual model that elucidates the mechanisms linking digital literacy to circular economy (CE) adoption, while also identifying critical gaps for future research and policy design. The integration of digital technologies with CE principles is a burgeoning area of research, as highlighted by Okorie et al., who propose a synergistic framework combining Industry 4.0 and CE to guide future research and policy directions. This integration is crucial for small and medium-sized enterprises (SMEs), which face unique challenges in transitioning to a CE due to limited resources and expertise. Ahmadov et al. emphasize the importance of a multi-level perspective (MLP) framework to understand the dynamics of CE transition within SMEs, providing practical recommendations for overcoming these challenges (Ahmadov et al., 2023). Furthermore, Medaglia et al. explore the role of digital government in facilitating CE transitions, identifying gaps in the current understanding of how digital technologies can support CE initiatives across different stages of the product life cycle (Medaglia et al., 2024). In the built environment, Aral et al. highlight the regional variations in digital technology adoption, underscoring the need for tailored strategies to accelerate CE implementation. Liu et al. propose a framework identifying critical digital functions that enhance CE strategies, revealing gaps in empirical and theoretical research that need addressing. The connection between CE and sustainable development goals (SDGs) is also explored, with Yaroson et al. linking CE strategies to SDGs, thereby providing a framework for organizations to enhance sustainable business performance (Yaroson et al., 2023). Farahmand and Rahimiaghdas identify barriers and drivers of CE transformation, emphasizing the need for comprehensive implementation strategies that integrate digital technologies (Farahmand & Rahimiaghdas, 2024). The potential of Industry 4.0 technologies to enable CE principles is further explored, with a focus on new value chain characteristics and operations models that support circular design and collaboration ("How can Digitalisation Enable the Transi...", 2022). Finally, Sehnem et al. identify megatrends in CE research, highlighting the need for more rigorous empirical studies

to build CE-specific theories and address existing research gaps (Sehnem et al., 2021). Collectively, these studies provide a comprehensive overview of the current state of research on digital literacy and CE, offering a conceptual model that clarifies the mechanisms linking the two and identifying critical areas for future exploration.

METHODS
Research Design and Review Framework

This study employed a Systematic Literature Review (SLR) approach to synthesize empirical and conceptual evidence on how digital literacy influences the adoption of circular economy (CE) models among micro, small, and medium enterprises (MSMEs/SMEs). The SLR followed a transparent, replicable, and theory-driven protocol consistent with PRISMA guidelines and was structured using the SPIDER framework (Sample, Phenomenon of Interest, Design, Evaluation, Research type). The SPIDER framework was selected because of its suitability for mixed empirical and qualitative evidence, allowing the review to capture diverse methodological traditions within SME research, circular economy studies, and digital transformation scholarship. Based on the SPIDER components, the primary research question formulated for this review was: How does digital literacy influence the adoption of circular economy business models among micro, small, and medium enterprises (MSMEs)? This question guided all subsequent stages of the review process, including search strategy development, screening, appraisal, extraction, and synthesis.

Search Strategy Development

A comprehensive search strategy was designed to identify peer-reviewed journal articles addressing the intersection of digital literacy (or its operational proxies), digital transformation, and circular economy adoption by SMEs. To capture a broad yet relevant body of literature, the search query combined controlled keywords and Boolean operators without imposing title-specific restrictions. The final search string used across databases was:

("digital literacy" OR "digital skills" OR "digital readiness" OR "digital transformation") AND ("circular economy" OR "circularity" OR "sustainable business model" OR "green business model") AND (SMEs OR "small enterprises" OR "small business" OR "micro enterprises" OR UMKM).

The search was conducted on Google Scholar, which was selected for its inclusive coverage of peer-reviewed journals across business, sustainability, and digital innovation domains. Filters were applied to restrict the search to journal articles, open-access publications, and works written in English. This ensured accessibility, transparency, and alignment with the review's scope. The initial search yielded forty papers, forming the basis for subsequent screening.

Study Selection Process

The selection process followed a multi-stage filtering procedure. First, titles and abstracts of all forty retrieved papers were screened using predefined inclusion and exclusion criteria. Studies were included if they examined SMEs or micro-

enterprises, addressed some form of digital literacy or digital capability, and investigated circular economy adoption or related sustainable business transitions. Studies were excluded if they focused exclusively on large corporations, addressed digitalisation without relevance to CE, examined sustainability unrelated to circularity, or lacked peer-reviewed status.

Following title and abstract screening, seven papers remained eligible. Full-text assessment was performed on these papers, and five were successfully retrieved in complete form. These five papers were then evaluated using a standardized quality appraisal procedure. Only studies that met a minimum methodological rigor threshold based on the appraisal tools were retained, resulting in five high-quality papers included in the final synthesis.

