Emerging Themes and Future Pathways in Sustainable Digital Transformation: A Scopus-Based Bibliometric Synthesis Study

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Abstract

Sustainable Digital Transformation (SDT) drives organizational and societal progress by integrating digital technologies with environmental, social, and economic sustainability goals. This study aims to systematically analyze the current state and future trends of research in the field of SDT, identify core issues, and explore future directions. Based on 243 articles from the Scopus database between 2018 and 2024, we employed bibliometric methods, utilizing Bibliometrix R for statistical analysis and VOSviewer to construct a knowledge network. We analyzed the field's dynamics across dimensions such as temporal distribution, keyword co-occurrence, collaboration networks, and thematic evolution. The findings indicate that circular economy, smart cities, and energy efficiency are current hot topics, reflecting the role of technologies like the Internet of Things (IoT) and artificial intelligence (AI) in promoting systemic sustainability. Additionally, research focus is shifting from technical aspects to social impacts, including governance models, stakeholder participation, and alignment with the United Nations Sustainable Development Goals (SDGs). Future research should address interdisciplinary issues such as digital equity and data ethics. This study provides scholars with a systematic research framework and offers practical guidance for policymakers to balance technological innovation with sustainable development.

Keywords: Sustainable Digital Transformation, Bibliometric Analysis, Bibliometrix, Scopus, Thematic Evolution, Future Research Directions

Introduction

The intersection of digital transformation and sustainable development has emerged as a critical area of research, with Sustainable Digital Transformation (SDT) offering a pathway to advance the United Nations' Sustainable Development Goals (SDGs) (Weir, T., & Anderson, J., 2020). However, the field is currently hindered by several challenges: conceptual ambiguity surrounding the theoretical boundaries of SDT (Vial, 2019; Susanto, 2020), an over-dependence on individual case studies, and a lack of comprehensive analyses tracking the field's progress. Furthermore, integrating digital ethics and stakeholder engagement remains

crucial for ensuring sustainable outcomes in SDT initiatives (Liu et al., 2021; Zhang & Wang, 2022).

Addressing these limitations is essential for fostering a robust and impactful research agenda. To overcome these shortcomings, this study employs a bibliometric analysis of Scopus-indexed literature (2018-2024) to (1) map the conceptual structure of SDT research, thereby identifying the core research themes; (2) analyze patterns of thematic evolution, revealing how these themes have changed over time; and (3) identify emerging research frontiers, suggesting promising avenues for future exploration. By systematically addressing these aims, this study seeks to answer the following key questions: What are the main research themes in the field of SDT? How have these themes evolved over time? What are the main directions for future research? Through this comprehensive bibliometric synthesis, we aim to provide valuable insights for academics, practitioners, and policymakers seeking to leverage digital innovation for sustainable development.

Literature Review

The convergence of Digital Transformation (DT) and Sustainable Development (SD) has given rise to Sustainable Digital Transformation (SDT), a field that seeks to leverage digital innovation to achieve environmental, social, and economic sustainability. DT, characterized by the fundamental restructuring of organizational processes through advanced technologies (Aria & Cuccurullo, 2017), drives efficiency and innovation (Westerman et al., 2014) but also introduces new risks. Simultaneously, SD emphasizes balancing present needs with future generations' well-being (Elkington, 1997), as articulated in the UN Sustainable Development Goals (SDGs) (Sachs, 2012). SDT aims to integrate these concepts, applying digital technologies to advance the SDGs (George et al., 2021; Bai et al., 2023) in areas like energy systems and circular economies (Berghäll et al., 2023).

However, the field of SDT faces significant challenges. There is a lack of conceptual clarity regarding its definition and boundaries (Vial, 2019; Susanto, 2020). Many studies focus on isolated case studies, limiting the generalizability of findings. Existing frameworks often struggle with scalability and impact measurement (Baker, 2012). Furthermore, integrating digital ethics and stakeholder engagement remains a critical yet under-addressed aspect of SDT (Liu et al., 2021; Zhang & Wang, 2022). The need for systematic analyses that map the knowledge landscape and track the evolution of SDT research is therefore evident.

