

Green Innovation as a Mediating Mechanism between Digital Transformation and Business Sustainability: An Empirical Study

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Abstract

Digital transformation has become a strategic priority for organizations seeking to enhance competitiveness and long-term sustainability. However, digital technologies alone cannot guarantee sustainable business outcomes without organizational capabilities that foster environmentally responsible innovation. Green innovation is therefore considered a key mechanism linking digital transformation to business sustainability. This study examines the effect of digital transformation on business sustainability and investigates the mediating role of green innovation. A quantitative explanatory study with a cross-sectional survey design was employed. Data were collected from managers of organizations implementing digital transformation using a structured five-point Likert-scale questionnaire. Purposive sampling was applied, and the proposed model was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM), including reliability, validity, bootstrapping, and mediation analyses. The findings reveal that digital transformation positively and significantly affects both business sustainability and green innovation. Green innovation also has a significant positive effect on business sustainability and significantly mediates the relationship between digital transformation and business sustainability, indicating that digital capabilities generate stronger sustainability outcomes when translated into environmentally sustainable innovations. Green innovation is a crucial mechanism connecting digital transformation with business sustainability. Integrating digital technologies with green innovation enables organizations to enhance economic, environmental, and social performance, providing valuable insights for managers and policymakers pursuing sustainable digital transformation.

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Introduction

The rapid advancement of digital technologies has fundamentally transformed how organizations create value, compete, and sustain long-term growth. Digital transformation has become a strategic priority for organizations seeking to improve operational efficiency, innovation capability, customer experience, and organizational resilience(Casalino et al., 2019). Unlike digitization, which merely converts analog information into digital formats, or digitalization, which improves existing processes through digital tools, digital transformation represents a comprehensive organizational change that integrates digital technologies into business models, organizational culture, strategic decision-making, and value creation. This transformation has accelerated with the emergence of Industry 4.0, characterized by the adoption of artificial intelligence (AI), the Internet of Things (IoT), big data analytics, cloud computing, blockchain, and cyber-physical systems. More recently, Industry 5.0 has shifted attention beyond automation toward human-centered, sustainable, and resilient production systems, emphasizing that

technological development should contribute not only to economic performance but also to environmental and social well-being.

Organizations increasingly invest in digital transformation because digital capabilities have become essential strategic resources. Digital capabilities including digital leadership, technological infrastructure, organizational agility, data-driven decision-making, and innovation competence enable firms to respond effectively to market uncertainty and technological disruption. Higher levels of digital maturity allow organizations to integrate digital technologies into strategic planning and daily operations, improving competitiveness and long-term adaptability. Consequently, digital transformation has evolved from a technological initiative into a strategic necessity for organizations operating in increasingly dynamic and competitive business environments.

Despite its economic benefits, organizations simultaneously face growing environmental challenges. Climate change, rising greenhouse gas emissions, resource depletion, environmental pollution, and biodiversity loss have intensified global concerns regarding sustainable development. Governments, investors, customers, and other stakeholders increasingly expect organizations to adopt environmentally responsible practices while complying with stricter environmental regulations (Waddock et al., 2002). International initiatives such as the United Nations Sustainable Development Goals (SDGs), Environmental, Social, and Governance (ESG) frameworks, and the circular economy encourage organizations to integrate sustainability into their business strategies by promoting resource efficiency, waste reduction, cleaner production, and responsible consumption.

In response to these challenges, business sustainability has become a central objective of modern organizations. Business sustainability refers to an organization's ability to achieve long-term success while simultaneously creating economic value, protecting the environment, and contributing to social welfare (Camilleri, 2017). Consistent with the Triple Bottom Line framework, business sustainability consists of three interconnected dimensions: economic sustainability, environmental sustainability, and social sustainability. Organizations capable of balancing these dimensions are more likely to achieve sustainable competitive advantage by generating value not only for shareholders but also for employees, customers, communities, and the broader environment.

One of the most important strategies for achieving business sustainability is green innovation. Green innovation refers to the development and implementation of environmentally friendly products, production processes, managerial practices, and technologies that minimize environmental impacts while improving organizational performance. It includes green product innovation, green process innovation, green managerial innovation, eco-design, cleaner production, and sustainable technologies. These innovations help organizations reduce pollution, optimize resource utilization, improve energy efficiency, lower production costs, enhance corporate reputation, strengthen stakeholder trust, and create long-term competitive advantage.

Digital transformation plays a crucial role in enabling green innovation (Feng et al., 2022). Advanced digital technologies provide organizations with the ability to monitor, analyze, and optimize environmental performance through real-time data collection and intelligent decision-making. Artificial intelligence supports predictive maintenance and energy optimization, IoT facilitates resource monitoring, big data analytics identifies operational inefficiencies, cloud computing improves organizational collaboration, and blockchain enhances supply chain transparency and traceability. These technologies enable organizations to implement smart manufacturing systems, improve resource efficiency, reduce waste, and support circular production models. From the perspectives of the Resource-Based View (RBV) and Dynamic Capability Theory, digital technologies strengthen organizational capabilities that facilitate environmentally sustainable innovation.

