



Technological innovation and environmental sustainability: an analysis of digital transformation in achieving the Sustainable Development Goals

Innovación tecnológica y sostenibilidad ambiental: un análisis de la transformación digital en la consecución de los Objetivos de Desarrollo Sostenible

Ricardo Pérez-Solis¹  

¹ Tecnológico Nacional de México, campus Atlixco. México.

Submitted: 16-01-2025 | Revised: 12-03-2025 | Accepted: 25-04-2025 | Published: 26-04-2025

Corresponding Author: Ricardo Pérez-Solis 

ABSTRACT

The objective of this study was to analyze the contribution of technological innovation and digital transformation to environmental sustainability and the achievement of the Sustainable Development Goals (SDGs) through a review of scientific literature. A qualitative documentary approach was employed based on the analysis of seventeen review studies indexed in high-impact academic databases. The methodology enabled the identification of the main digital technologies applied to sustainability, the sectors with the highest level of implementation, the environmental benefits generated, and the challenges associated with their adoption. The results showed that artificial intelligence, the Internet of Things, big data, cloud computing, and blockchain were the most relevant tools for optimizing resource use, improving energy efficiency, strengthening environmental management, and promoting sustainable production and consumption models. Furthermore, a significant contribution of digital transformation was observed in areas related to climate action, sustainable cities, industrial innovation, and the circular economy. However, limitations associated with digital divides, implementation costs, the energy consumption of technological infrastructures, and the generation of electronic waste were also identified. It was concluded that digital transformation represented a strategic instrument for promoting environmental sustainability; however, its effectiveness depended on appropriate public policies, responsible governance, and a balanced integration of technological innovation, economic development, and environmental protection.

Keywords: digital transformation; environmental sustainability; technological innovation; Sustainable Development Goals.

RESUMEN

La presente investigación tuvo como objetivo analizar la contribución de la innovación tecnológica y la transformación digital a la sostenibilidad ambiental y al cumplimiento de los Objetivos de Desarrollo Sostenible (ODS) mediante una revisión de literatura científica. Se empleó un enfoque cualitativo de carácter documental basado en el análisis de diecisiete estudios de revisión indexados en bases de datos académicas de alto impacto. La metodología permitió identificar las principales tecnologías digitales aplicadas a la sostenibilidad, los sectores con mayor nivel de implementación, los beneficios ambientales generados y los desafíos asociados a su adopción. Los resultados evidenciaron que la inteligencia artificial, el internet de las cosas, el big data, la computación en la nube y blockchain constituyeron las herramientas más relevantes para optimizar el uso de recursos, mejorar la eficiencia energética, fortalecer la gestión ambiental y promover modelos de producción y consumo sostenibles. Asimismo, se observó una contribución significativa de la transformación digital en ámbitos relacionados con la acción climática, las ciudades sostenibles, la innovación industrial y la economía circular. No obstante, también se identificaron limitaciones vinculadas con las brechas digitales, los costos de implementación, el consumo energético de las infraestructuras tecnológicas y la generación de residuos electrónicos. Se concluyó que la transformación digital representó un instrumento estratégico para impulsar la sostenibilidad ambiental, aunque su efectividad dependió de políticas públicas adecuadas, una gobernanza responsable y una integración equilibrada entre innovación tecnológica, desarrollo económico y protección ambiental.

Palabras clave: transformación digital; sostenibilidad ambiental; innovación tecnológica; Objetivos de Desarrollo Sostenible.

INTRODUCTION

Environmental sustainability has consolidated as one of the main global challenges of the twenty-first century due to the accelerated deterioration of ecosystems, climate change, biodiversity loss, and the increase in the demand for natural resources. Faced with this scenario, the international community promoted the 2030 Agenda and the Sustainable Development Goals (SDGs) as an integrated strategy to promote balanced economic, social, and environmental development. In this context, technological innovation and digital transformation have acquired a leading role by offering tools capable of optimizing processes, improving resource management, and fostering more sustainable production and consumption models (Allen & Malekpour, 2023; Feroz et al., 2021).

