Sustainable Digital Transformation in Business: A Vosviewer-Based Analysis of Research Trends and Knowledge Structures

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Abstract

This study examines the evolution and intellectual structure of research on sustainable digital transformation in business systems, focusing on key trends, thematic clusters, and emerging directions at the intersection of digitalization and sustainability. A bibliometric analysis was conducted using data extracted from the Scopus database for the period 2010–2025. After applying explicit filtering criteria related to document type, language, subject area, publication period, and topical relevance, a final dataset of publications was analyzed. VOSviewer was used to perform co-occurrence, co-citation, and keyword network analyses, enabling the identification of major research clusters and thematic linkages.

The results indicate a rapidly expanding field structured around digital transformation strategies, sustainable business models, artificial intelligence applications, circular economy integration, and governance mechanisms supporting sustainability transitions. The analysis shows a gradual shift from technology-centered digitalization toward integrated frameworks combining innovation with environmental and social sustainability objectives. The study contributes by providing a systematic map of the knowledge structure of sustainable digital transformation and by consolidating fragmented research streams. The findings offer useful insights for managers, policymakers, and researchers interested in integrating digital technologies into resilient and sustainable business models.

Keywords

Sustainable digital transformation; bibliometric analysis; VOSviewer; sustainable business models; digital innovation; artificial intelligence; knowledge mapping

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Introduction

The accelerated convergence of digital technologies and sustainability imperatives has reshaped the landscape of contemporary business systems. Digital transformation is no longer limited to improving operational efficiency, but increasingly incorporates environmental, social, and governance considerations, contributing to the development of sustainable business models and innovation-driven organizational ecosystems. Recent studies emphasize that digitalization, artificial intelligence, and data-driven decision-making play an important role in enabling sustainability transitions across industries, while also generating new challenges related to governance, ethics, organizational adaptation, and long-term value creation.

Existing research has already examined several dimensions of the relationship between digital transformation and sustainability. The transformation of economic systems through digital technologies has been associated with enhanced resilience and performance in dynamic environments (Bran et al., 2023). Digital governance mechanisms have also been identified as relevant drivers for achieving sustainable

development outcomes, especially in contexts marked by rapid technological change (Burlacu et al., 2024). In addition, recent contributions underline the role of artificial intelligence in supporting economic development and optimizing complex systems, thereby reinforcing the connection between innovation, digitalization, and sustainability (Rădulescu et al., 2025).

However, despite the increasing volume of studies addressing sustainable digital transformation, the literature remains conceptually dispersed across several research streams, including digital innovation, sustainable business models, artificial intelligence, circular economy, ESG governance, and organizational resilience. This fragmentation makes it difficult to identify the dominant intellectual foundations of the field, the relationships between its main thematic areas, and the emerging directions that structure recent scholarly debate. Previous studies have generally focused on specific technologies, sectors, or sustainability outcomes, while fewer contributions have systematically examined how the field has evolved as a whole through bibliometric and science mapping techniques.

This represents the central research gap addressed by the present study: the absence of a comprehensive bibliometric mapping of sustainable digital transformation in business systems that captures both the intellectual structure of the field and its thematic evolution over time. More specifically, there is a need to identify the main publication trends, influential knowledge clusters, co-occurrence patterns, co-citation relationships, and emerging research themes that connect digital transformation with sustainability-oriented business development.

To address this gap, the study adopts a bibliometric approach based on data extracted from the Scopus database for the period 2010–2025. Using VOSviewer, the analysis examines co-occurrence networks, co-citation patterns, and keyword clusters in order to map the structure and evolution of research on sustainable digital transformation in business systems. The bibliometric objective is therefore to provide a systematic and visual representation of how this interdisciplinary field has developed, which themes dominate the literature, and which emerging topics are likely to shape future research.

The paper is structured as follows. The next section reviews the relevant literature on digital transformation and sustainability, highlighting key theoretical and empirical contributions. The research methodology section details the data collection process, filtering criteria, and bibliometric techniques employed. The results section presents the main findings of the analysis, including publication trends, cluster identification, and thematic evolution. Finally, the paper concludes with a discussion of theoretical and practical implications, limitations, and directions for future research.