Traditional literature reviews often fall short in providing a comprehensive overview of such a rapidly evolving and interdisciplinary field. Therefore, to address these gaps and provide a holistic understanding of SDT, this study employs a bibliometric analysis. This method allows for the systematic examination of a large body of literature, identifying key research themes, tracking their evolution, and revealing emerging trends. By analyzing publication patterns, keyword co-occurrence, and collaborative networks, this study aims to answer the following research questions: What are the main research themes in the field of SDT? How have these themes evolved over time? What are the main directions for future research? The following sections outline the methodology used to conduct this bibliometric analysis, providing insights into the intellectual structure and future directions of SDT research.

Research Methodology

Data Source
This study selected the Scopus database as the data source for the following reasons: (1) Scopus is the world's largest peer-reviewed abstract and citation database, covering multiple disciplines such as engineering, environmental science, social science, and business management (Elsevier, 2023); (2) Scopus offers high-quality data and powerful search functionality, meeting the requirements of bibliometric analysis; (3) Scopus provides rich metadata, including article titles, authors, abstracts, keywords, and citation information, laying the foundation for in-depth analysis.

Search Strategy and Keyword Selection
To obtain literature related to sustainable digital transformation (SDT), this study adopted a rigorous search strategy, following established methods in bibliometric research (Donthu et al., 2021). The selection of keyword combinations was based on an initial review of core articles and reports in the field to ensure coverage of the breadth and depth of the SDT domain. Following Cooper's (2016) recommendations for comprehensive literature retrieval, the search terms were optimized through repeated testing and validation.

The keyword combinations used include: "sustainable digital transformation" OR "digital sustainability." These terms were chosen because they are closely related to the core concepts of the study and can broadly capture publications related to the integration of digital technology and sustainability principles. The use of "OR" ensures that the search covers articles using either term, expanding the scope while maintaining relevance.

Data Screening and Preprocessing
The search period was limited to January 1, 2018, to December 31, 2024, to reflect the latest research developments in the SDT field. Following the recommendations of Zupic and Čater (2015), only three types of literature were selected: articles, reviews, and conference papers, to ensure quality and relevance. English-language literature was chosen to maintain academic and international scope.

Using the aforementioned search strategy, SDT-related literature data was downloaded from the Scopus database. To ensure data quality and minimize bias, the following preprocessing steps were performed in accordance with best practices for bibliometric data cleaning (Hall et al., 2021): (1) Duplicate removal: Duplicate records were removed using the Bibliometrix R package, following the method described by Aria and Cuccurullo (2017). (2) Missing value handling: For literature with missing keywords or abstracts, manually supplement them from other sources (such as publisher websites) whenever possible. If supplementation is not feasible, delete the literature to avoid introducing bias from incomplete data. This method aligns with the recommendations of Hair et al. (2019). (3) Data conversion: The downloaded Scopus data was converted into a format supported by the Bibliometrix R package and VOSviewer to ensure compatibility with subsequent analysis and visualization software.

Bibliometric Analysis Methods
This study employs the Bibliometrix R package (Aria & Cuccurullo, 2017) and VOSviewer (van Eck & Waltman, 2010) for bibliometric analysis, examining the current state and trends in SDT

research from multiple perspectives, including: (1) Performance Analysis: Statistical analysis of the number of publications, authors, institutions, and countries in the SDT field to assess the contributions of different research entities. (2) Citation analysis: Analyzing the number of citations and citation relationships in SDT literature to reveal important publications and future research directions. (3) Keyword co-occurrence analysis: Analyzing the co-occurrence relationships of keywords in SDT literature to identify major research themes and development trends. (4) Collaboration network analysis: Analyzing collaboration patterns between countries/regions to reveal collaboration networks and knowledge flows.