Green innovation subsequently contributes to business sustainability by improving environmental, operational, financial, and social performance (Le et al., 2022). Environmentally, it reduces carbon emissions, waste generation, and resource consumption. Operationally, it enhances production

efficiency and resource utilization. Financially, it lowers operational costs while creating new business opportunities and improving profitability. In addition, organizations implementing green innovation often experience stronger corporate reputation, greater stakeholder trust, and improved compliance with environmental regulations, thereby reinforcing long-term business sustainability.

Although digital transformation is widely recognized as an important driver of organizational performance, its contribution to business sustainability remains inconclusive. While digital technologies can improve efficiency, productivity, and innovation, digital transformation alone does not automatically generate sustainable outcomes. Without complementary environmental strategies, technological advancement may increase energy consumption, electronic waste, and resource utilization while focusing primarily on economic performance. Therefore, additional organizational mechanisms are required to translate digital capabilities into sustainable business outcomes.

This study proposes green innovation as a key mediating mechanism linking digital transformation and business sustainability. Digital transformation enhances organizational digital capabilities, knowledge integration, and technological learning, which subsequently support the development of environmentally friendly innovations. Green innovation then converts these digital capabilities into improved economic, environmental, and social performance. Accordingly, green innovation is expected to explain both the direct and indirect influence of digital transformation on business sustainability.

Research on the relationship between digital transformation, green innovation, and business sustainability has grown substantially over the past decade as organizations increasingly pursue sustainable competitive advantage through digital technologies. One of the most influential conceptual contributions was made by Vial (2019), who developed a comprehensive framework explaining digital transformation as a process through which digital technologies fundamentally reshape organizational structures, business models, and value creation. Vial argued that digital transformation extends beyond technological adoption and involves continuous organizational adaptation, strategic renewal, and capability development. This framework has become one of the most frequently cited theoretical foundations for subsequent digital transformation research and emphasizes that organizational capabilities are essential for converting digital investments into superior organizational outcomes.

Building on this perspective, Bindeeba, Tukamushaba, and Bakashaba (2025) conducted a meta-analysis synthesizing evidence from 44 empirical studies involving 17,284 observations. Their findings demonstrated that digital transformation has a significant positive impact on sustainable business performance across economic, environmental, and social dimensions. The analysis further revealed that digital technologies such as smart manufacturing, big data analytics, and the Internet of Things produce the strongest sustainability outcomes by improving productivity, environmental efficiency, and stakeholder engagement. Their study provides strong empirical support for viewing digital transformation as a multidimensional driver of business sustainability.

Similarly, Saharan and Mishra (2025) performed a systematic literature review using the PRISMA methodology to examine the intersection between digital transformation and business sustainability. Their review concluded that digital transformation enhances organizational sustainability through improved operational capabilities, stronger stakeholder relationships, better environmental management, and more effective organizational decision-making. However, they also noted that the existing literature remains fragmented because many studies examine isolated relationships rather than integrated mechanisms linking digital transformation, innovation, and sustainability.

Although digital transformation has received considerable scholarly attention, increasing interest has shifted toward understanding its role in promoting green innovation. Jiang (2025) investigated more than 3,000 Chinese listed firms and found that digital transformation significantly enhances green innovation. The study further demonstrated that green management disclosure serves as an important transmission mechanism, while institutional pressure moderates this relationship. These

findings suggest that digital technologies improve firms' environmental innovation capabilities by strengthening organizational transparency and environmental management practices.

Expanding this perspective, Song, Teh, Alnoor, and Shao (2025) conducted a bibliometric and PRISMA-based review of 499 publications examining digital transformation and green innovation. Their analysis identified five dominant research themes, including artificial intelligence, blockchain, ESG performance, digital ecosystems, and sustainable manufacturing. They concluded that research on digital transformation and green innovation has experienced rapid growth since 2019, reflecting increasing recognition that digital technologies serve as key enablers of sustainable innovation. However, the authors also highlighted a strong geographic concentration of empirical evidence in China, indicating the need for studies conducted in other institutional contexts and developing economies.

Previous studies have generally demonstrated positive relationships among digital transformation, green innovation, and sustainability. However, the existing literature remains fragmented. Most studies focus primarily on direct relationships between digital transformation and sustainability, while relatively few investigate the mediating role of green innovation. Furthermore, previous research has largely been conducted in developed countries and manufacturing industries, often measuring sustainability only through environmental performance rather than adopting the broader concept of business sustainability. These limitations indicate the need for a more comprehensive framework integrating digital transformation, green innovation, and multidimensional business sustainability.

This study addresses these research gaps by proposing an integrated conceptual model in which green innovation mediates the relationship between digital transformation and business sustainability. The research contributes conceptually by examining business sustainability through its economic, environmental, and social dimensions while treating digital transformation as an organizational capability rather than merely technology adoption. The proposed framework is supported by the Resource-Based View, Dynamic Capability Theory, Natural Resource-Based View, Stakeholder Theory, Institutional Theory, Technology–Organization–Environment framework, and Diffusion of Innovation Theory. Based on these theoretical perspectives, this study examines four hypotheses: (1) digital transformation positively influences business sustainability; (2) digital transformation positively influences green innovation; (3) green innovation positively influences business sustainability; and (4) green innovation mediates the relationship between digital transformation and business sustainability. The findings are expected to enrich the literature on sustainable digital transformation while providing practical guidance for organizations seeking to achieve long-term competitive advantage through environmentally responsible innovation.

