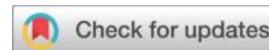


The contribution of digital transformation and green innovation to achieving sustainable performance. A Literature Review



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Abstract:

This paper examines the extent to which digital transformation and green innovation contribute to achieving sustainable performance. A descriptive approach was employed to identify relevant concepts, alongside a review of existing literature. Our study's findings suggest that digital transformation can improve the quality and quantity of green innovations, particularly in state-owned enterprises and large companies. Green innovation can also contribute to sustainable performance through positive effects arising from customer pressure, resources and capabilities, and management commitment and orientation towards sustainability.

Furthermore, digital transformation may contribute to sustainable performance both directly and indirectly via green innovation practices. However, institutions may face various challenges when adopting digital transformation to achieve green innovation and sustainable performance, including technological, organisational and environmental barriers. Accordingly, the study recommends paying greater attention to, and demonstrating greater commitment to, environmental sustainability in order to effectively link digital transformation, green innovation, and sustainable performance. It also emphasises the need to direct digital transformation towards achieving economic and social performance while closing the gap with environmental performance.

Furthermore, the study emphasises the importance of developing suitable mechanisms to address the challenges faced by institutions in this area. It also calls for a deeper understanding of digital transformation to enable it to play a vital role in sustainable transformation, and for the research gap between digital transformation, green innovation and sustainable performance to be closed. These recommendations serve as a roadmap for future research and practical implications for organisations seeking to overcome these challenges. Finally, this article enriches the existing literature on digital transformation, green innovation and sustainable performance by providing valuable insights for researchers and practitioners in this field.

Keywords: digital transformation, green innovation, sustainable performance.

Introduction

As digital technology has gradually developed and grown in popularity, large companies have begun to adopt digital transformation as a crucial strategic decision. Managers therefore need to

understand and apply this new management tool in order to address various issues, such as environmental problems (Jiang, 2025, p. 1).

The phenomenon of “Industry 4.0” has emerged. The ‘4’ in ‘Industry 4.0’ reflects the four-directional development orientation of the industrial revolution. The first industrial revolution was steam-powered, the second was powered by electricity, the third was based on automation, and the fourth is centred on the integration of the Internet of Things, intelligent robots, artificial intelligence, virtual reality and other digital technologies. There are billions of connected devices that enable rapid and flexible interaction between humans and intelligent robots. Thanks to digital transformation, Industry 4.0 is rapidly taking shape and has become one of the most widely discussed concepts worldwide (Zahra & Shafay, 2024, p. 90).

Digital transformation also alters the traditional innovation process. Firms can use digital technologies to integrate key elements of multiple value-chain relationships within the innovation process, thereby reducing innovation time and costs while ultimately improving performance. Additionally, ‘smart’ transformation in organisations significantly enhances the quantity and quality of green innovation while strengthening technological innovation in new energy firms. Digitally mature organisations cultivate innovation-centred cultures that embed experimentation and organisational learning. This establishes adaptive frameworks that enable rapid responses to technological and market disruptions (Guo, Chen & Chen, 2025, p. 3).

Recent Academic Focus on Digital Transformation and Sustainability

Recent academic studies have increasingly focused on the relationship between digital transformation and sustainability performance. Some research suggests that digital technologies such as big data analytics and the Internet of Things (IoT) can significantly improve sustainability outcomes by reducing resource consumption and enhancing decision-making processes (Wenting & Yahya, 2024, p. 232).

Digital transformation is a driver of environmental sustainability, enabling firms to adapt production processes and design eco-friendly products in response to environmental concerns. Consequently, digital transformation has become a vital enabler for manufacturers seeking to enhance sustainability. It provides alternative means to support decision-making, improve processes to increase resource-use efficiency, foster innovation in green technologies, enhance supply-chain transparency and empower consumers to make more sustainable choices (Asbeetah, Alzubi & Khadem, 2025, p. 2).