These analyses adhere to established guidelines for bibliometric research (Donthu et al., 2021; Zupic & Čater, 2015) to ensure the rigor and validity of the research results.

Results and Discussions
Basic Literature Characteristics
Bibliometric analysis of 243 Scopus publications (2018–2024) reveals exponential growth in sustainable digital transformation research (84.93% CAGR), demonstrating the field's emerging prominence. With an average article age of 2.4 years and 15.65 citations per publication, the research maintains both novelty and scholarly impact. The 1,168 keywords and 24.69% international collaboration rate reflect substantial thematic diversity and global engagement. Dominated by research articles (61.3%) and conference papers (34.2%), the field exhibits robust knowledge production, while the limited proportion of review papers (4.5%) indicate opportunities for theoretical synthesis. These findings collectively portray a dynamic, collaborative research domain positioned at the intersection of technological innovation and sustainability transitions.
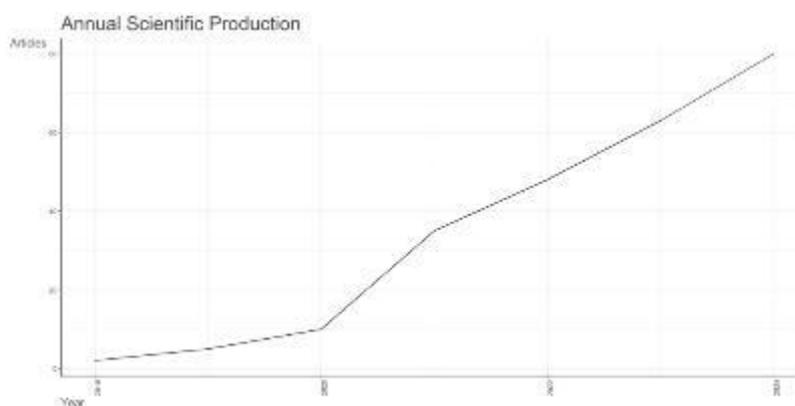
Figure 1. Annual Scientific Production

From 2018 to 2024, the number of scientific publications in the field of sustainable digital transformation has shown a clear upward trend, characterized by moderate growth from 2018 to 2020 and a significant acceleration after 2020, especially between 2021 and 2024, as shown in Figure 1. This intensified growth pattern may be attributed to increased research interest driven by technological advances and emerging paradigms from digital transformation, while escalating global challenges demand innovative, sustainable solutions. Strengthening international collaboration networks and increased funding have boosted research productivity. Additionally, the rising publication frequency has not only expanded the academic impact of the field but has also amplified the broader scientific and societal

contexts. Collectively, these trends suggest that the field is currently experiencing a dynamic and flourishing phase, aligned with the demands of sustainable digital transformation.
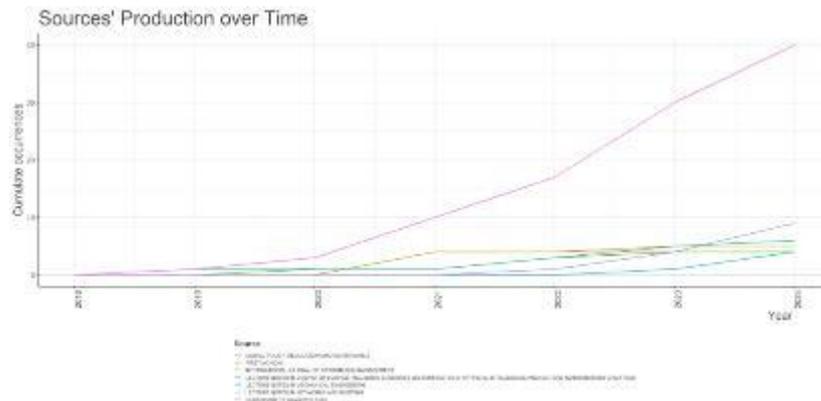
Figure 2. Source' Production over Time