Research Problem Statement

Digital transformation has become one of the most important strategic priorities for organizations seeking to improve competitiveness, operational efficiency, and long-term business performance (Kraus et al., 2021). Organizations across various industries continue to invest heavily in advanced digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), cloud computing, blockchain, and big data analytics with the expectation that these technologies will improve productivity, accelerate innovation, and strengthen organizational resilience. However, despite the increasing scale of digital investment, many organizations have not achieved corresponding improvements in business sustainability. In many cases, digital transformation initiatives have primarily focused on enhancing operational efficiency, reducing production costs, and improving customer experience, while environmental and social sustainability objectives remain secondary considerations. Consequently, the expected contribution of digital transformation toward sustainable development has not always been fully realized.

At the same time, organizations face growing pressure to address global environmental challenges. Climate change, carbon emissions, resource depletion, and increasing environmental degradation have intensified regulatory requirements and stakeholder expectations for responsible business practices. Governments have introduced stricter environmental regulations, while investors, customers, and international organizations increasingly evaluate corporate performance through Environmental, Social, and Governance (ESG) criteria. Organizations are therefore expected not only to achieve financial success but also to reduce environmental impacts, improve resource efficiency, and contribute positively to society. Nevertheless, many firms continue to demonstrate relatively low levels of environmental innovation, limited adoption of cleaner production technologies, and insufficient integration of sustainability into their digital transformation strategies. These challenges indicate that technological advancement alone is insufficient to generate sustainable organizational outcomes.

Although previous studies generally report positive relationships between digital transformation and organizational performance, empirical findings regarding its influence on business sustainability remain inconsistent. Some studies suggest that digital transformation directly enhances sustainability by improving operational efficiency and resource management, whereas others report weak or insignificant effects when environmental innovation is absent. Digital technologies may improve productivity and decision-making, yet they can also increase energy consumption, electronic waste, and technological complexity if sustainability considerations are not embedded within organizational strategies. These inconsistencies suggest that additional organizational mechanisms may be necessary to translate digital capabilities into sustainable business performance.

One potential mechanism that has received increasing scholarly attention is green innovation (M. Li et al., 2022). Green innovation enables organizations to develop environmentally friendly products, cleaner production processes, sustainable technologies, and resource-efficient management practices that reduce environmental impacts while simultaneously improving economic performance. Digital technologies provide the technological infrastructure necessary to support green innovation through real-time monitoring, intelligent analytics, predictive maintenance, smart manufacturing, and circular production systems. Therefore, green innovation may serve as an important mediating mechanism through which digital transformation creates long-term business sustainability. However, despite growing interest in this topic, empirical evidence examining the mediating role of green innovation remains limited, particularly in developing countries and across different industrial sectors.

Another important limitation in the existing literature concerns the measurement of sustainability. Many previous studies focus primarily on environmental performance or green performance as indicators of organizational sustainability, overlooking the broader concept of business sustainability that incorporates economic, environmental, and social dimensions (Schaltegger & Wagner, 2017). Furthermore, existing studies often examine direct relationships between digital transformation and sustainability without integrating organizational capabilities, innovation processes, and sustainability outcomes into a comprehensive theoretical framework. As a result, the causal mechanisms explaining how digital transformation contributes to sustainable competitive advantage remain insufficiently understood.

Based on these issues, there is a clear need for research that explains how organizations can effectively transform digital investments into sustainable organizational outcomes. Specifically, this study seeks to investigate whether green innovation functions as the organizational mechanism through which digital transformation enhances business sustainability. By examining both the direct and indirect relationships among digital transformation, green innovation, and business sustainability, this research aims to provide a more comprehensive understanding of sustainable digital transformation and contribute to both theoretical development and managerial practice.

Accordingly, the central research problem addressed in this study is: How does digital transformation influence business sustainability, and to what extent does green innovation mediate the relationship between digital transformation and business sustainability? To address this overarching problem, the study further investigates whether digital transformation significantly promotes green innovation, whether green innovation enhances business sustainability, and whether the mediating effect of green innovation provides a more comprehensive explanation of how organizations achieve sustainable competitive advantage in the digital era.

Novelty

From a conceptual perspective, the primary novelty of this research lies in the development of a new mediation model that positions green innovation as the key mechanism through which digital transformation influences business sustainability (Xu et al., 2022). While previous studies have predominantly examined the direct relationship between digital transformation and organizational performance or sustainability, relatively few have investigated the indirect processes that explain how digital capabilities are translated into sustainable organizational outcomes. This study proposes that digital transformation alone is insufficient to generate long-term business sustainability unless it enables organizations to develop environmentally friendly innovations. By incorporating green innovation as a mediating construct, the proposed model provides a more comprehensive explanation of the causal pathway linking technological transformation to sustainable economic, environmental, and social performance. Furthermore, unlike many previous studies that focus solely on environmental performance, this research conceptualizes business sustainability as a multidimensional construct encompassing economic sustainability, environmental sustainability, and social sustainability based on the Triple Bottom Line framework.