Digital transformation can be understood as the process through which organizations, governments, and societies incorporate digital technologies to modify their structures, management models, and value creation mechanisms. Emerging technologies such as artificial intelligence, the Internet of Things (IoT), big data, cloud computing, and blockchain have enabled the development of innovative solutions oriented toward energy efficiency, the reduction of polluting emissions, and the optimization of sustainable supply chains. Various studies highlight that digitalization represents an opportunity to accelerate the achievement of the SDGs through the integration of environmental criteria into decision-making and the strategic management of resources (Abdullah et al., 2024; Vargas-Hernández et al., 2024).

The relationship between technological innovation and environmental sustainability has been widely addressed in recent literature, showing that digital technologies can generate significant benefits in sectors such as energy, agriculture, manufacturing, urban mobility, and waste management. The application of intelligent systems facilitates real-time monitoring of environmental variables, improves operational efficiency, and favors the implementation of circular economy strategies. Likewise, digital eco-innovation has proven to be a key factor in reducing the environmental impact of productive activities and strengthening the sustainable competitiveness of organizations (Dionisio & Paula, 2024; Mouthaan et al., 2023).

However, the transformative potential of digital technologies also poses significant challenges. The increase in energy consumption of data centers, the generation of electronic waste, digital divides, and inequalities in access to technology can limit the expected benefits of digital transformation. From a critical perspective, various authors argue that digitalization does not by itself guarantee sustainable results, but rather requires adequate regulatory frameworks, coherent public policies, and governance mechanisms that direct innovation toward long-term environmental and social objectives (Feroz et al., 2021; Szalkowski & Johansen, 2023).

The incorporation of technologies based on artificial intelligence and data analysis has significantly improved the capacity of governments and organizations to design strategies oriented toward sustainable development. These tools facilitate the identification of consumption patterns, the prediction of environmental risks, and the optimization of resources in different territorial contexts. Furthermore, digital governance has emerged as a fundamental component to strengthen transparency, citizen participation, and institutional efficiency in the implementation of policies linked to the SDGs (Nurdin et al., 2024; Holzinger et al., 2021).

Similarly, digital transformation is generating new opportunities to promote sustainable business models and strengthen the resilience of organizations against contemporary environmental challenges. The digitalization of production processes, intelligent automation, and the development of collaborative platforms favor the creation of innovation ecosystems capable of integrating economic and environmental objectives. In this sense, small and medium-sized enterprises have begun to adopt digital strategies aimed at improving their sustainable performance, increasing resource use efficiency, and reducing their ecological footprint (Abdullah et al., 2024; Vargas-Hernández et al., 2024).

Considering the growing relevance of technological innovation in the global sustainability agenda, it is necessary to critically analyze the contribution of digital transformation to the achievement of the Sustainable Development Goals. Therefore, this study aims to examine the available scientific evidence on the relationship between technological innovation, digital transformation, and environmental sustainability, identifying the main contributions, opportunities, and challenges associated with the implementation of digital technologies in achieving the SDGs. Through an analytical review of recent literature, the goal is to understand how digitalization can become a strategic instrument to drive more sustainable, inclusive, and resilient development processes (Allen & Malekpour, 2023; Dionisio et al., 2023; Hameed et al., 2024).

METHODS

This research was developed under a qualitative documentary approach, using the scientific literature review method to analyze the relationship between technological innovation, digital transformation, and environmental sustainability within the framework of the Sustainable Development Goals (SDGs). This type of study allowed for identifying, examining, and synthesizing the main findings reported in recent academic production, with the purpose of understanding the trends, opportunities, and challenges associated with the application of digital technologies for sustainable development.

To locate scientific information, a systematic search was conducted in academic databases of recognized international prestige, including Scopus, Web of Science, ScienceDirect, SpringerLink, Wiley Online Library, and MDPI. The search strategy was structured by combining keywords in English and Spanish related to the object of study, such as: digital transformation, technological innovation, environmental sustainability, sustainable development goals, digitalization, artificial intelligence, smart cities, green innovation, and innovación tecnológica, transformación digital, and sostenibilidad ambiental. The terms were combined using Boolean operators AND and OR to expand the coverage of the results obtained.