Quality Appraisal

The methodological quality of each study was assessed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools (Aromataris et al., 2024). JBI was selected due to its applicability across qualitative, quantitative, conceptual, and mixed-method designs, which aligned with the heterogeneity of studies found in this review. Specific JBI checklists were applied according to study design, including analytical cross-sectional, qualitative research, mixed-methods, and text/opinion appraisal tools.

Two external validators independently assessed each paper to minimize bias. Appraisal involved evaluating clarity of aims, appropriateness of methodology, adequacy of data collection, validity of analysis, transparency of findings, and logical coherence between conclusions and evidence. Only papers deemed methodologically sound by both validators were included. All five studies met the required threshold and were retained for data extraction.

Data Extraction

A structured extraction procedure was applied to all five included studies. The extraction sheet captured core bibliographic, contextual, methodological, and conceptual elements relevant to the research question. Extracted components included authorship and publication year, research design, study location, population or sample characteristics, contextual focus, dependent variables or outcomes, key findings, and reported limitations. Two additional elements were included to enhance analytical depth: the operationalization of digital literacy within each study and the documented relationship between digital literacy and CE adoption. Table 1 illustrates the standardized extraction template applied across all studies.

Table 1. Standardized Data Extraction Template

Component	Description
Author (Year)	First author surname and publication year
Research Design	Type of design used (quantitative, qualitative, mixed, conceptual)
Study Location	Country or geographical context
Population	Sample characteristics (SMEs, sector, participants)
Context	Digital or circular economy conditions examined
Outcome / Dependent Variable	Key variables or outputs measured

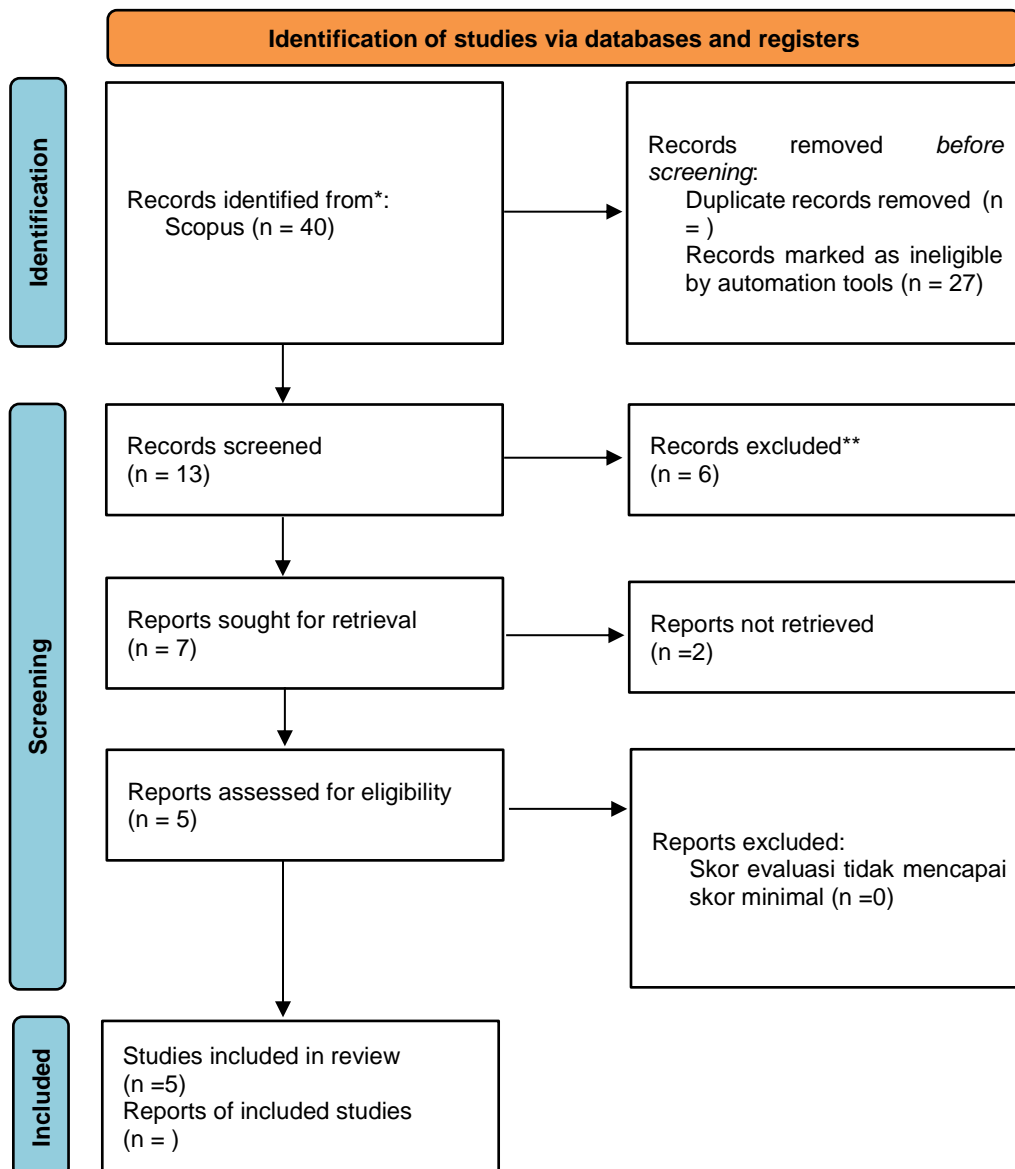| Findings	Principal results relevant to RQ
Limitations	Author-reported constraints
Operationalization of Digital Literacy	Conceptual or empirical representation of digital capability
Relationship to CE Adoption	How digital literacy influences or shapes CE processes