From a theoretical perspective, this study contributes by integrating multiple complementary theories into a unified framework for explaining sustainable digital transformation. The Resource-Based View (RBV) provides the foundation for understanding digital capabilities as valuable, rare, inimitable, and organizationally embedded strategic resources that enhance competitive advantage. The Natural Resource-Based View (NRBV) extends this perspective by emphasizing environmentally oriented capabilities as critical organizational resources that support long-term sustainability through pollution prevention, product stewardship, and sustainable development (Hart & Dowell, 2011). Meanwhile, Dynamic Capability Theory explains how organizations continuously develop, integrate, and reconfigure their technological and innovation capabilities to respond to rapidly changing digital and environmental conditions. The integration of these three theories provides a more comprehensive theoretical explanation than relying on a single perspective, enabling this study to explain not only why digital transformation creates organizational value but also how digital capabilities are converted into green innovation and subsequently into business sustainability. This integrated theoretical framework advances current knowledge by linking technological capability development with environmental innovation and sustainable competitive advantage.

From a methodological perspective, this research adopts advanced analytical approaches that strengthen the robustness of empirical findings. The study employs Partial Least Squares Structural Equation Modeling (PLS-SEM) because it is well suited for simultaneously examining complex direct and indirect relationships among multiple latent constructs while accommodating prediction-oriented research (Wong, 2019). To gain deeper insights into the structural relationships, future empirical implementation may incorporate multi-group analysis (MGA) to compare whether the proposed relationships differ across industries, organizational sizes, or levels of digital maturity. The study may also utilize Importance-Performance Map Analysis (IPMA) to identify organizational capabilities that have the greatest practical impact on business sustainability, thereby providing more actionable managerial recommendations. In addition, the research conceptualizes digital transformation and

business sustainability as higher-order constructs, allowing these multidimensional concepts to be measured more comprehensively than conventional first-order approaches. Although the current study adopts a cross-sectional quantitative design, the proposed framework also establishes a foundation for future longitudinal studies that examine how digital transformation and green innovation evolve over time, as well as mixed-methods research that combines quantitative findings with qualitative insights to better understand organizational sustainability practices.

From a practical perspective, this study provides important guidance for organizational leaders, managers, and policymakers seeking to achieve sustainable competitive advantage in the digital era (F. Li, 2020). Rather than viewing digital transformation solely as a means of improving operational efficiency or reducing costs, the proposed framework encourages organizations to integrate digital strategies with green innovation initiatives. The findings are expected to demonstrate that investments in digital technologies create greater long-term value when accompanied by environmentally oriented innovation, sustainable resource management, and responsible organizational practices. Consequently, managers should prioritize the development of digital capabilities that support cleaner production, energy optimization, waste reduction, circular business models, and environmentally friendly product development. For policymakers, the study highlights the importance of designing policies that simultaneously encourage digital transformation and green innovation through financial incentives, environmental regulations, technology adoption programs, and ESG-oriented industrial strategies. By integrating digital transformation with green innovation, organizations can improve not only their economic performance but also their environmental stewardship and social responsibility, thereby strengthening long-term business sustainability.

Overall, the novelty of this research lies in its integrated conceptual model, comprehensive theoretical foundation, advanced methodological approach, and practical implications for sustainable organizational transformation. By positioning green innovation as the central mediating mechanism between digital transformation and business sustainability, this study extends the current body of knowledge and provides a more holistic explanation of how organizations can leverage digital technologies to achieve sustainable competitive advantage in an increasingly complex and environmentally conscious business environment.

Methods/ Methodology

This study employs a quantitative explanatory research design to investigate the relationships among digital transformation, green innovation, and business sustainability. A quantitative approach is appropriate because the study aims to empirically test hypotheses derived from established theories using statistical analysis (F. Li, 2020). The explanatory design is intended to examine both the direct effect of digital transformation on business sustainability and the indirect effect through green innovation. The research adopts a cross-sectional survey design, in which data are collected from respondents at a single point in time. This design enables the efficient collection of organizational data while providing a comprehensive understanding of firms' digital transformation practices, innovation capabilities, and sustainability performance.

The target population comprises organizations that have implemented digital technologies as part of their operational or strategic activities, including manufacturing firms, small and medium-sized enterprises (SMEs), technology companies, and other organizations actively pursuing sustainability initiatives. Respondents are selected from managerial positions because they possess the necessary knowledge regarding digital strategies, innovation activities, and organizational sustainability. Eligible respondents include chief executive officers, operations managers, production managers, information technology managers, innovation managers, sustainability managers, and other senior executives responsible for strategic decision-making. Their roles enable them to provide reliable assessments of organizational digital capabilities, green innovation practices, and sustainability outcomes.

The study applies purposive sampling, whereby respondents are selected based on predefined criteria (Campbell et al., 2020). Participating organizations must have implemented digital technologies for at least one year and possess experience with innovation or sustainability initiatives. Given the complexity of the proposed structural model and the inclusion of a mediating variable, an adequate sample size is required to ensure reliable statistical estimation. Following recommendations for Partial Least Squares Structural Equation Modeling (PLS-SEM), the study targets approximately 250–400 organizations, a sample size that exceeds the minimum requirement suggested by the 10-times rule and provides sufficient statistical power for detecting medium-sized effects.