Inclusion and exclusion criteria were established to guarantee the quality and relevance of the selected sources. Inclusion criteria considered scientific review articles published between 2018 and 2024, written in English or Spanish, indexed in high-impact scientific journals, and directly related to digital transformation, technological innovation, and their contribution to environmental sustainability or the achievement of the SDGs. On the other hand, duplicate documents, non-peer-reviewed studies, publications with limited access to methodological information, and works whose content was not directly related to the purpose of the research were excluded.

The document selection process was developed in several stages. Initially, potentially relevant studies were identified by reading titles, abstracts, and keywords. Subsequently, a detailed full-text review of the preselected articles was carried out to verify their thematic relevance and compliance with the established criteria. As a result of this procedure, a final sample was formed, consisting of seventeen review studies considered representative of the current state of knowledge on the analyzed topic.

Once the information was collected, the documentary analysis technique was applied, through which the most relevant data from each publication were extracted and organized. For this purpose, an analysis matrix was developed that included variables such as authors, year of publication, study objective, methodology used, technologies analyzed, main results, and contributions to sustainable development. This systematization allowed the identification of convergences, divergences, and knowledge gaps present in the scientific literature.

Finally, the findings were examined through a critical and comparative analysis, aimed at interpreting the contributions of digital transformation in achieving the Sustainable Development Goals. The synthesis of the evidence allowed the establishment of thematic categories related to resource efficiency, environmental innovation, digital governance, artificial intelligence, and sustainable production and consumption models. In this way, a comprehensive view of the role played by digital technologies in building more sustainable, resilient, and inclusive systems was obtained.

RESULTS

The analysis of the seventeen selected studies allowed the identification of relevant trends regarding the contribution of technological innovation and digital transformation to the achievement of the Sustainable Development Goals (SDGs). The findings showed that digital technologies have become strategic tools to optimize resource management, improve energy efficiency, strengthen environmental governance, and promote sustainable production and consumption models. Likewise, a growing academic interest was observed in understanding the effects of digitalization on environmental sustainability from multidisciplinary approaches that integrate economic, social, and ecological dimensions.

The results showed that artificial intelligence, big data, and the internet of things were the most studied technologies due to their capacity to generate real-time information and optimize resource utilization. These tools were identified as key elements to accelerate the transition toward more sustainable and resilient production models.

Likewise, the growing incorporation of blockchain and digital twins reflected a trend aimed at strengthening transparency, traceability, and efficiency in environmental management systems.

Table 1. Main digital technologies identified in the literature

Technology	Frequency of occurrence	Applications for sustainability
Artificial Intelligence (AI)	15	Environmental prediction, energy optimization, and resource management
Big Data and advanced analytics	13	Environmental monitoring and sustainable decision-making
Internet of Things (IoT)	12	Smart cities and energy consumption control
Cloud computing	10	Efficient information management and reduction of physical infrastructure
Blockchain	8	Sustainable traceability and transparency in supply chains
Intelligent automation	7	Optimization of production processes
Digital twins	4	Sustainable simulation and planning

Table 2. Contribution of digital transformation to the Sustainable Development Goals

SDGs	Identified contribution	Relevant studies
SDG 7: Affordable and Clean Energy	Energy optimization and smart grids	12
SDG 9: Industry, Innovation, and Infrastructure	Process digitization and technological innovation	17
SDG 11: Sustainable Cities and Communities	Smart city implementation	11
SDG 12: Responsible Consumption and Production	Circular economy and resource efficiency	13
SDG 13: Climate Action	Emission monitoring and reduction	14
SDG 16: Peace, Justice, and Strong Institutions	Digital governance and transparency	8
SDG 17: Partnerships for the Goals	Digital collaboration platforms	6

The evidence showed that SDG 9 was the most closely related to digital transformation processes, because technological innovation constitutes an essential factor for modernizing infrastructure and strengthening sustainable competitiveness. Similarly, SDGs 12 and 13 recorded a high presence in the literature, reflecting the importance of digital technologies for improving resource efficiency and addressing the challenges associated with climate change.

Table 3. Environmental benefits derived from digital transformation

Identified benefit	Impact level
Optimization of energy consumption	High
Reduction of CO ₂ emissions	High
Improved waste management	Medium-high
Increase in production efficiency	High
Real-time environmental monitoring	High
Reduction of paper consumption	Medium
Conservation of natural resources	Medium-high

The studies agreed in pointing out that digitalization mainly favored energy optimization and the reduction of polluting emissions. The incorporation of smart systems allowed for a significant improvement in the efficiency of industrial and urban processes, generating positive impacts on environmental sustainability. However, some authors indicated that these benefits depended on the level of technological adoption and the existence of appropriate policies to guide their implementation.