Synergy between digital transformation and green innovation

Digital transformation and green innovation have emerged as key corporate strategies for achieving sustainable development. Companies and governments are increasingly recognising the importance of environmental stewardship, not only through governmental policy, but also by integrating green principles into their operational practices. At the same time, firms that adopt digital transformation not only improve operational efficiency, but also achieve optimal resource utilisation and recycling, thereby promoting sustainable growth. This highlights the synergy between technology and environmental protection as a principal driver of healthy global socio-economic and ‘green’ development (Zhang, 2024, p. 70).

Based on the above, the following research problem can be formulated:

Research Problem:

To what extent do digital transformation and green innovation contribute to achieving sustainable performance?

Study hypotheses:

- Digital transformation contributes to achieving sustainable performance.

Green innovation contributes to achieving sustainable performance.

- Digital transformation and green innovation contribute jointly to achieving sustainable performance.

From the research problem, the following sub-questions are proposed:

- What are digital transformation, green innovation and sustainable performance?
- Does digital transformation contribute to achieving sustainable performance?
- Does green innovation contribute to achieving sustainable performance?
- Do digital transformation and green innovation contribute jointly to achieving sustainable performance?

Study objectives

The objectives of this study are as follows:

- To identify digital transformation and green innovation as tools that organisations should utilise to achieve sustainable performance.
- To examine the relationship between digital transformation and sustainable performance.
- To examine the relationship between green innovation and sustainable performance.
- Derive findings that can be utilised in organisations and in future research.

Study Methodology

This study employed a descriptive approach and a literature review methodology. Specifically, prior studies were reviewed to investigate the relationship between digital transformation, green innovation and sustainable performance, and to determine the extent to which digital transformation and green innovation contribute to achieving sustainable performance. A set of relevant studies on the same topic were analysed.

First: Digital transformation, green innovation and sustainable performance

1. Digital Transformation

1.1 Definition of digital transformation

Digital transformation, both as a business process and as a term used to describe organisational activities related to the information technology sector, has roots dating back to the mid-twentieth century. The development of early computers and the conversion of analogue data into digital content altered the course of technological progress (Lozic & Čiković, March 2024, p. 327).

Lucas et al. (2013) defined digital transformation as 'a radical change in the traditional ways of conducting business by redefining business capabilities, processes, and relationships' (Pucihar et al., 18–21 June 2017, p. 434). According to the OECD (2018), digital transformation involves the use of

digital technologies and data, as well as their interconnection, resulting in new activities or changes to existing ones (Verina & Titko, May 2019, p. 721).

Generally speaking, digital transformation involves the application of modern technologies in firms, such as artificial intelligence, big data and cloud computing, where these advanced information technologies enable comprehensive management and production. The aim of digital transformation is to strengthen firms' core competitiveness, change how value is created to achieve growth, improve the quality of information and production efficiency through more effective information flows, and reorganise and enhance production resources to deliver substantial improvements in business performance (Xuqian, 2024, p. 3).

1.2 Dimensions of digital transformation

The dimensions of digital transformation include the following (Alkhazali, Aqrabawi, Al-Abbadi, Abu Rumman & Alshawabkeh, 2025, p. 546):

1.2.1 Managerial capability

Digital transformation has become a necessity for organisations seeking to develop their services and ensure continuity in a way that guarantees the highest level of satisfaction for all relevant stakeholders. This implies the need to adopt an integrated programme within the organisation that addresses management methods, both internal and external work practices, and how to deal with beneficiaries. The programme also aims to deliver services to target groups more easily and efficiently.

1.2.2 Operational capability

Digital transformation helps organisations connect with one another to provide shared services with greater transparency. It also involves investing in advanced information technology tools and systems, and paying increased attention to improving service delivery through faster transaction processing and the availability of digital innovations across all digital channels, websites and smartphone applications to reach all relevant parties.

2.Green innovation

2.1 Definition of green innovation

Green innovation refers to the development of environmentally friendly products and processes by adopting organisational practices, particularly the use of more eco-friendly raw materials and smaller quantities of materials when designing products based on eco-design principles. The aim is to reduce emissions and decrease the consumption of water, electricity and other raw materials (Kumar, Del, Roberto & Domenico, 2020, p. 3).