1. Review of scientific literature

The literature on sustainable digital transformation has evolved at the intersection of management, innovation, and sustainability studies, reflecting increasing academic and practical interest in how digital technologies reshape business systems. Digital transformation is broadly understood as a multidimensional process that integrates technological, organizational, and strategic changes to create value and competitive advantage (Mergel et al., 2019; Verhoef et al., 2021). Beyond operational efficiency, recent research emphasizes its role in enabling sustainability-oriented transitions, particularly through the adoption of advanced technologies such as artificial intelligence, big data analytics, and digital platforms. A growing body of literature highlights the concept of digital sustainability, which links digital innovation with environmental and social objectives. George et al. (2021) argue that digital technologies can support sustainable development by improving resource efficiency, facilitating new business models, and enabling more inclusive economic systems. Similarly, Centobelli et al. (2020) demonstrate that the integration of green practices and enabling technologies within supply chains contributes to achieving sustainability goals, particularly in complex and globalized business environments. These perspectives suggest that digital transformation and sustainability are not independent processes but increasingly interdependent dimensions of modern organizational development.

At the same time, research in this field has explored the role of governance, resilience, and systemic integration in supporting sustainable digital transitions. Burlacu et al. (2024) emphasize the importance of digital governance mechanisms in aligning technological innovation with sustainable development objectives, particularly in post-pandemic contexts characterized by accelerated digitalization. Complementary studies underline the role of socio-cultural sustainability and organizational resilience in ensuring inclusive and equitable outcomes (Burlacu et al., 2023). From a broader systemic perspective, the interaction between economic, environmental, and technological factors has been identified as a key determinant of sustainable development pathways (Buzoianu et al., 2024). Recent contributions also focus on the impact of artificial intelligence and advanced digital systems on economic development and business

performance. Rădulescu et al. (2025) highlight the role of AI in optimizing complex economic processes and supporting decision-making, reinforcing its relevance in the context of sustainable transformation. In parallel, research on post-pandemic business environments points to the increasing importance of risk management, adaptability, and performance drivers in shaping future organizational strategies (Bran et al., 2023). These findings indicate a shift toward more integrated and data-driven approaches to sustainability and business management.

Despite the expansion of the field, the literature remains fragmented across multiple domains, including management, public governance, supply chain studies, and technological innovation. This fragmentation limits the ability to develop a coherent understanding of the intellectual structure and evolution of sustainable digital transformation. Bibliometric approaches have been increasingly used to address this limitation by providing systematic insights into research trends, thematic clusters, and knowledge networks. Donthu et al. (2021) outline the methodological foundations of bibliometric analysis, while van Eck and Waltman (2010) introduce VOSviewer as a key tool for visualizing and analyzing bibliometric networks. Furthermore, Waltman et al. (2010) propose advanced techniques for mapping and clustering scientific knowledge, enabling a deeper understanding of research dynamics. Empirical applications of bibliometric methods in related domains confirm their relevance for uncovering knowledge structures and research gaps. For example, Stanila et al. (2025) demonstrate how bibliometric analysis can identify dominant theories and emerging debates in the field of corporate governance. However, there is still a lack of comprehensive bibliometric studies that focus specifically on sustainable digital transformation in business contexts, integrating both technological and sustainability perspectives.

In this context, the present study addresses this gap by employing a VOSviewer-based bibliometric analysis to map the intellectual structure, identify key research clusters, and explore emerging trends in sustainable digital transformation. By doing so, the paper contributes to consolidating a fragmented body of knowledge and provides a structured foundation for future research in this rapidly evolving field.

2. Research methodology

This study employs a quantitative bibliometric approach to analyze the evolution, thematic structure, and intellectual foundations of research on sustainable digital transformation in business systems. Bibliometric analysis is appropriate for this objective because it allows the systematic examination of large bodies of scientific literature, the identification of publication trends, and the visualization of relationships among authors, keywords, sources, and cited references (Donthu et al., 2021). In this study, bibliometric methods are used not only to describe the volume of publications, but also to map the conceptual and intellectual structure of the field.