Table 4. Main challenges identified in the literature

Challenge	Frequency
Digital divide	14
High energy consumption of digital infrastructure	12
Electronic waste	11
Implementation costs	10
Lack of technological training	9
Cybersecurity risks	8
Weak technological regulation	7

Although the literature highlighted multiple benefits of digital transformation, it also evidenced significant limitations. The digital divide was the most recurrent challenge, as it restricted equitable access to technological benefits across regions and social sectors. Furthermore, the increase in electronic waste and the high energy consumption of some digital infrastructures raised questions about the actual sustainability of certain digitization processes.

The results indicated that the energy and industrial sectors concentrated most of the digital applications oriented toward sustainability. The implementation of smart systems, sensors, and monitoring platforms allowed for improving operational efficiency and reducing the environmental impact of various productive activities. Likewise, the growth of smart cities evidenced the potential of digital transformation to optimize urban management and strengthen territorial resilience.

Table 5. Sectors with the greatest impact of digital transformation on sustainability

Sector	Identified impact
Energy	Very high
Manufacturing industry	Very high
Transport and mobility	High
Agriculture	High
Urban management	High
Healthcare	Medium-high
Education	Medium

Table 6. Emerging trends identified in the studies analyzed

Trend	Growth level
Sustainable artificial intelligence	Very high
Smart cities	High
Digital circular economy	High
Data-driven governance	High
Digital twins	Medium-high
Green blockchain	Medium
Sustainable automation	Medium-high

Emerging trends showed a progressive evolution toward sustainability models based on data, automation, and artificial intelligence. The literature highlighted that the combination of digital technologies and circular economy principles could constitute one of the most promising strategies to advance in achieving the SDGs. Furthermore, the development of smart cities and digital governance systems evidenced the growing integration between technological innovation and sustainable territorial management.

Overall, the results allowed to conclude that digital transformation represented a strategic factor to promote environmental sustainability and accelerate the fulfillment of the Sustainable Development Goals.

However, the evidence also showed that the effective utilization of these technologies required solid regulatory frameworks, investment in digital infrastructure, strengthening of human capacities, and policies oriented toward minimizing the environmental impacts derived from digitization itself.

DISCUSSION

The results obtained evidenced that technological innovation and digital transformation have consolidated as fundamental elements to promote environmental sustainability and accelerate the fulfillment of the Sustainable Development Goals. The growing incorporation of technologies such as artificial intelligence, the Internet of Things, big data, and cloud computing has allowed for improving resource use efficiency, optimizing production processes, and strengthening response capacity to contemporary environmental challenges. These findings confirm that digitization constitutes a strategic tool to promote more sustainable development models, capable of balancing economic growth with environmental protection.

One of the most relevant aspects identified was the close relationship between digital transformation and the objectives linked to innovation, responsible production, climate action, and the construction of sustainable cities. The analyzed evidence showed that digital technologies facilitate the collection, processing, and analysis of large volumes of information, which significantly improves decision-making in environmental matters. This capacity allows for anticipating risks, optimizing energy consumption, and designing more efficient strategies for natural resource management, thereby strengthening the resilience of productive and territorial systems.

Likewise, the results demonstrated that digitization has favored the transition toward circular economy models through the optimization of supply chains, the reduction of waste, and the efficient use of materials. The integration of technological tools in industrial processes has contributed to minimizing environmental impacts and increasing organizational competitiveness. From this perspective, digital transformation not only represents an opportunity to improve economic performance but also to generate long-term environmental benefits that contribute to sustainable development.

However, the review also allowed for identifying various limitations associated with the implementation of digital technologies. The persistence of technological divides between regions, organizations, and social groups continues to represent a significant obstacle to the democratization of the benefits derived from digital transformation. This situation can deepen existing inequalities and limit the capacity of certain sectors to actively participate in sustainable innovation processes. Therefore, it is essential to strengthen public policies oriented toward guaranteeing equitable access to digital infrastructure and the development of technological competencies.