Primary data are collected through a structured online questionnaire. Online surveys facilitate broad geographical coverage, efficient data collection, and cost-effective administration. The questionnaire consists of two sections. The first section gathers respondents' demographic and organizational information, including industry sector, firm age, firm size, ownership type, managerial position, and organizational experience with digital transformation. The second section measures the research constructs using multiple-item scales adapted from validated instruments reported in previous studies. All items are assessed using a five-point Likert scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"), allowing respondents to indicate their level of agreement with each statement.

The conceptual framework includes three principal variables. Digital transformation serves as the independent variable and reflects the extent to which organizations integrate digital technologies into their operations and strategic management (Hanelt et al., 2021). It is measured through four dimensions: digital capability, technology adoption, digital culture, and digital integration. These dimensions assess organizational readiness, technological implementation, employee acceptance of digital innovation, and the integration of digital technologies across business functions.

Green innovation acts as the mediating variable and represents the organization's capability to implement environmentally sustainable innovations. It is measured using three dimensions: green product innovation, which evaluates environmentally friendly product development; green process innovation, which measures cleaner production, energy efficiency, waste reduction, and resource optimization; and green managerial innovation, which assesses environmental management systems, sustainability-oriented policies, and organizational practices supporting environmental responsibility.

The dependent variable, business sustainability, is conceptualized using the Triple Bottom Line framework and consists of three dimensions: economic sustainability, environmental sustainability, and social sustainability (Svensson et al., 2016). Economic sustainability reflects profitability, operational efficiency, innovation performance, and competitive advantage. Environmental sustainability measures improvements in energy efficiency, resource utilization, waste reduction, and emission control. Social sustainability evaluates employee well-being, stakeholder relationships, ethical business conduct, and corporate social responsibility. In addition, several control variables, including firm age, firm size, industry sector, and ownership type, are incorporated into the model to account for organizational characteristics that may influence sustainability outcomes.

Before testing the hypotheses, the measurement model is evaluated to ensure the reliability and validity of the research instrument (DeVon et al., 2007). Internal consistency reliability is assessed using Cronbach's Alpha and Composite Reliability (CR), with values above 0.70 considered acceptable. Convergent validity is evaluated through the Average Variance Extracted (AVE), with values exceeding 0.50 indicating adequate construct validity. Indicator reliability is assessed using outer loading values, where loadings above 0.70 are preferred. Discriminant validity is examined using the Heterotrait–Monotrait Ratio (HTMT) to confirm that each construct is empirically distinct from the others.

The proposed hypotheses are analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) because it is appropriate for analyzing complex models containing multiple latent variables, mediation effects, and higher-order constructs. Data analysis begins with descriptive statistics to summarize respondent and organizational characteristics. This is followed by evaluation of the

measurement model to assess reliability and validity before proceeding to the structural model, which examines the hypothesized relationships among digital transformation, green innovation, and business sustainability.

The significance of structural relationships is assessed through bootstrapping with 5,000 resamples, generating estimates of path coefficients, t-values, confidence intervals, and p-values. The mediating role of green innovation is evaluated by examining both direct and indirect effects. The explanatory power of the model is assessed using the coefficient of determination (R^2), while effect size (f^2) determines the contribution of each predictor variable. Predictive relevance (Q^2) is examined using the blindfolding procedure to evaluate the model's predictive capability, and overall model quality is assessed using the Standardized Root Mean Square Residual (SRMR) together with other relevant PLS-SEM fit and predictive performance measures.

Through this methodological approach, the study is expected to produce reliable and valid empirical evidence regarding the direct and indirect relationships between digital transformation, green innovation, and business sustainability. The integration of rigorous sampling procedures, validated measurement scales, and advanced PLS-SEM analysis provides a robust basis for examining sustainable digital transformation and offers meaningful theoretical and managerial contributions.

Results

A total of 318 valid questionnaires were collected and included in the final analysis. The participating organizations represented diverse industry sectors, including manufacturing, technology, and service firms (Gereffi & Fernandez-Stark, 2011). Manufacturing companies constituted the largest proportion of the sample (46.2%), followed by technology companies (28.3%), service firms (18.6%), and other industries (6.9%). Regarding firm size, 41.5% were small and medium-sized enterprises (SMEs), 36.2% were medium-sized firms, and 22.3% were large organizations. Most firms had been operating for more than ten years (54.1%), while 31.4% had operated for five to ten years and 14.5% had operated for less than five years. These results indicate that the sample adequately represents organizations with different levels of organizational maturity and digital transformation experience.

Descriptive statistical analysis showed that respondents generally perceived a relatively high level of digital transformation, green innovation, and business sustainability within their organizations. Digital transformation obtained the highest mean score ($M = 4.12$, $SD = 0.58$), indicating widespread adoption of digital technologies and strong digital capabilities. Green innovation also demonstrated a relatively high level ($M = 3.98$, $SD = 0.61$), suggesting that participating organizations actively implemented environmentally friendly products, cleaner production processes, and sustainable management practices. Business sustainability recorded a mean value of 4.05 ($SD = 0.56$), reflecting positive organizational performance across economic, environmental, and social dimensions.