Data Synthesis Approach

The synthesis employed a qualitative thematic integration approach suitable for mixed bodies of evidence, allowing explicit comparison across quantitative findings, qualitative insights, and conceptual contributions. Since the five included studies varied considerably in design and theoretical orientation, a narrative synthesis was adopted to accommodate methodological heterogeneity while ensuring conceptual coherence.

The synthesis process involved iterative reading, coding, and clustering of extracted information into higher-order themes. These themes captured definitions and operationalizations of digital literacy, conceptualizations of circular economy adoption, mechanisms linking digital capabilities to CE practices, enabling and inhibiting conditions, methodological patterns, theoretical lenses used in prior research, and key research gaps. The integration process aimed not merely to summarize prior findings but to construct a conceptual explanation of how digital literacy functions as a strategic capability enabling SMEs to transition toward circular business models.

Construction of the Conceptual Model

The final step of synthesis involved integrating thematic insights into a conceptual model that reflects the mechanisms through which digital literacy influences circular economy adoption. This model emerged inductively from recurring patterns identified across the five studies. Digital literacy was found to operate along three reinforcing pathways: an operational pathway enabling efficiency and waste reduction, an innovation pathway supporting green entrepreneurship and product redesign, and an ecosystem pathway connecting SMEs to digital infrastructures, policy environments, and consumer-facing digital platforms.

The conceptual model derived from this synthesis forms the analytical backbone of the review's discussion section and proposes a unified perspective that bridges fragmented theoretical and empirical approaches in the literature.

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Identification of studies via databases and registers

Identification

Records identified from*:
Scopus (n = 40)

Records removed *before screening*:
Duplicate records removed (n =)
Records marked as ineligible by automation tools (n = 27)

Screening

Records screened
(n = 13)

Records excluded**
(n = 6)

Reports sought for retrieval
(n = 7)

Reports not retrieved
(n =2)

Reports assessed for eligibility
(n = 5)

Reports excluded:
Skor evaluasi tidak mencapai skor minimal (n =0)

Included

Studies included in review
(n =5)
Reports of included studies
(n =)

RESULT AND DISSCUSSION

Table 2. Extraction Results

No	Component	Extraction Results				
1	First author's last name (year)	Waqar (2025)	Chung (2025)	Sklavos (2024)	Megawati (2024)	Martín-Cervantes (2025)
2	Research Design	• Multi-case study of 4 SMEs in Kitakyushu, Japan • Semi-structured interviews (90–120 minutes) • Field observation and cross-verification among researchers	Qualitative – Multiple Case Study	Quantitative survey based on the Likert questionnaire 5 points	• Quantitative survey of 200 culinary SMEs in Surabaya • Analysis using PLS-SEM (SmartPLS 4)	Bibliometric scientometric analysis uses *Bibliometrix (R)*, PRISMA, and co-word analysis to map the research landscape of digital marketing & circular economy.
3	Research location	Pakistan (Lahore, Sialkot, Gujranwala, Wazirabad, Gujarat)	Japan (Kitakyushu City)	Yunani (Greece), Agrifood Sector	Indonesia (Surabaya City)	Not location-specific (global dataset). The focus of the analysis comes from international publications on the Scopus database. Indonesia is recorded as the most productive country.
4	Population/ Research subjects	340 respondents from MSME managerial staff	4 SMEs (Cases A–D), CEO/manager as informant	288 agrifood executives SMEs	200 culinary SME owners	276 scientific publications related to Digital Marketing & Circular Economy (2001–2024)
5	Treatment/C ontext studied	Fintech Adoption (FA) as a form of digital transformation; Circular Economy Practices (CEPs); Green Innovation (GI)	Digital Transformation (DX) journey in SMEs; focus on unintended consequences; DX's relationship with the CE ecosystem	Factors influencing *digital transformation* and *green entrepreneurship* in SMEs	Integrated policy framework: Circular Economy Policy (CEP), Digital Economy Policy (DEP), Social Security Policy (SSP); moderation by Innovation Capabilities	The connection between digital marketing (online marketing, internet marketing, electronic marketing, cybermarketing) and the circular economy, including themes such as