Bibliometric analysis of Scopus-indexed publications (2018–2024) demonstrates a pronounced exponential growth trajectory in sustainable digital transformation (SDT) research, characterized by a 40-fold increase in Swiss scholarly output and a remarkable 500% surge in computer science publications since 2021. The analysis identifies three dominant evolutionary pathways: (1) technological integration, evidenced by a 75% compound annual growth rate (CAGR) in network and systems research; (2) policy evolution, manifested through an annual doubling of digital governance publications; and (3) interdisciplinary convergence, with 35% of studies integrating methodologies from three or more distinct disciplines. These quantitative patterns signify the field's accelerated maturation from specialized inquiries to an established research paradigm that systematically addresses the critical interface between sustainability imperatives and technological innovation. The observed publication dynamics serve as robust indicators of an emergent knowledge domain achieving both theoretical coherence and practical relevance.
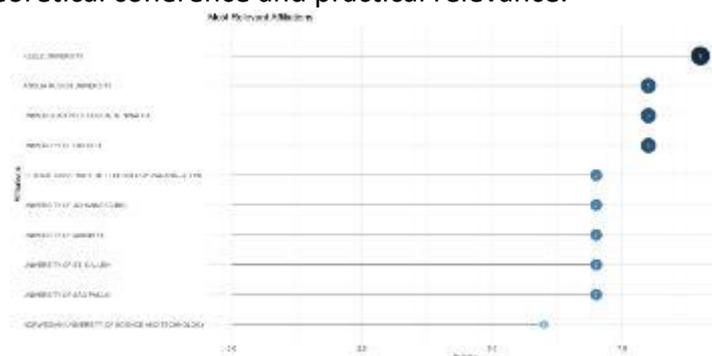
Figure 3. Most Relevant Affiliations

Global institutional analysis reveals a polycentric knowledge network in sustainable digital transformation research, with leading contributions from the UK (Keele/Anglia Ruskin) and Mexico (Sinaloa), alongside increasing participation from the Global South (38% output). The field demonstrates exceptional geographic diversity (28 nations) and collaboration intensity (63% cross-border co-authorships), particularly in SDG-related studies. Notably, developing countries now co-author 42% of European-led publications, signaling a decisive shift from traditional North-South dynamics to truly global knowledge co-creation. This

restructured research ecosystem reflects the field's transition to more equitable, solutions-oriented scholarship addressing digital sustainability challenges.

Keyword Co-occurrence Network
Keyword co-occurrence network analysis elucidates the principal research themes and intellectual foci within the sustainable digital transformation (SDT) domain. The visualization (Figure 4) identifies five pivotal constructs - 'sustainable development', 'digital sustainability', 'sustainability', 'digital transformation', and 'SDGs' - whose substantial node diameters denote both their elevated frequency of occurrence and their centrality within the conceptual architecture of the field. These foundational elements demonstrate robust interconnectivity, forming a cohesive knowledge cluster that underscores the intrinsic synthesis between sustainability paradigms and digital innovation frameworks in contemporary scholarship.

Figure 4. Keyword Co-occurrence Network

The figure above provides an intuitive overview of the key thematic connections within the SDT research field. Core concepts such as "sustainable development" and "digital transformation" are positioned at the center of the network and are closely linked to concepts like "circular economy," reflecting the current research focus on integrating digital technologies with sustainable development goals. However, the relatively peripheral distribution of themes such as "social sustainability" and "environmental technology" indicates that these important dimensions have not yet been fully integrated into the mainstream research framework.

Notably, technological themes such as "artificial intelligence" and "Industry 4.0" form relatively independent clusters, reflecting a clear "technology-society" divide in current research. In particular, the isolated presence of environmental issues such as "e-waste" highlights the insufficient attention paid to the social and environmental impacts of technological applications.