The measurement model demonstrated satisfactory reliability and validity. Cronbach's Alpha values ranged from 0.861 to 0.924, while Composite Reliability values ranged between 0.903 and 0.941, exceeding the recommended threshold of 0.70. Average Variance Extracted (AVE) values ranged from 0.652 to 0.741, confirming adequate convergent validity (Mohammed & Kinyó, 2022). All indicator outer loadings exceeded 0.70, indicating that each indicator reliably measured its respective construct. Furthermore, the Heterotrait–Monotrait Ratio (HTMT) values were below 0.85, demonstrating satisfactory discriminant validity among the constructs. These findings confirm that the measurement model is both reliable and valid for structural model analysis.

The structural model revealed that digital transformation had a significant positive effect on business sustainability ($\beta = 0.298$, $t = 4.921$, $p < 0.001$), supporting the first hypothesis (Wier et al., 2007). Digital transformation also significantly influenced green innovation ($\beta = 0.681$, $t = 15.274$, $p < 0.001$), indicating that organizations with stronger digital capabilities were more likely to develop environmentally sustainable innovations. Green innovation significantly affected business sustainability

($\beta = 0.472$, $t = 8.643$, $p < 0.001$), demonstrating that environmentally oriented innovation contributes substantially to long-term organizational sustainability.

The explanatory power of the model was satisfactory. Digital transformation explained 46.4% of the variance in green innovation ($R^2 = 0.464$), while digital transformation and green innovation jointly explained 61.8% of the variance in business sustainability ($R^2 = 0.618$) (Berrou et al., 2020). Blindfolding analysis produced Q^2 values of 0.331 for green innovation and 0.421 for business sustainability, indicating good predictive relevance. Effect size analysis showed that digital transformation exerted a large effect on green innovation ($f^2 = 0.865$), whereas green innovation had a moderate-to-large effect on business sustainability ($f^2 = 0.382$). The direct effect of digital transformation on business sustainability was moderate ($f^2 = 0.146$). The overall model demonstrated acceptable fit with an SRMR value of 0.061, which is below the recommended threshold of 0.08.

Bootstrapping analysis with 5,000 resamples confirmed the statistical significance of all hypothesized relationships (Testa et al., 2017). Mediation analysis indicated that the indirect effect of digital transformation on business sustainability through green innovation was significant ($\beta = 0.321$, $t = 7.842$, $p < 0.001$). Because both the direct and indirect effects remained statistically significant, green innovation was found to partially mediate the relationship between digital transformation and business sustainability. These findings suggest that digital transformation contributes to business sustainability both directly by improving organizational capabilities and indirectly by facilitating environmentally sustainable innovation.

The hypothesis testing results demonstrated strong empirical support for the proposed conceptual framework (Dong et al., 2008). H1 was accepted because digital transformation positively influenced business sustainability. H2 was accepted because digital transformation significantly enhanced green innovation. H3 was accepted because green innovation positively affected business sustainability. Finally, H4 was accepted because green innovation significantly mediated the relationship between digital transformation and business sustainability.

Overall, the findings indicate that digital transformation is an important strategic capability for achieving sustainable organizational performance. However, the results further demonstrate that digital transformation creates greater sustainability benefits when it stimulates green innovation. Organizations that integrate digital technologies with environmentally oriented innovation are more likely to improve economic performance, environmental responsibility, and social value simultaneously, thereby achieving long-term business sustainability.

Discussion

Discussion of the Relationships among Digital Transformation, Green Innovation, and Business Sustainability

The findings of this study demonstrate that digital transformation positively influences business sustainability, both directly and indirectly through green innovation. These results indicate that organizations that successfully develop digital capabilities are better positioned to achieve long-term economic, environmental, and social performance. The findings are consistent with the Resource-Based View (RBV), which argues that strategic organizational resources create sustainable competitive advantage when they are valuable, rare, difficult to imitate, and effectively integrated into organizational processes. Digital transformation represents such a strategic resource because it enables organizations to improve operational efficiency, enhance decision-making, strengthen organizational agility, and develop new business models that support long-term sustainability.

Digital transformation contributes to business sustainability by enabling organizations to optimize resource utilization, improve productivity, and enhance organizational resilience (Miceli et al., 2021). Technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, cloud computing, and blockchain allow firms to collect and analyze real-time information, automate

routine operations, predict equipment failures, optimize supply chains, and reduce unnecessary resource consumption. These technological capabilities improve economic performance through cost reduction and operational efficiency while simultaneously supporting environmental sustainability by minimizing waste, reducing energy consumption, and lowering carbon emissions. Moreover, digital technologies improve transparency, stakeholder communication, and organizational responsiveness, thereby contributing to the social dimension of business sustainability through better governance, employee engagement, and customer satisfaction.

The positive relationship between digital transformation and business sustainability also supports Dynamic Capability Theory, which proposes that organizations achieve superior performance by continuously integrating, developing, and reconfiguring internal capabilities in response to changing business environments. Digital transformation enhances organizational flexibility and innovation capacity, allowing firms to respond more effectively to evolving market demands, technological disruption, and environmental challenges. Rather than functioning merely as a technological investment, digital transformation becomes an organizational capability that strengthens long-term adaptability and resilience. These findings suggest that organizations should view digital transformation as a strategic process that integrates technology with organizational learning, leadership, and sustainability objectives.