					consumer perception, micro-enterprises, and sustainable development.
6	Outcome / Dependent variable / Data collected	Environmental Sustainability Performance (ENSP) & Economic Sustainability Performance (ESP)	Does not use formal dependent variables; outcomes are unintended consequences themes: digital talent cost, power concentration, data standardization, increased complexity	Willingness toward digital transformation & green entrepreneurship	- Independent variables: - Circular Economy Policy (CEP) - Digital Economy Policy (DEP) - Social Security Policy (SSP) - Moderating variable: - Innovation Capabilities - Dependent variables: - Green Business Innovation (GBI) - Sustainable Business Performance (SBP)	- Publication volume, annual trends, citations. - Intellectual, social, thematic structure. - Identification of *motor themes, emerging themes, basic themes* related to DM–CE.
7	Research findings	Four main themes of unintended consequences were found (pages 6–7): - High digital talent cost - Digital power concentration - Data standardization challenges - Increased complexity	Four main themes of unintended consequences were found (pages 6–7): - High digital talent cost - Digital power concentration - Data standardization challenges - Increased complexity	Found 5 main factors that influence SMEs' readiness to adopt digital transformation and green entrepreneurship: (1) lack of digital HR skills and funding; (2) product innovation & consumer awareness; (3) sustainable materials & LCA; (4) executive training on circular economy; (5) executive knowledge related to ESG & green entrepreneurship	Significant Effects - CEP → GBI (t = 6.503, p < 0.001) - SSP → GBI (t = 3.848, p < 0.001) - GBI → SBP (t = 24.418, p < 0.001) Non-significant Effect DEP → GBI (t = 0.725, p = 0.468) → It means that digital economy policies have not been effective in boosting green innovation in SMEs.	- DM-CE research is still very new and fragmented. - Indonesia, China, India are the most productive countries. *Motor themes*: consumer perception, micro-enterprises, sustainable development (digital marketing in CE). Digital marketing has great potential to encourage the adoption of circular practices but lacks applicable research - There is no established theoretical framework;

		Most relevant to CE are that these consequences: • can hinder circular transformation, • create inequality in CE capabilities among SMEs, • strengthen the dominance of large companies in the CE supply chain	Most relevant to CE are that these consequences: • can hinder circular transformation, • create inequality in CE capabilities among SMEs, • strengthen the dominance of large companies in the CE supply chain.			international collaboration is still low.
8	Research limitations	Pakistan focus only → low generalizability; limited sample size; only considers ENSP & ESP (does not include social sustainability); other variables such as organizational culture or regulatory support have not been studied	The study only covered 4 SMEs in Japan → limited generalizability; all cases came from one city; did not differentiate digital maturity levels; did not assess CE outcomes quantitatively; risk of qualitative bias	Limitations on data control, use of focus groups that make data quality dependent on respondents' abilities; limited generalizability to the Greek agrifood sector	• Only covers culinary SMEs in Surabaya → limited generalizability • The quantitative approach does not yet explore the dynamics of CE adoption behavior • The internal innovation variable still does not fully reflect CE capabilities	• There is no universal definition of digital marketing, making it difficult to be consistent with keywords. • Only one database (Scopus). • Not using systematic procedures for keyword selection. • The field of research is still young so the results are temporary.
9	Data types & Data sources (additional components)	Digital literacy is operationalized through the variable *Fintech Adoption*—a representation of SMEs' digital capabilities in using fintech platforms, blockchain, digital	DX provides benefits (operational efficiency, cost reduction, SDG alignment), but it also produces unintended consequences that impact circular economy readiness:	PCA (Principal Component Analysis), Cronbach α reliability test, chi-square, descriptive statistics	Digital literacy is represented through the *Digital Economy Policy* which includes digital skills training, digital platform support, digital payment integration, cybersecurity protection for SMEs.	Bibliographic data from Scopus, 2001–2024, filtered by PRISMA; final total of 276 articles/journals/proceedings.