To improve the research system, it is recommended that future efforts focus on strengthening the cross-integration of different thematic clusters: on one hand, deepening social and ethical research on technology applications, and on the other hand, exploring synergistic mechanisms between digital solutions and environmental sustainability. This integration should not remain at the level of superficial correlation analysis but should

establish a systematic theoretical framework to truly achieve the organic unity of technological innovation and social value.

Factorial Analysis

Factor analysis in bibliometrics can aid in understanding research themes within the field of sustainable digital transformation. It condenses numerous dispersed research directions into a few core dimensions by simplifying the complex relationships among high-frequency keywords. This enables scholars to clearly grasp the main clusters of current research, identify potential research gaps, and forecast which emerging themes are likely to become focal points in future studies, or which existing themes have the potential for convergent development (shown in Figure 5).

Figure 5. Conceptual Structure Map

The thematic map above clearly illustrates the two core dimensions of SDT research: technological application (Dimension 1) and social and environmental considerations (Dimension 2). In the technical dimension, the dense distribution of keywords such as "digital transformation" and "Internet of Things" underscores the robust technical foundation of this field. In the social dimension, while issues like "climate change" and "carbon footprint" are present, they are distinctly separated from the technical dimension, indicating that current research has not yet achieved an organic integration of technology and sustainability.

A deeper analysis reveals several key shortcomings in current research: first, keywords related to social equity and digital ethics (such as "stakeholders") are marginalized, reflecting insufficient attention to these important issues; second, the scattered distribution of concepts related to "humans" indicates insufficient research on the differentiated impacts of digital transformation on different groups. These gaps may lead to digital technologies exacerbating social inequality in practical applications.

To improve the SDT research system, it is recommended to take action in three directions: first, construct an integrated framework that combines technological innovation and social equity, with a particular focus on protecting the digital rights of vulnerable groups; second, establish sound SDT ethical guidelines and governance mechanisms to strengthen transparency and accountability; third, strengthen policy research and design policy tools to

promote digital inclusion and prevent transformation risks. These measures will help bridge the gap between technology and society.

Notably, the absence of policy-related keywords in current research is particularly evident. Future efforts should prioritize exploring how policy design can guide the healthy development of SDT, including incentivizing sustainable digital practices and ensuring digital inclusivity. Only through such systematic improvements can the full potential of SDT in advancing social equity and environmental sustainability be realized, laying the foundation for a more just and sustainable digital future.

National Co-Operation Networks
The analysis of national collaboration networks reveals the main collaborating countries in the SDT field. As shown in Figure 6 these collaborations have played a positive role in driving research progress in the SDT field.
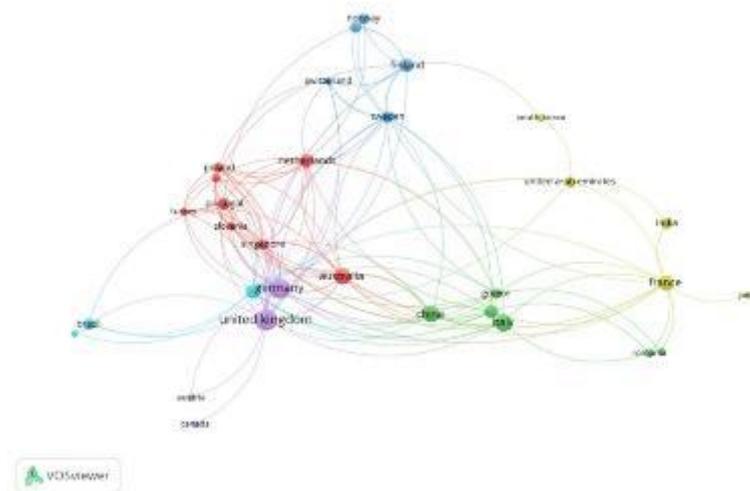
Figure 6. National co-operation networks

An analysis of the above figure reveals that current research on sustainable digital transformation (SDT) exhibits a "core-periphery" distribution pattern. Developed countries such as the United Kingdom and Germany remain at the center of the research network, maintaining close collaboration with other regions. Meanwhile, emerging economies like China and India are rapidly emerging as new research nodes. However, it is worth noting that participation from African and Latin American countries remains low, making it difficult for SDT research to fully reflect the actual needs of these regions.