The results further indicate that digital transformation significantly promotes green innovation. This finding suggests that digital technologies provide the technological infrastructure and organizational capabilities required to develop environmentally sustainable products, cleaner production processes, and green management practices. Advanced digital technologies enable organizations to monitor resource utilization in real time, identify operational inefficiencies, optimize production processes, and support data-driven environmental decision-making (Andronie et al., 2021). Artificial intelligence facilitates predictive maintenance and energy optimization, IoT sensors monitor emissions and resource consumption, big data analytics identifies opportunities for waste reduction, and blockchain improves transparency across sustainable supply chains. These technological capabilities create favorable conditions for organizations to design innovative environmental solutions while simultaneously improving operational performance.

This finding is consistent with the Natural Resource-Based View (NRBV), which emphasizes that environmentally oriented organizational capabilities constitute strategic resources capable of generating sustainable competitive advantage. Digital transformation strengthens these capabilities by improving organizational knowledge, technological flexibility, and innovation capacity. As organizations become digitally mature, they are better able to integrate environmental considerations into product development, manufacturing systems, and managerial decision-making. Consequently, digital transformation serves as an important catalyst for green innovation by enabling organizations to adopt cleaner technologies, circular production systems, and environmentally responsible business practices. The findings also align with the Technology–Organization–Environment (TOE) framework, which suggests that technological readiness, organizational capability, and external environmental pressures jointly influence innovation adoption. Firms possessing stronger digital capabilities are therefore more likely to implement green innovations in response to increasing regulatory requirements and stakeholder expectations (He & Su, 2022).

The study also demonstrates that green innovation positively influences business sustainability. This finding confirms that environmentally friendly innovation represents a critical mechanism through which organizations simultaneously improve economic, environmental, and social performance. Green innovation enhances environmental sustainability by reducing carbon emissions, minimizing waste generation, improving energy efficiency, and promoting responsible resource utilization. These improvements not only reduce ecological impacts but also strengthen compliance with environmental regulations and international sustainability standards.

From an economic perspective, green innovation contributes to business sustainability by increasing operational efficiency, lowering production costs through resource optimization, and creating opportunities for product differentiation and market expansion (Qiu et al., 2020). Organizations that develop environmentally friendly products and cleaner production processes are increasingly able to meet growing consumer demand for sustainable products while strengthening their competitive advantage. In addition, environmentally responsible innovation improves organizational reputation, attracts sustainability-oriented investors, and enhances customer loyalty, thereby supporting long-term financial performance.

Green innovation also strengthens the social dimension of business sustainability (Le, 2022). Organizations implementing sustainable innovations often demonstrate greater commitment to employee health and safety, ethical business practices, stakeholder engagement, and community development. These practices increase stakeholder trust and reinforce corporate legitimacy, which are essential for maintaining long-term organizational success. The findings therefore support Stakeholder Theory, which argues that organizations create sustainable value by balancing the interests of multiple stakeholders rather than focusing exclusively on shareholder returns.

An important contribution of this study is the finding that green innovation mediates the relationship between digital transformation and business sustainability. This result indicates that digital transformation alone is insufficient to maximize sustainability outcomes unless digital capabilities are translated into environmentally oriented innovations. Digital technologies provide the necessary resources and information-processing capabilities, but it is through green innovation that these technological resources are converted into measurable improvements in environmental, economic, and social performance. This finding extends previous research by demonstrating that green innovation represents a critical organizational mechanism linking technological transformation with sustainable competitive advantage.

Comparison with Previous Studies

The findings of this study are generally consistent with previous research demonstrating that digital transformation plays a significant role in improving organizational sustainability through enhanced technological capability and innovation. The positive relationship between digital transformation and business sustainability supports the findings of Vial (2019), who argued that digital transformation extends beyond technology adoption by fundamentally reshaping organizational processes, business models, and value creation. Similarly, the results align with the meta-analysis conducted by Bindeeba, Tukamushaba, and Bakashaba (2025), which concluded that digital transformation significantly improves sustainable business performance across economic, environmental, and social dimensions. The present study reinforces this conclusion by providing empirical evidence that organizations with stronger digital capabilities are better able to achieve multidimensional business sustainability.

The finding that digital transformation significantly promotes green innovation is also consistent with previous empirical studies. Jiang (2025) reported that digital transformation enhances corporate green innovation by strengthening organizational technological capability and environmental management practices. Likewise, Song, Teh, Alnoor, and Shao (2025) identified digital technologies such as artificial intelligence, blockchain, big data analytics, and digital ecosystems as major drivers of green innovation and sustainable manufacturing. The results of the present study further support these findings by demonstrating that digital transformation provides organizations with the technological infrastructure necessary to develop environmentally friendly products, cleaner production processes, and sustainable managerial practices.

Furthermore, the positive influence of green innovation on business sustainability is consistent with a substantial body of sustainability literature. Previous studies have consistently shown that green innovation improves environmental performance, operational efficiency, financial performance, and

corporate competitiveness by reducing pollution, increasing resource efficiency, and encouraging sustainable production. The present findings extend this evidence by demonstrating that green innovation contributes not only to environmental sustainability but also to economic and social sustainability. This broader perspective supports the Triple Bottom Line framework, suggesting that environmentally responsible innovation simultaneously creates value for organizations, society, and the natural environment.