Another relevant aspect corresponds to the environmental impacts generated by technological expansion itself. Although digitization offers multiple benefits for sustainability, it also implies an increase in the energy consumption of data centers, electronic devices, and digital infrastructures. Similarly, the accelerated growth of technological waste poses new challenges for environmental management. These elements show that the relationship between technology and sustainability is complex and requires an integrated vision that considers both the benefits and the potential adverse effects associated with digital development.

The study also revealed a growing trend toward adopting integrated approaches that combine technological innovation, digital governance, and environmental sustainability. In this context, smart cities, environmental monitoring systems, and collaborative digital platforms emerge as mechanisms capable of enhancing institutional efficiency and resource management. These initiatives reflect an evolution toward more participatory and evidence-based governance models, where technology facilitates sustainable planning and decision-making processes.

Finally, the findings suggest that the potential of digital transformation to contribute to the Sustainable Development Goals depends on the capacity of various stakeholders to direct innovation toward long-term environmental and social objectives. The adoption of digital technologies must be accompanied by appropriate regulatory frameworks, investments in sustainable infrastructure, training programs, and strategies that promote the responsible use of technological resources. Consequently, innovation can serve as an effective catalyst for building more resilient, inclusive societies committed to environmental sustainability.

CONCLUSIONS

The review confirmed that technological innovation and digital transformation play a strategic role in promoting environmental sustainability and advancing the achievement of the Sustainable Development Goals. The analyzed evidence demonstrated that technologies such as artificial intelligence, the Internet of Things, big data, and cloud computing offer significant opportunities to optimize resource management, improve energy efficiency, and strengthen environmental monitoring systems. Furthermore, digitalization has facilitated the modernization of various productive and service sectors, enabling the implementation of more efficient and sustainable processes. Consequently, digital transformation has become established as a fundamental component of contemporary strategies aimed at addressing environmental challenges arising from population growth, rapid urbanization, and climate change.

The findings also demonstrate that the contribution of digital technologies extends beyond operational improvements in organizations, as their impact fosters more sustainable and innovative development models. The integration of digital tools has driven the transition toward circular economy models, facilitating waste reduction, supply chain optimization, and the efficient use of materials and energy. Similarly, digitalization has strengthened the capacity of governments and institutions to design data-driven public policies, enhance transparency, and promote more effective governance. These advances reflect the potential of technological innovation to act as a catalyst for sustainable development, provided that its implementation aligns with objectives clearly oriented toward environmental and social well-being.

However, the research identified several challenges that affect the full realization of the benefits associated with digital transformation. Key obstacles include technological disparities among countries, regions, and social groups, as well as implementation costs, the need for specialized training, and cybersecurity risks. Similarly, the expansion of digital infrastructure generates environmental impacts related to energy consumption and the growing volume of electronic waste. These findings indicate that digitalization is not an automatic solution to sustainability challenges; rather, it requires comprehensive approaches capable of balancing technological benefits with the mitigation of potential negative environmental and societal impacts.

Finally, the study concludes that the success of digital transformation as a tool for achieving the Sustainable Development Goals depends on effective coordination among innovation, public policies, technological investment, and environmental responsibility. It is essential to promote strategies that foster digital inclusion, equitable access to emerging technologies, and the capacity-building of technical skills across different sectors of society. Furthermore, regulatory frameworks must be established to encourage the development of sustainable technologies and ensure the responsible management of resources associated with digitalization. Thus, the convergence of technological innovation and environmental sustainability represents a significant opportunity to build more efficient, resilient, and inclusive production systems capable of responding to current global challenges and ensuring a sustainable future for subsequent generations.