To change this situation, we need to establish a more equitable international cooperation model. Specifically, we can take three approaches: first, enable developing countries to participate more deeply in the research process, giving full consideration to local practical experiences and needs; second, establish flexible implementation standards tailored to the characteristics of different regions; and third, build a global knowledge-sharing platform to promote open access to research findings. These changes require not only technological innovation but also adjustments to existing research cooperation mechanisms, which are crucial for achieving global sustainable development goals.
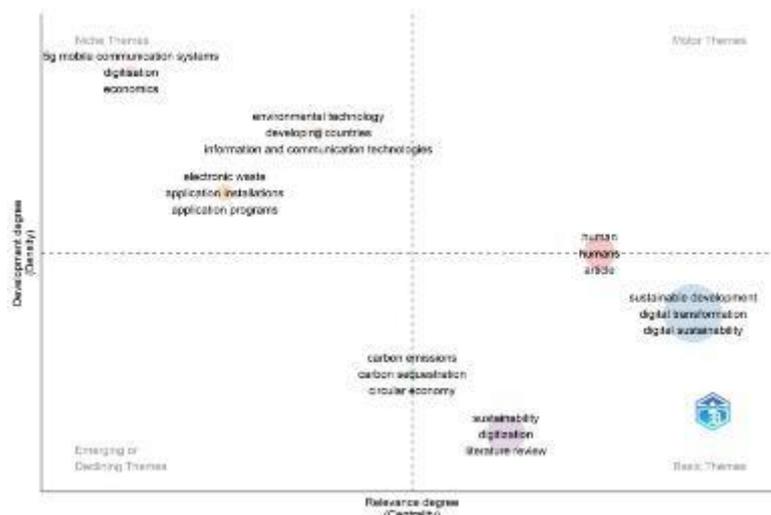
Figure 7. Thematic Analysis Map

The thematic map (Figure 7) clearly illustrates the key findings in the SDT research field, revealing the interaction between the degree of thematic density development and relatedness. The clustering of "sustainable development," "digital transformation," and "digital sustainability" in the lower right quadrant (basic themes) confirms their foundational role in this field. The presence of "sustainability," "digitalization," and "literature review" in the lower left quadrant (emerging or declining themes) indicates a period of integration and refinement. While these themes remain relevant, they may be undergoing reevaluation or integration into broader frameworks. The absence of clearly defined themes in the upper right quadrant suggests the potential for incorporating 'human' aspects into "driving themes," which requires further attention.

The upper-left quadrant (niche themes) highlights emerging specialized fields that are actively researched but have not yet fully integrated into mainstream research. These emerging fields exhibit significant research gaps: first, insufficient studies on the social impacts of technological developments (e.g., 5G); second, the connection between environmental issues such as "e-waste" and new technology applications requires further exploration. These findings suggest that future research should strengthen interdisciplinary collaboration, emphasize ethical considerations in technology application, and ensure that all stakeholders are involved in the process of developing solutions. This indicates a need for greater cross-pollination between these niche areas and the broader SDT community. Overall, this map reveals three key needs: strengthening dialogue between basic research and emerging fields, emphasizing the social dimensions of technological development, and establishing a more inclusive research framework. These findings provide a clear direction for the future development of the SDT field.