		payments, and digital analytics to increase efficiency and sustainability.	digital power shifts, data challenges, talent costs, and complexity. DX can drive CE but requires risk mitigation.			
10	Practical implications (additional components)	Fintech (as a form of digital literacy readiness) facilitates circular practices through: the use of data for resource efficiency, supply chain transparency (blockchain), optimization of material use, and integration of CEPs in MSME business processes.			Low digital literacy causes DEP → GBI to be insignificant. The authors explain that low digital skills, high technology costs, lack of incentives, and digital access barriers hinder CE adoption through green innovation.	• Digital marketing can increase consumer awareness of circular products. • Strengthen the adoption of CE in micro-enterprises through education, personalization, and engagement. • Applicative research is needed so that DM can really be a driver of behavioral change towards CE.

Synthesis Results

1. Definition and Operationalization of Digital Literacy

    The five studies show that none of them use the term "digital literacy" explicitly, but all of them operationalize it through various proxies such as fintech adoption, digital transformation capability, digital skills, digital economy policy, and digital marketing capability. This variation emphasizes that digital literacy in the context of MSMEs is understood as the ability of organizations and individuals to utilize digital technology to support business processes. Although the definitions vary, all studies are consistent that digital literacy includes technical, cognitive, and organizational aspects that affect the readiness of MSME actors to undergo digital transformation and sustainability.

2. Definition and Form of Circular Economy Adoption in MSMEs

    The circular economy is defined differently in each study, from the operational practices of waste reduction and material efficiency, to the innovation of green business models and public policies that drive sustainability. In some studies, CE is seen as a component of green innovation, while in other studies, CE is present as a policy or ecosystem that must be supported by digital capabilities. This diversity shows that CE in MSMEs is a multidimensional concept that includes practices, policies, and strategic orientations that are all influenced by the use of digital technology.

3. The Relationship between Digital Literacy and Circular Economy Adoption

    The synthesis of five studies shows that digital literacy plays an important role as an enabler in the adoption of the circular economy. Digital capabilities help MSMEs improve operational efficiency, supply chain transparency, use data to reduce waste, and develop green innovations. However, low digital literacy is a significant obstacle, causing technology to not be used optimally, digital policies to be ineffective, and circular innovations to fail to develop. Thus, digital literacy forms the foundation for the entire circular transformation process of MSMEs.

4. Enabler and Barrier Factors

    The main enablers in the digital–CE relationship are digital capabilities, the availability of digital talent, digital policy support, and the ability of organizations to integrate technology into circular processes. Digital technology makes it easier to reduce waste, improve product design, and educate consumers. On the contrary, barriers arise from low digital skills, limited resources, lack of executive knowledge, high technology costs, and complexity of digital implementation. These barriers slow down the adoption of CE and affirm that digital readiness is a key prerequisite for successful circularity in MSMEs.

5. Study Methodological Pattern

    All five studies used diverse methodological approaches, including quantitative PLS-SEM, exploratory PCA, in-depth qualitative case studies, and global bibliometric analysis. This diversity shows that the issues of digital literacy and CE

cannot be approached with a single method. Quantitative approaches uncover relationships between variables, while qualitative studies provide an understanding of internal processes, and bibliometrics map the global conceptual landscape. This methodological pattern shows the need for integrative, longitudinal, and multimethod research to comprehensively understand the digital–circular transition.

6. Theoretical Framework Used

Emerging theories include Resource-Based View, dynamic capabilities, entrepreneurship innovation, public policy, and consumer behavior approaches in digital marketing. Although there is no single dominant theory, there is a common thread that digital literacy is a strategic capability that affects the readiness and ability of MSMEs to adopt the circular economy. This theoretical fragmentation indicates the need for an integrative conceptual framework that combines technology, organizational, policy, and consumer behavior perspectives to understand the digital–CE literacy relationship.

7. Research Gaps

Some research gaps are clearly visible, namely the absence of a uniform operational definition of digital literacy, the absence of longitudinal research, the lack of cross-border comparative studies, and the limited exploration of mediator and moderator factors in the digital literacy–CE relationship. In addition, the perspective of consumers in the circular ecosystem still receives less attention even though bibliometric studies show the importance of market behavior aspects. This methodological and theoretical fragmentation opens up opportunities for further research to develop more robust and cross-contextual models.