A recent study defines green innovation as 'new or modified products and processes, including technological, managerial and organisational innovations, that contribute to preserving the environment'. Green innovation may also refer to 'a creative initiative that reduces negative environmental impacts or generates environmental benefits by adding value to the market'.

Green innovation can be divided into two types: Green product innovations (developing new green products for consumers) and green process innovations (or 'greening' operational procedures) (Wang et al., 2021, p. 3).

2.2 Types of Green Innovation

Green innovation is divided into two types:

2.2.1 Green product innovation

Green product innovation involves developing products that are designed to minimise their environmental impact throughout their entire life cycle. The concept also encompasses improvements in product functionality and the adoption of sustainable practices (Das, Alam & Hawlader, 2025, p. 249).

As markets expand, developing eco-friendly products enables companies to access new markets. As global awareness of environmental sustainability increases, more opportunities emerge for such products. Firms that adopt an environmentally intelligent approach to using such products can lead the market more effectively, strengthen their financial efficiency and improve their overall performance.

Furthermore, eco-friendly products provide an improved means of complying with environmental regulations. As institutions and governments enact stricter environmental legislation, eco-friendly products are becoming a means of avoiding fines and penalties (Takyi, Gavurova & Asamoah, 2024, p. 1242).

2.2.2 Green process innovation

In contrast, green process innovation focuses on improving industrial technologies and organisational systems to mitigate the negative environmental impacts of production. This type of innovation is essential for changing operational practices in order to achieve sustainability objectives (Das, Alam & Hawlader, 2025, p. 249).

Companies use green processes to reduce costs and increase operational efficiency. Developing green process innovations helps firms to reduce waste and make optimal use of company resources, positively reflecting on performance (Takyi, Gavurova & Asamoah, 2024, p. 1242)

3. Sustainable performance

Sustainable performance refers to the harmonious development of the three pillars of sustainable development: economic, social and environmental performance. These are commonly known as the 'triple bottom line' (Zhang, Zhu & Lee, 2024, p. 4).

From an economic perspective, sustainable performance reflects an organisation's ability to maintain profitability, reduce operating costs and enhance its long-term competitive advantage. Social performance encompasses factors such as tenant and employee satisfaction and community well-being. Together, these contribute to a positive living environment and strengthen the organisation's reputation. Environmental performance focuses on optimising resource use, reducing pollution, and taking responsibility for the environment through environmentally friendly operating practices (Loogsorn & U-on, 2026, p. 1172).

Second: The Contribution of Digital Transformation and Green Innovation to Achieving Sustainable Performance

1. Digital transformation and green innovation

The emergence of new digital technologies, such as artificial intelligence, the internet and big data, offers firms new avenues for innovation. These technologies provide cumulative capabilities and enable incremental improvements in processes, stimulating green innovation by enhancing resource utilisation and reducing waste (Sun, Zhao, Mehrotra, Salam & Yaqub, 2025, p. 435).

There are two main driving forces behind green innovation: External pressures, which primarily operate at institutional and market levels, and internal drivers, relating to an organisation's resources and capabilities, managerial perceptions, and environmental responsibilities. It is also important to note that digital technology is a facilitating force in the current digital transformation landscape that cannot be ignored. Digital technologies — such as big data, cloud computing, and artificial intelligence — enable information to be linked, aggregated, processed, and simulated. This brings fundamental changes to organisational characteristics, improves operational processes, and has a transformative impact on business processes, business models, and organisational structures. It also generates and invests firm value based on a new logic (Wang, Liu & Li, 2024, p. 4).

Xue et al.'s study showed that digital transformation can enhance green technology innovation by alleviating financing constraints and attracting government support, particularly compared to non-state-owned firms and small to medium-sized enterprises (SMEs). Digital transformation plays an even more significant role in enhancing green technology innovation within state-owned enterprises and large firms. Additionally, Huang and Lau discovered that digital transformation can significantly enhance the quality of green innovation within organisations. This positive effect is further strengthened by the presence of CEOs with digital expertise and in regions with high levels of intellectual property protection.