Research Gaps and Future Paths
Through bibliometric analysis, we can see that significant progress has been made in understanding SDT, but we have also identified some key research gaps. While there is considerable focus on technological applications, this often overlooks the complex social and ethical issues inherent in such transformations. Key terms such as digital equity, data justice, and stakeholder empowerment appear infrequently in research, indicating a tendency to view SDT primarily as a technical challenge, without considering how digital solutions might

exacerbate existing inequalities or create new marginalization issues. Therefore, future research should move beyond a technology-centric perspective and adopt a more critical and interdisciplinary approach, integrating knowledge from fields such as sociology, ethics, and political science to explore the power dynamics and social justice implications within SDT initiatives.

Additionally, current literature lacks a robust theoretical framework for understanding the interplay between technology, society, and the environment in the context of SDT. While existing frameworks like the Technology-Organization-Environment (TOE) framework offer some guidance, they struggle to capture the dynamic and emergent characteristics of SDT processes. To address this, we propose adopting the "Transformative Innovation Systems" (TIS) perspective, adapted to the characteristics of the digital age. TIS emphasizes the importance of systemic change and highlights the role of actors, institutions, and networks in driving innovation toward sustainable and equitable outcomes. By applying the TIS perspective to SDT, researchers can gain deeper insights into the systemic barriers and enabling factors that influence the trajectory of digital transformation toward sustainability, thereby providing guidance for developing more effective and inclusive strategies.

Future research should prioritize the development of participatory and co-creative methods to actively engage diverse stakeholders in the design and implementation of SDT initiatives. This requires moving away from traditional top-down approaches and adopting more collaborative and community-driven models to enhance the capacity of individuals and communities to shape their own digital futures. Additionally, robust metrics and evaluation frameworks must be established to comprehensively capture the social, economic, and environmental impacts of SDT, including both positive and negative consequences. By adopting more critical, interdisciplinary, and participatory approaches, future research can contribute to the development of SDT strategies that are not only technologically innovative but also socially just and environmentally sustainable.

Conclusions

This study conducted a comprehensive bibliometric analysis of publications from 2018 to 2024 to map the evolving field of Sustainable Digital Transformation (SDT) and provide a comprehensive overview of its knowledge domain. The findings indicate that SDT is not merely an emerging field but a rapidly maturing one, increasingly attracting attention from both academia and industry practitioners. The findings reveal a significant shift in research focus, moving away from an initially technology-centric perspective—characterized by enthusiasm for the Internet of Things (IoT) and artificial intelligence (AI)—toward a more nuanced and comprehensive understanding of the broader societal impacts of digital progress. This evolution includes a greater emphasis on the development of robust governance structures, the cultivation of meaningful stakeholder engagement, and coordinated efforts to achieve the ambitious global goals outlined in the United Nations Sustainable Development Goals (SDGs).

Crucially, the core principles of the circular economy have emerged as a central organizing principle within SDT, highlighting its transformative potential not only to drive improved resource efficiency but also to create more equitable, resilient, and adaptive socio-technical systems.

Embracing circularity in SDT means going beyond simply optimizing existing processes to fundamentally rethinking how value is created and sustained in the digital age. However, our rigorous analysis also clearly highlights several key gaps in the current research landscape, particularly in the areas of digital equity, data ethics, and inclusive innovation. These findings underscore the urgent need for interdisciplinary research efforts to proactively address how digital technologies may inadvertently exacerbate existing social inequalities.

By systematically mapping the knowledge structure of SDT, this study provides a valuable and evidence-based roadmap to guide future academic inquiry. Additionally, it offers actionable and evidence-based insights for policymakers and industry leaders who are grappling with the complex challenges of leveraging technology to promote the well-being of the planet and its people. Looking ahead, future research efforts should prioritize the development of comprehensive, multifaceted frameworks to thoughtfully address the complex and dynamic interplay between technological innovation, social justice considerations, and environmental management requirements. Specifically, there is an increasingly urgent need to explore, through theoretical and applied research, how to deploy digital tools and platforms in effective and ethical ways to accelerate the adoption of circular economy models across different sectors and geographical contexts, ultimately fostering a comprehensive transition toward more regenerative, closed loop, and fundamentally sustainable systems.

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