8. Integrative Conceptual Framework

The integration of the five studies resulted in a conceptual framework that positions digital literacy as the foundation for three main pathways of CE adoption in MSMEs: operational pathways that improve efficiency and waste reduction; innovation pathways that drive the development of circular products and processes; as well as ecosystem pathways involving digital policies and influence on consumers through digital marketing. This relationship is reciprocal and contextual, so digital literacy is a key capability that determines whether MSMEs are able to transform their business models towards a circular economy effectively and sustainably.

Discussion

The systematic literature reviews and studies provided collectively underscore the pivotal role of digital literacy in shaping SMEs' readiness, ability, and motivation to adopt circular economy (CE) practices. Digital literacy is identified as a foundational capability that influences SMEs across various dimensions, including operational, innovative, and ecosystem aspects. This capability enables SMEs to effectively utilize data, integrate technology, and innovate processes, which are crucial for successful circular transitions. For instance, the integration of digital technologies is highlighted as a key strategy for enhancing sustainable performance

in small businesses, facilitating eco-innovation and stakeholder engagement. Moreover, digital literacy acts as a catalyst in the adoption of technological innovations, thereby enhancing the competitiveness of SMEs in a technology-driven global economy. The transition to a CE is further supported by digitalization, which optimizes resource efficiency and supply chain operations, thus reinforcing the systemic changes necessary for a sustainable economic model (Mugoni et al., 2025). Additionally, the role of digital literacy in mediating entrepreneurial orientation and dynamic capabilities is crucial for technology adoption among SMEs, as it significantly influences their intention to adopt new technologies (Latifah et al., n.d.). The empirical evidence from Italian SMEs also supports the notion that digital innovation policies, such as Piano Industria 4.0, are positively correlated with the adoption of CE innovations, demonstrating the heterogeneous impact of digital literacy across different CE practices (Montanaro, 2022). Despite these advancements, challenges such as financial constraints and technological readiness remain significant barriers, particularly in developing countries, highlighting the need for targeted interventions to enhance digital literacy and support CE adoption (Mishra et al., 2024). Overall, the synthesis of these studies illustrates that digital literacy not only serves as a technical enabler but also as a strategic driver for SMEs in their journey towards a circular economy, emphasizing the importance of comprehensive digital readiness assessments and supportive policy frameworks (Susanty & Anindyanari, 2022).

The review of the literature reveals a nuanced understanding of the relationship between digital capability and circular economy adoption, highlighting specific linkages that have been underexplored in previous frameworks on green innovation and digital transformation. The integration of digital technologies such as AI, blockchain, and IoT has been shown to significantly enhance the efficiency and sustainability of circular economy practices by optimizing resource use and enabling predictive maintenance. This is further supported by the bibliometric analysis which identifies a rapid increase in research on digital transformation and sustainability, emphasizing the need for a more integrated theoretical framework to address conceptual fragmentation in areas like performance measurement and corporate social responsibility (Mihai et al., 2025). The convergence of digital transformation and sustainability is also evident in the development of Digital Business Model Innovation for Sustainability (DBMI-S), which is rapidly maturing as a research area with a distinct intellectual core, focusing on sustainable value creation and circular economy principles (Ariesty et al., 2025). Moreover, the systematic literature review on digital technologies and circular economy underscores the critical role of digitalization in facilitating the transition to circular business models by addressing knowledge gaps and enhancing processes such as reverse logistics (Scholtysik et al., 2025). Empirical studies further demonstrate that digital transformation initiatives, when coupled with R&D investments, significantly boost eco-innovation outcomes, thereby reinforcing the strategic importance of digital ecosystems in sustainable innovation (Zhao, 2025). Additionally, the role of digitalization as a catalyst for systemic change is highlighted, with implications for policy reform and strategic interventions aimed at accelerating the transition to a green economy (Sari & Veri,

2025). The synthesis of these findings suggests that fragmented proxies of digital literacy used in past studies converge towards a coherent construct when systematically analyzed, offering a refined understanding of how digital capabilities can drive circular economy adoption and sustainable innovation (Lü, 2024) (Hammerschmidt et al., 2025). This comprehensive overview underscores the potential of digital transformation to not only support but also accelerate the adoption of circular economy principles, thereby contributing to broader sustainability goals.