Furthermore, Liu et al.'s results revealed substantial improvements in the size and quality of green technological innovations resulting from firms' digital transformation, with clear enhancements to innovation quality. This shift, driven by improved resource allocation, facilitates green technological innovation by strengthening human capital formation, reducing information asymmetry and increasing investment in research and development. The strongest effects are seen in state-owned enterprises.

This study corroborates the findings of Wang et al. that driving digital transformation for green innovation exhibits distinct phased characteristics. Digital transformation significantly increases the quantity of green innovation during the guidance period and substantially affects both the quantity and quality of green innovation across the formation and development stages. Furthermore, top management's environmental concerns positively moderate digital transformation-driven green innovation by strengthening absorptive and innovative capabilities. The study also reveals the sequential evolution of dynamic capabilities during the digital transformation stage.

These results are consistent with those of Sun and He, who showed that firms' digital transformation can substantially improve the quality and quantity of their green innovations, while financial constraints reduce the positive effects. Additionally, top management's environmental concern positively reinforces green innovation through digital transformation, with a more evident effect in state-owned, large-scale firms that face relatively high financing constraints and do not incur substantial environmental costs.

The findings corroborate those of Li and Shu (2010–2023), who found that digital transformation positively affects the quantity and quality of green innovation, with a more pronounced effect in state-owned firms and advanced-technology enterprises. Sun et al. also indicate that the higher a firm's level of digital transformation, supported by the accumulation and change of capabilities, the more conducive it is to green innovation. This is because it enables the integration of existing information related to green environmental protection and low-carbon energy efficiency, followed by recombination and transformation. This facilitates firms' attainment of meaningful and pioneering green innovations.

Jiang shows that digital transformation positively affects green innovation and that green management disclosure is one of the channels through which this effect operates. Additionally, industry-level institutional pressure negatively moderates the relationship between digital transformation and green innovation. Yang et al. report that digital transformation can significantly promote green innovation in the manufacturing sector. Corporate environmental responsibility partially mediates the impact of digital transformation on green innovation. Meanwhile, media attention can strengthen the positive effect of digital transformation on green innovation.

Digital technologies broaden firms' horizons by providing opportunities for comprehensive open innovation through information exchange and enhancing communication and collaboration. However, given the complexity and dynamism of innovation in green technology, opportunistic behaviour by firms in collaborative innovation leading to short-term and unstable cooperation remains an important factor hindering inter-firm collaboration in green innovation activities. Consequently, during digital transformation, firms tend to utilise information technology to bolster their independent innovation capabilities, reinforce green innovation and realise high-quality development (Li, Zhao & Yan, 2024, p. 179).

2. Digital Transformation and Sustainable Performance

The study conducted by Sun et al. highlights a close relationship between digital transformation and improved sustainable performance. This improvement is attributed to reduced supply chain concentration and increased diversification. A further study by Ma et al. shows that digital transformation has a significantly positive effect on sustainable supply chain performance.

Additionally, Mohaghegh et al.'s findings suggest that digital transformation strengthens the capabilities of the three-dimensional supply chain. However, improving overall sustainable performance does not require all three of these capabilities. The results show that supply chain resilience and adaptability are the two capabilities that primarily mediate the relationship between digital transformation and sustainable performance.

Zaida et al. suggest that disruptive technologies, such as the Internet of Things, artificial intelligence, blockchain technology and big data, can help organisations achieve sustainable supply chain performance as part of supply chain digitalisation. Latif et al. conclude that digital transformation positively affects sustainable performance and that this relationship is strengthened through supply chain management systems. Accordingly, the results demonstrate how digital transformation can enhance sustainability practices in manufacturing firms.