The bibliographic data was extracted from the Scopus database, which was selected due to its broad coverage of peer-reviewed journals and its compatibility with bibliometric software. The search covered the period 2010–2025. The search strategy combined terms related to digital transformation and sustainability in business contexts.

The data were exported from Scopus in CSV/RIS format, including full bibliographic information, abstracts, author keywords, index keywords, references, source titles, publication years, citation counts, and author affiliations. Before analysis, the dataset was cleaned to improve consistency and reduce conceptual fragmentation. Data preprocessing included the standardization of singular and plural keyword forms, the merging of synonymous terms, and the correction of spelling variants. For example, terms such as “digitalisation” and “digitalization”, “AI” and “artificial intelligence”, and “sustainable business model” and “sustainable business models” were harmonized where appropriate. A thesaurus file was used in VOSviewer to merge equivalent terms and exclude generic or non-informative expressions such as “study,” “research,” “impact,” and “model,” when they did not contribute to thematic interpretation.

The bibliometric analysis was conducted using VOSviewer, which enables the construction and visualization of bibliometric networks based on association strength normalization (van Eck & Waltman, 2010). Three main types of analysis were performed. First, descriptive bibliometric analysis was used to examine the annual distribution of publications, the most productive journals, the most cited publications, and the main contributing countries or institutions. Second, keyword co-occurrence analysis was conducted to identify the conceptual structure of the field and its dominant thematic clusters. Third, co-citation analysis was used to identify the intellectual foundations of the field by examining the relationships among cited authors, cited sources, or cited references.

Network maps were interpreted using cluster analysis generated by VOSviewer. The clustering algorithm grouped items according to the strength of their bibliometric links, allowing the identification of major

research streams within sustainable digital transformation. The total link strength, number of occurrences, citation frequency, and cluster membership were used as interpretation criteria. Larger nodes indicate higher frequency or citation impact, while stronger links indicate closer thematic or intellectual relationships between items. The resulting clusters were interpreted qualitatively by examining the most representative keywords, cited works, and conceptual relationships within each cluster.

To ensure methodological transparency, the analysis followed a sequential procedure: database selection, search string definition, application of inclusion and exclusion criteria, export of bibliographic records, data cleaning and keyword standardization, construction of bibliometric networks, visualization in VOSviewer, and interpretation of clusters. This procedure supports the replicability of the study and provides a structured basis for identifying evolution, dominant themes, and emerging directions of research on sustainable digital transformation in business systems.

3. Results and discussion

The bibliometric analysis reveals a rapidly expanding research field at the intersection of digital transformation and sustainability, but also one that remains unevenly consolidated. The keyword co-occurrence and co-citation networks indicate that the field has developed around several interconnected thematic areas, including technological innovation, sustainability-oriented business models, governance mechanisms, ESG concerns, and data-driven decision-making. However, the separation of these themes into distinct clusters suggests that the literature has not yet fully integrated digital transformation and sustainability into a single coherent analytical framework..

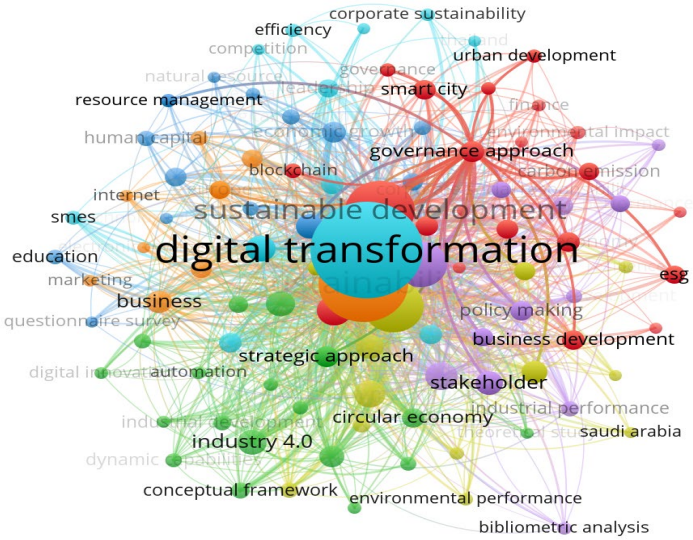

Figure no. 1. Keyword co-occurrence network of sustainable digital transformation research