The synthesis of the provided papers highlights the critical role of digital skills development in accelerating the uptake of circular economy practices among SMEs. The digital divide, characterized by infrastructure challenges, financial constraints, and skills gaps, significantly hampers SMEs' ability to adopt digital technologies, which are essential for circular economy transitions (Kang, 2024). Digital skills enhancement is crucial for improving operational efficiency, expanding markets, and increasing competitiveness, as evidenced by the positive impacts of digital training programs on MSMEs (Azuwandri, 2024). In Moldova, targeted support for digital skills development among SMEs has been identified as a key strategy to overcome these barriers, with policy options including enhanced policy effectiveness, improved skills assessment, and strengthened support mechanisms ("Fostering digital skills development amo...", 2023) ("Way forward", 2023). The integration of digital and circular economy strategies fosters innovation and sustainability, with digitalization enhancing resource efficiency and enabling closed-loop systems essential for a circular economy (Arroyabe et al., 2024). However, challenges such as data security, digital divide, and unequal access to advanced technologies persist, necessitating an integrated policy approach that combines technological innovation with supportive regulatory frameworks (Williams et al., 2024). The transition from a linear to a circular economy is further supported by digital technologies that optimize resource use and facilitate efficient recycling and maintenance processes (Brinkmann, 2023). The multi-level perspective framework provides a comprehensive understanding of the factors influencing SMEs' transition to a circular economy, offering practical recommendations for policymakers and industry associations to support this transition (Ahmadov et al., 2023). Digital technologies, including AI, blockchain, and IoT, play a transformative role in advancing sustainability and circular economy goals, although challenges such as data privacy and e-waste must be addressed. Collectively, these findings underscore the need for policymakers, SME support institutions, and industry associations to prioritize digital skills development and implement actionable pathways, such as digital training programs, affordable technological infrastructure, and targeted policy incentives, to enhance SMEs' digital readiness for circular transitions.

The review of digital literacy research underscores the necessity for more explicit and standardized operationalizations of digital literacy to enhance conceptual clarity and facilitate cross-study comparability. This need arises from the current lack of a generic measure of digital literacy, particularly in business contexts, which hinders the ability to link digital literacy effectively to employability and innovative work behavior (Caroline et al., 2025). The diverse interpretations and applications of

digital literacy across various disciplines, such as education, media studies, and computing, further complicate the establishment of a unified framework (Ray, n.d.). The absence of common frameworks and the presence of diverse barriers, including access to technology and cultural differences, highlight the challenges in achieving digital literacy. Moreover, the concept of digital literacy is often pluralistic, avoiding a clear definition, which complicates its application in contemporary contexts (Biezā, 2020). To address these challenges, a collaborative, multi-pronged approach involving educators, governments, technology providers, and community organizations is essential (Phippen, 2024). Additionally, there is a call for more empirically grounded investigations to examine the causal mechanisms linking digital literacy to circular innovation outcomes. This involves understanding how digital literacy can optimize digital business environments by improving efficiency, encouraging innovation, and promoting inclusiveness (Wang et al., 2021). Future research should employ various methodologies and theoretical frameworks to explore these topics, considering the rapid pace of technological development and the need for contextually adapted, inclusive, and sustainable digital literacy programs (Caroline et al., 2025). By advancing digital literacy through tailored, lifelong learning programs and multi-sectoral collaboration, individuals and organizations can be better equipped to participate fully in the digital age, thereby closing the skills gap and fostering societal development (Junaedi et al., 2024).

Future research on the interplay between digital capability development and circular economy (CE) implementation should indeed employ longitudinal and mixed-method designs to capture the dynamic nature of this relationship over time. The integration of digital technologies into CE practices has been shown to enhance both environmental and economic performance, as evidenced by studies on manufacturing firms where digital capabilities were linked to improved CE practices through the alignment of digital technology with environmental business strategies (Türkcan et al., 2025). Comparative studies across different countries and sectors are crucial, as demonstrated by the analysis of Southern African countries, which highlighted the role of digital technologies in overcoming barriers to sustainable development in diverse economic contexts (Mweha, 2025). Similarly, an exploratory analysis of EU countries revealed that digitalization variables such as human capital and digital public services are key drivers of CE variability, suggesting that contextual factors significantly influence digital literacy's impact on CE adoption (Gil-Lamata et al., 2023). Furthermore, the consumer side of digital engagement is pivotal for ecosystem-level circularity, as digitalization not only optimizes resource efficiency and supply chain management but also influences consumer behavior towards more sustainable economic decisions (Sari & Veri, 2025). The role of digital technologies as dynamic capabilities in supporting CE innovation, particularly in the food supply chain, underscores the importance of absorptive capacity in enhancing digital CE innovation (Bag et al., n.d.). Additionally, the development of frameworks linking digital technologies to CE strategies, such as those focusing on slowing, narrowing, and closing material loops, provides a structured approach for future research to explore the synergies between digital functions and CE strategies (Scholtysik et al., 2025). These insights collectively highlight the need for comprehensive, context-

sensitive research methodologies to fully understand and leverage the potential of digital technologies in advancing circular economy goals.