The results also indicate that, on a broad scale, digitalisation is one of the most important factors in ensuring sustainable performance. They also identify supply chain management systems as playing a crucial role in strengthening digital processes through digital products and services to achieve sustainability.

The study conducted by Bindeeba et al. highlights the emergence of smart factories and the importance of big data analytics and the Internet of Things in achieving sustainable outcomes. The results also illustrate the multidimensional benefits of digital transformation, particularly with regard to improving productivity, reducing environmental impact and enhancing stakeholder engagement.

The study by Hassani et al. shows that responsible digital transformation, when integrated with ethical, environmental and social considerations, enhances sustainable performance beyond operational efficiency. It also reveals that regulatory balance is a key enabling factor. In contrast, Li finds that, while digital transformation accelerates economic performance, it is inversely related to

environmental performance. Furthermore, digital transformation has a faster impact on economic performance when market disruption is low. However, when market disruption is high, higher levels of digital transformation are associated with a deterioration in environmental performance.

A study by Meng et al. indicates that supply chain resilience mediates the effects of digital transformation on economic and social performance, particularly when there is a high level of perceived business strength. However, no effect was observed on environmental performance.

3. Green Innovation and Sustainable Performance

The study conducted by Saudi et al. confirms that economic and environmental performance are positively and significantly affected by green product and process innovation. Top management's environmental concern positively and significantly moderates the relationship between green product and process innovations, as well as between these innovations and environmental performance. However, there is no evidence of a moderating effect of top management's environmental concerns on the relationships between green process innovation and economic performance or between green product innovation and economic performance.

The results of the study by Öztürk et al. show that green supply chain management significantly enhances both green infrastructure and sustainable carbon productivity. Additionally, Imran et al. demonstrate that green innovation influences sustainable performance. The empirical findings of Lestari and Sunyoto indicate that customer pressures, resources, capabilities and management commitment towards green innovation positively influence sustainable performance. Similarly, Uvidia et al. find that green innovation, whether in products or processes, positively affects firms' sustainable performance. They also identify sustainability orientation as a key mediating factor in this relationship, although this effect is observed only among firms within the same cluster.

These findings further emphasise the importance of cooperation and knowledge exchange in such environments, enhancing the effectiveness of green initiatives as sustainable strategies. A study by Aftab et al. shows that green innovation mediates the relationship between environmental corporate ethics and sustainable performance in social, economic and environmental terms. However, O'Brien et al. reveal that, despite extensive research on green innovation, direct links to sustainable performance remain scarce and are disproportionately represented across different dimensions. The literature overwhelmingly focuses on environmental aspects, whereas social and economic dimensions are underrepresented. China stands out as the leading country in terms of research output and influence. Furthermore, the theoretical development of green innovation and sustainable performance remains incomplete: although environmental dimensions have been well theorised, social and economic dimensions are underdeveloped.

4. Digital Transformation, Green Innovation and Sustainable Performance

A study by Thuy et al. shows that digital transformation has a positive direct effect on sustainable performance, while the indirect effect through innovation is substantial. Accordingly, the study confirms the mediating role of innovation in this relationship.

The findings of Liu et al. indicate that digital transformation significantly improves environmental performance, with green innovation and green management acting as effective mediators in this relationship. Xu et al. further found that digital strategy and digital capabilities significantly enhance process and product innovation, as well as environmental management. Process, product and environmental management innovations also improve sustainable performance. At the same time,

environmental innovation contributes partially to the positive relationship between digital transformation and sustainable performance.

Zhu and Li report that digital transformation and green innovation have a strong positive effect on firms' sustainability performance, indicating a 'multiplicative effect' compared to the individual effects of digital transformation or green innovation alone. Environmental regulations positively moderate the relationship between digital risk management (DGT) and corporate social sustainability effectiveness (CSP).

(Jiang et al.) demonstrate that digital transformation does not directly improve organisational performance; rather, it achieves this by strengthening organisational capabilities, transforming processes, implementing innovation initiatives and conducting sustainability-focused activities. The study also found that capability-based mechanisms were the most common, followed by operational pathways and pathways mediated by innovation.