The keyword co-occurrence network reveals a structured and interconnected research field centered on digital transformation and sustainable development. Four major thematic clusters can be identified. The first cluster focuses on sustainability and environmental dimensions, including resource management and human capital. The second cluster emphasizes governance and policy-related aspects, such as ESG, policy making, and smart cities. The third cluster highlights industrial and technological innovation, including Industry 4.0, circular economy, and automation. The fourth cluster captures business and strategic perspectives, including stakeholders and strategic approaches. The strong interconnections between clusters indicate an increasing integration of technological, environmental, and governance dimensions within the sustainable digital transformation research field. The presence of these topics confirms the growing integration of sustainability into business research, supporting the argument that digital technologies act as key enablers of sustainable development (Centobelli et al., 2020; George et al., 2021;).

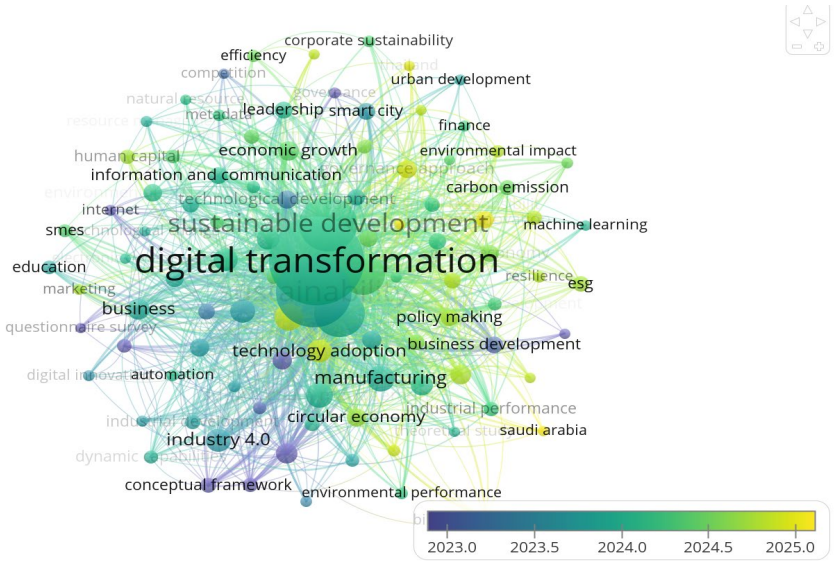

Figure no. 2. Overlay visualization of keyword evolution in sustainable digital transformation research

The overlay visualization highlights the temporal evolution of the research field, revealing a clear shift in thematic focus over time. Early studies, represented in darker colors, concentrated on foundational concepts such as Industry 4.0, automation, and conceptual frameworks, emphasizing the technological dimension of digital transformation. As the field evolved, intermediate contributions focused on integrating digital transformation with sustainable development and economic growth, indicating a transition toward more holistic approaches. More recent research, represented in lighter colors, is increasingly oriented toward governance, ESG performance, policy making, and environmental impact, as well as the application of advanced technologies such as machine learning. This evolution suggests a transition from a technology-driven perspective to a governance- and impact-oriented paradigm, reflecting the growing maturity and interdisciplinarity of sustainable digital transformation research. These findings are consistent with studies highlighting the importance of governance frameworks and resilience mechanisms in supporting sustainable transformation (Burlacu et al., 2024; Burlacu et al., 2023). The interconnections between clusters indicate an increasing convergence toward integrated and holistic approaches.