The systematic literature review (SLR) approach is a powerful method for integrating diverse types of evidence, such as quantitative models, qualitative case studies, and bibliometric analyses, into a cohesive understanding of the relationship between digital literacy and critical engagement (CE). This method's strength lies in its structured protocol, rigorous screening process, and independent quality appraisal, which collectively enhance the credibility, transparency, and replicability of the findings. For instance, the SLR conducted by Ilomäki et al. on critical digital literacies (CDL) in school education utilized a systematic protocol to map out key elements of CDL, drawing from 139 research articles and policy documents to inform a research-based framework for education (Ilomäki et al., 2023). Similarly, the review by Ghafar et al. on digital competencies for upper secondary students in Malaysia employed the PICOC framework to systematically evaluate digital competency models, resulting in a structured framework that aligns with the Fourth Industrial Revolution (Ghafar et al., 2025). The bibliometric review by Adima et al. further exemplifies the integration of heterogeneous evidence by employing the PRISMA framework and VOSviewer for bibliometric analysis, highlighting trends and gaps in digital literacy research from an Islamic perspective (Adima et al., 2025). These examples demonstrate how SLRs can synthesize varied evidence to provide comprehensive insights into digital literacy's role across different educational contexts. Moreover, the systematic approach ensures that the findings are not only robust but also applicable to policy-making and educational practice, as seen in the implications for continuous professional development and pedagogical support highlighted in the studies. Overall, the SLR method's ability to integrate diverse evidence types into a unified conceptual explanation underscores its value in advancing our understanding of digital literacy and its critical role in modern education and society.

The review's limitations, as highlighted, stem from its reliance on open-access English-language journal articles, potentially excluding significant studies published in other languages or restricted-access databases. This constraint is evident in the field of digital literacy, which is still in its nascent stages, as reflected by the limited number of empirical studies directly addressing the nexus between digital literacy and cognitive engagement (CE). The existing literature underscores the importance of digital literacy across various educational contexts, from K-12 to higher education, and its role in developing 21st-century skills, yet it also reveals significant gaps and challenges. For instance, studies have shown that digital literacy is crucial for enhancing students' academic performance and employability, but there is a lack of comprehensive empirical research that directly links digital literacy to cognitive engagement in educational settings. Furthermore, the integration of digital literacy in early childhood education is shown to impact cognitive development, yet the research is limited in scope and often lacks longitudinal data to assess long-term effects (Karnita et al., 2025). In higher education, digital literacy is essential for adapting to technological transformations, but there is a noted deficiency in media literacy development and empirical studies that explore new perspectives of digital

transformation (Farias-Gaytan et al., 2023). Additionally, the digital literacy of specific populations, such as people with disabilities and adult migrants, is under-researched, with existing studies primarily focusing on qualitative methods and lacking quantitative data to generalize findings (Venkatesan, 2024). The bibliometric analyses of digital literacy research further highlight the fragmented nature of the field, with studies often focusing on specific aspects like AI literacy or employee digital literacy, rather than a holistic approach that includes cognitive engagement (Zhang et al., 2024). Overall, the field's early development stage and the limited empirical studies constrain the generalizability of findings, emphasizing the need for more inclusive and comprehensive research methodologies that consider diverse linguistic and cultural contexts to better understand the digital literacy-CE relationship.

CONCLUSION

This systematic literature review demonstrates that digital literacy functions as a foundational capability shaping SMEs' ability to adopt circular economy practices. Across the five high-quality studies reviewed, digital literacy consistently emerges—whether explicitly defined or indirectly measured—as a critical determinant that enhances operational efficiency, supports green innovation, and enables engagement with broader digital ecosystems. The synthesis further reveals that digital literacy fosters circular transitions through multiple pathways, including data-driven process optimization, digital-enabled resource efficiency, digital transformation readiness, and consumer-facing sustainability communication. Despite these convergent insights, current evidence remains fragmented, with inconsistent operationalization of digital literacy and limited empirical clarity on causal mechanisms.

Based on the gaps identified, this review recommends that future research adopt more standardized conceptual definitions and develop robust, multidimensional measures of digital literacy specifically suited to SME contexts. Longitudinal and mixed-method designs are needed to capture the dynamic nature of digital capability development and circular adoption over time. Policymakers and SME support institutions should prioritize digital capacity-building programs, accessible technological infrastructure, and supportive regulatory frameworks to accelerate digital–circular integration. Strengthening digital literacy at both organizational and ecosystem levels will be crucial for enabling SMEs to participate effectively in the global transition toward circular and sustainable business models.

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