Using detailed empirical data from Chinese firms listed in Category (A), (Zhang et al.) clarify how digital transformation and, specifically, green innovation contribute to improving environmental performance. Their study also confirms the mediating role of green innovation as a crucial mechanism linking digital transformation to better environmental performance. The study concludes that firms' digital transformation significantly enhances their environmental performance by accelerating the pace of green innovation.

(Karikari et al.) find that adopting digital technologies positively affects sustainable performance both directly and indirectly through green innovation practices. Their importance-performance analysis indicates that green innovation practices have the strongest impact on sustainable performance.

The results of Yarkarami further demonstrate that green digital transformation capability significantly strengthens green process innovation and sustainable supply chain resilience. It also mediates the effect of these factors on sustainable performance. The quality of data governance reinforces the relationship between green digital transformation capability and sustainable supply chain resilience, while institutional pressure strengthens the relationship between sustainable supply chain resilience and sustainable performance.

Additionally, Yordanova identifies the key barriers that organisations face when adopting digital transformation to achieve green innovation and sustainable performance, classifying them into three categories: technological, organisational and environmental. Technological barriers include issues related to technological readiness, data management, interoperability and cybersecurity. Organisational barriers include challenges related to organisational culture, leadership, change management and resistance to change. Environmental barriers involve external factors such as regulatory frameworks, legal constraints, and stakeholder pressure. The review concludes that these barriers can significantly hinder organisations' efforts to promote green innovation and drive sustainable performance.

Conclusion:

This research paper aimed to synthesise a wide range of scholarly references and empirical studies related to digital transformation, green innovation and sustainable performance. The focus was on research examining the relationships and effects among these variables. The aim was to integrate findings from studies that approach the topic from different perspectives and use various mediating variables, consequently reporting different results. This was done in an effort to draw multiple implications for the literature and managerial practice.

Our study provides clear, systematic evidence to help reduce ambiguity and inconsistency in the understanding of the interaction between an integrated set of elements, including digital transformation, green innovation and sustainable performance. It also offers different conceptual and operational dimensions across the literature on these topics. The study concludes the following:

1. Digital transformation can enhance the quality and quantity of firms' green innovations, particularly when top management teams are environmentally focused, green management disclosure is present and media attention is high. Furthermore, digital transformation plays an even more significant role in strengthening green innovation within state-owned firms and large enterprises.
2. Digital transformation can contribute to achieving sustainable performance through supply chain management. Certain technologies can support this process, such as the Internet of Things, artificial intelligence, blockchain technology and big data.
3. Digital transformation can enable economic and social performance outcomes; however, in some cases, this improvement may occur without corresponding environmental performance gains.
4. Organisations may face technological, organisational and environmental barriers when adopting digital transformation to achieve green innovation and sustainable performance.
5. Green innovation can support sustainable performance through positive effects such as customer pressure, resources, capabilities, management commitment and sustainability orientation.
6. Digital transformation can improve sustainable performance both directly and indirectly through green innovation practices — meaning that green innovation may play a mediating role in the relationship.

In addition, our study makes the following recommendations:

1. Strengthen commitment to environmental and sustainability goals to ensure effective alignment between digital transformation, green innovation and sustainable performance.
2. Direct digital transformation towards achieving economic and social performance outcomes while addressing the gap between these and environmental performance.
3. Develop appropriate mechanisms to overcome the technological, organisational and environmental barriers faced by organisations when adopting digital transformation to achieve green innovation and sustainable performance.
4. Enhance understanding of digital transformation so that it can play a vital role in sustainable transitions and help to bridge the research gap between digital transformation, green innovation and sustainable performance.

Overall, this study broadens the scope of research findings and deepens understanding of the mechanisms through which digital transformation and green innovation affect sustainable performance. It also suggests that companies should use digital transformation to improve disclosure of green management information and reduce the negative impact of institutional pressures in order to implement green innovations and achieve sustainable performance.

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