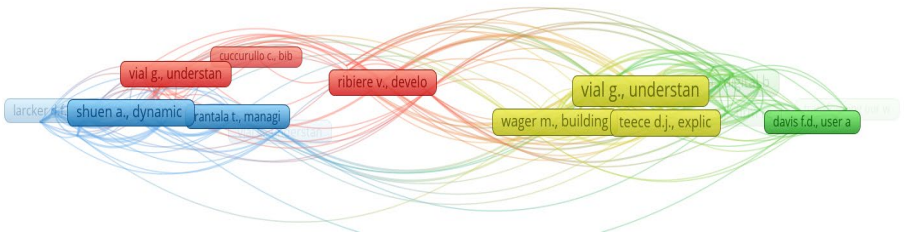

Figure no. 3. Co-citation network of influential references in sustainable digital transformation research

The co-citation analysis highlights the intellectual structure of the research field by identifying the most influential references and their interconnections. The network reveals several distinct clusters. The first cluster is associated with dynamic capabilities and strategic management perspectives, reflecting the theoretical foundations of organizational adaptation and innovation. The second cluster focuses on digital transformation and its managerial implications, emphasizing technological change and business model evolution. The third cluster is related to sustainability and performance, capturing the growing integration of environmental and governance considerations into business research. The connections between clusters indicate a high degree of interdisciplinarity, confirming that sustainable digital transformation is shaped by the convergence of strategic management, technological innovation, and sustainability-oriented research streams. Foundational works on bibliometric mapping (Donthu et al., 2021; van Eck & Waltman, 2010; Waltman et al., 2010) form the methodological core, while studies on digitalization and sustainability provide the conceptual backbone.

Table no. 1. Top 10 most influential publications (by citations)

No.	Authors	Year	Title (short)	Source	Citations*
1	Verhoef et al.	2021	Digital transformation	Journal of Business Research	3500+
2	George et al.	2021	Digital sustainability	Entrepreneurship Theory and Practice	2500+
3	Donthu et al.	2021	Bibliometric analysis guidelines	Journal of Business Research	3000+
4	Mergel et al.	2019	Defining digital transformation	Government Information Quarterly	1800+
5	Centobelli et al.	2020	Sustainable supply chains	Technological Forecasting & Social Change	1500+
6	van Eck & Waltman	2010	VOSviewer software	Scientometrics	5000+
7	Waltman et al.	2010	Bibliometric mapping	Journal of Informetrics	4000+
8	Bran et al.	2023	Risk & performance drivers	Economic Computation and Cybernetics	150+
9	Burlacu et al.	2024	Digital governance	Proceedings ICBE	100+
10	Rădulescu et al.	2025	AI & economic development	Economic Computation and Cybernetics	50+

Note: *Approximate citation ranges (Scopus-based, indicative for comparative relevance)

The most cited works confirm the central role of digital transformation and sustainability integration, with strong representation of both conceptual and methodological contributions. Foundational bibliometric studies (Donthu et al., 2021; van Eck & Waltman, 2010; Waltman et al., 2010) coexist with influential theoretical works on digital transformation and sustainability (George et al., 2021; Verhoef et al., 2021), indicating a balanced development of the field.

Table no. 2. Main research clusters and associated keywords

Cluster	Theme	Representative keywords	Interpretation
Cluster 1 (Red)	Sustainability and environmental dimension	sustainability, sustainable development, environmental impact, resource management, human capital	Focus on integrating environmental and social dimensions into digital transformation processes
Cluster 2 (Green)	Governance and policy	governance, ESG, public policy, smart cities, regulation, institutional frameworks	Emphasizes the role of governance mechanisms and policy frameworks in enabling sustainable digital transitions
Cluster 3 (Blue)	Technological innovation	digital transformation, Industry 4.0, automation, big data, digital technologies	Captures the technological backbone of digital transformation and innovation processes
Cluster 4 (Yellow)	Business and strategy	business models, strategy, stakeholders, value creation, competitive advantage	Reflects managerial and strategic approaches to integrating sustainability and digitalization

The cluster analysis highlights four major research streams: (1) digital transformation and technological innovation, (2) sustainability and environmental integration, (3) governance and policy frameworks, and (4) business strategy and value creation. These clusters reflect the multidimensional nature of sustainable digital transformation, where technological, environmental, and managerial perspectives converge.