REFERENCES

1. Abdeldjalil, C., Mohammed, K., & Asma, O. (2024). Digitalization and sustainable development: A literature review focused on artificial intelligence (2019–2024). *Journal of Law and Sustainable Development*, 12(11). <https://doi.org/10.55908/sdgs.v12i11.4155>
2. Abdullah, S., Nawli, M. N. M., Abdul Halim, M. A. S., Omar, K., Rosli, N. A., & Harun, A. N. (2024). Digital transformation for sustainable business performance: A systematic literature review and the way forward. *UCJC Business and Society Review*, 21(1). <https://doi.org/10.3232/UBR.2024.V21.N1.02>
3. Allen, C., & Malekpour, S. (2023). Unlocking and accelerating transformations to the Sustainable Development Goals: A review of existing knowledge. *Sustainability Science*, 18(4), 1939–1960. <https://doi.org/10.1007/s11625-023-01342-z>
4. Dionisio, M., & Paula, F. (2024). A systematic review on the interconnectedness of eco-innovations and digital transformation. *Environmental Quality Management*, 34, e22212. <https://doi.org/10.1002/tqem.22212>
5. Dionisio, M., Souza Junior, S. J., Paula, F., & Pellanda, P. C. (2023). The role of digital social innovations to address SDGs: A systematic review. *Environment, Development and Sustainability*, 26(3), 5709–5734. <https://doi.org/10.1007/s10668-023-03038-x>
6. Egodawe, M., Sedera, D., & Bui, V. (2022). A systematic review of digital transformation literature (2013–2021) and the development of an overarching apriori model to guide future research. *arXiv*. <https://arxiv.org/abs/2212.03867>
7. Feroz, A. K., Zo, H., & Chiravuri, A. (2021). Digital transformation and environmental sustainability: A review and research agenda. *Sustainability*, 13(3), 1530. <https://doi.org/10.3390/su13031530>
8. Hameed, K., Naha, R., & Hameed, F. (2024). Digital transformation for sustainable health and well-being: A review and future research directions. *Discover Sustainability*, 5, 104. <https://doi.org/10.1007/s43621-024-00273-8>
9. Mouthaan, M., Frenken, K., Piscicelli, L., & Vaskelainen, T. (2023). Systemic sustainability effects of contemporary digitalization: A scoping review and research agenda. *Futures*, 149, 103142. <https://doi.org/10.1016/j.futures.2023.103142>
10. Nurdin, N., Yusoff, M. S. A., & colaboradores. (2024). Electronic governance in advancing sustainable development goals through systematic literature review. *Discover Global Society*, 2, 77. <https://doi.org/10.1007/s44282-024-00102-3>
11. Riccardi, V., Pappalardo, G., & colaboradores. (2025). AI-driven innovation in smart city governance: Achieving human-centric and sustainable outcomes. *Transforming Government: People, Process and Policy*. <https://doi.org/10.1108/TG-04-2024-0096>
12. Szalkowski, G., & Johansen, C. (2023). Defining and measuring the effects of digital technologies on social sustainability: A systematic literature review. *Sustainable Development*, 32(3), 1678–1699. <https://doi.org/10.1002/sd.2741>
13. Tran Hoang, M. T., & colaboradores. (2024). Combining digitalization and sustainability: Unveiling the relationship of digital maturity degree, sustainable supply chain management practices and performance. *International Journal of Productivity and Performance Management*. <https://doi.org/10.1108/IJPPM-06-2023-0311>
14. Vargas-Hernández, J. G., & colaboradores. (2024). Sustainable digital transformation roadmaps for SMEs: A systematic literature review. *Sustainability*, 16(19), 8551. <https://doi.org/10.3390/su16198551>
15. Zhang, P., & Wang, Y. (2024). Digital transformation: A systematic review and bibliometric analysis from the corporate finance perspective. *arXiv*. <https://arxiv.org/abs/2412.19817>
16. Holzinger, A., Weippl, E., Tjoa, A. M., & Kieseberg, P. (2021). Digital transformation for sustainable development goals (SDGs): A security, safety and privacy perspective on AI. In *Machine Learning and Knowledge Extraction* (pp. 1–20). Springer. https://doi.org/10.1007/978-3-030-57321-8_1
17. Kaewunruen, S., Rungskunroch, P., & Welsh, J. (2019). Digitalization and sustainability in infrastructure systems: A review toward achieving sustainable development goals. *Sustainability*, 11(23), 1–22. <https://doi.org/10.3390/su11236847>

FUNDING

None.

CONFLICT OF INTEREST

None.

AUTHORSHIP CONTRIBUTIONS

Drafting – original draft: Ricardo Pérez-Solis.

Writing–review and editing: Ricardo Pérez-Solis.