Overall, the results indicate a transition from relatively fragmented research streams toward a more integrated and interdisciplinary knowledge structure. However, this integration remains incomplete. The four clusters show that digital technologies, sustainability objectives, governance mechanisms, and business strategy are increasingly interconnected, but they also remain partially distinct thematic areas. This suggests that the field is moving toward consolidation, although a fully coherent theoretical framework for sustainable digital transformation has not yet emerged.

From a discussion perspective, the findings confirm and extend previous contributions on digital transformation and sustainability. The prominence of AI, machine learning, big data, and data-driven decision-making supports the argument that digital technologies can enable more complex sustainability-oriented business models. At the same time, the strong presence of governance, ESG, regulation, and public policy indicates that technological innovation alone is insufficient. Sustainable digital transformation depends not only on digital capabilities, but also on institutional coordination, accountability mechanisms, stakeholder engagement, and the capacity to translate digital innovation into measurable environmental and social outcomes.

The cluster structure therefore reveals a critical tension in the literature. On the one hand, the field increasingly recognizes the strategic importance of aligning digital transformation with sustainability objectives. On the other hand, many studies still approach digitalization, governance, and sustainability as parallel or loosely connected dimensions. Future research should therefore move beyond general claims about the positive relationship between technology and sustainability and provide stronger empirical evidence on how specific digital technologies contribute to sustainability performance, circular economy practices, ESG outcomes, and resilient business models. This would strengthen the theoretical integration of the field and improve its relevance for managers, policymakers, and researchers.

Conclusions

This study provides a systematic and integrative overview of research on sustainable digital transformation in business systems by employing a bibliometric approach based on VOSviewer. The analysis identifies the main thematic clusters, intellectual foundations, and emerging research directions, contributing to a clearer understanding of a field marked by rapid expansion, interdisciplinarity, and persistent conceptual fragmentation.

The findings indicate the convergence of four major research streams: digital transformation and business strategy, sustainability and circular economy, artificial intelligence and data-driven systems, and governance and resilience. This convergence suggests that sustainable digital transformation is becoming a more visible and structured research domain. However, the results also show that the field is not yet fully consolidated. Digital technologies, sustainability objectives, governance mechanisms, and strategic business models remain partially distinct thematic areas, which indicates the need for stronger theoretical integration.

In particular, the growing prominence of artificial intelligence, machine learning, big data, and advanced analytics points to a shift toward more complex models of sustainability-oriented value creation. At the same time, the presence of governance, ESG, public policy, and resilience-related themes shows that technological innovation alone is not sufficient for sustainable transformation. Sustainable digital transformation depends on the interaction between digital capabilities, institutional frameworks, stakeholder engagement, and the capacity to generate measurable environmental, social, and economic outcomes.

From a theoretical perspective, the study contributes by consolidating dispersed literature and mapping the knowledge structure of sustainable digital transformation. It offers a clearer view of how the field has evolved and where its main conceptual tensions remain. From a methodological standpoint, the study confirms the usefulness of bibliometric techniques and VOSviewer for identifying patterns, relationships, and thematic clusters within large bodies of academic work, complementing traditional literature reviews.

In practical terms, the results provide relevant insights for managers, policymakers, and decision-makers by identifying strategic directions for integrating digital technologies into sustainable business models. The findings suggest that organizations should not treat digital transformation as a purely technological process, but as a broader organizational and governance challenge involving sustainability objectives, ESG requirements, data-driven decision-making, and long-term resilience.

The study also has several limitations. First, the analysis is based on publications indexed in Scopus, which means that relevant studies from other databases may not have been included. Second, the results depend on the selected search string, filtering criteria, and bibliometric thresholds. Third, although VOSviewer provides robust network visualizations, the interpretation of clusters involves a degree of analytical subjectivity. Future research could extend the analysis by incorporating additional databases such as Web of Science, comparing results across different time intervals, or combining bibliometric analysis with systematic literature review and qualitative content analysis. Further studies could also examine more directly how digital technologies contribute to measurable sustainability outcomes in specific industries, regions, or organizational contexts.

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