A particularly important contribution of this study concerns the mediating role of green innovation (Wang, 2019). Although earlier studies have examined the direct relationship between digital transformation and sustainability, relatively few have investigated the organizational mechanisms through which digital transformation generates sustainable outcomes. The finding that green innovation significantly mediates the relationship between digital transformation and business sustainability supports recent research suggesting that organizational innovation is a critical pathway through which digital capabilities produce sustainability benefits. Unlike studies that primarily focus on direct effects, this research demonstrates that digital transformation creates greater organizational value when it is translated into environmentally oriented innovation. This finding provides stronger empirical support for the argument that digital capability alone is insufficient to achieve sustainable business performance unless accompanied by green innovation initiatives.

Despite these similarities, the present study differs from much of the previous literature in several important respects (Bernard et al., 2004). First, many earlier studies measured sustainability primarily through environmental performance or green performance, whereas this research adopts the broader concept of business sustainability encompassing economic, environmental, and social dimensions. Second, previous empirical studies have largely concentrated on manufacturing firms in developed economies or China, while the proposed framework is designed to be applicable across different organizational contexts, including firms operating in developing countries. Third, this study conceptualizes digital transformation as an organizational capability rather than merely the adoption of digital technologies, providing a more comprehensive understanding of how digital resources contribute to sustainable competitive advantage.

Another distinguishing feature of this study is its integration of multiple theoretical perspectives. While many previous studies rely on a single theoretical lens, such as the Resource-Based View or Dynamic Capability Theory, this research combines the Resource-Based View, Natural Resource-Based View, Dynamic Capability Theory, Stakeholder Theory, and the Technology–Organization–Environment framework. This integrated approach offers a more comprehensive explanation of how digital transformation strengthens organizational capabilities, stimulates green innovation, and ultimately enhances business sustainability. Consequently, the study contributes not only by confirming previous empirical findings but also by extending existing theoretical understanding of sustainable digital transformation.

Overall, the findings are largely consistent with previous research while providing several meaningful extensions to the existing literature. The study confirms that digital transformation is an important strategic capability, green innovation is a critical organizational mechanism, and business sustainability is best understood as a multidimensional outcome. By integrating these constructs into a single conceptual model, the research offers a more comprehensive explanation of how organizations can leverage digital technologies to achieve long-term sustainable competitive advantage.

Research Implications

From a theoretical perspective, this study enriches the existing literature by proposing and empirically validating an integrated conceptual framework that explains the mechanisms through which digital transformation contributes to business sustainability (El Hilali et al., 2020). While previous studies have primarily focused on the direct relationship between digital transformation and organizational performance, the present research demonstrates that green innovation functions as a critical mediating

capability that translates digital resources into sustainable outcomes. This finding extends the Resource-Based View (RBV) by emphasizing that digital capabilities become valuable strategic resources only when they are effectively utilized to generate environmentally responsible innovation. The study also strengthens the Dynamic Capability Theory by illustrating how organizations continuously develop and reconfigure technological capabilities to respond to changing environmental and market conditions. Furthermore, by incorporating the Natural Resource-Based View (NRBV), Stakeholder Theory, and the Technology–Organization–Environment (TOE) framework, this research offers a more comprehensive theoretical explanation of sustainable digital transformation than studies relying on a single theoretical perspective.

From a managerial perspective, the findings indicate that organizations should regard digital transformation as more than a technological modernization initiative. Investments in artificial intelligence, big data analytics, cloud computing, blockchain, and Internet of Things technologies should be strategically aligned with green innovation initiatives to maximize long-term business value. Managers should prioritize the development of digital capabilities that facilitate cleaner production, energy optimization, resource efficiency, predictive maintenance, waste reduction, and environmentally sustainable product development. The results further suggest that organizational leaders should cultivate a digital culture that encourages innovation, cross-functional collaboration, and sustainability-oriented decision-making. Integrating digital transformation with green innovation enables organizations to improve operational efficiency while simultaneously strengthening environmental performance, corporate reputation, stakeholder trust, and long-term competitiveness. Therefore, digital strategy and sustainability strategy should be developed as complementary rather than independent organizational initiatives.

The findings also have important implications for business sustainability management. Organizations seeking to improve their sustainability performance should adopt a multidimensional perspective that balances economic, environmental, and social objectives rather than focusing exclusively on financial outcomes. Green innovation should be incorporated into organizational strategy, product development, manufacturing processes, supply chain management, and corporate governance. Continuous investment in environmentally friendly technologies, employee capability development, and sustainable innovation programs can strengthen organizational resilience while improving compliance with environmental regulations and responding to increasing stakeholder expectations. Firms that successfully integrate digital transformation with sustainability initiatives are more likely to establish sustainable competitive advantage and maintain long-term organizational performance.

From a policy perspective, the study highlights the importance of creating an institutional environment that simultaneously promotes digital transformation and environmental sustainability (Kunkel & Matthes, 2020). Governments and policymakers should design policies that encourage organizations to adopt advanced digital technologies while investing in green innovation. Such policies may include financial incentives for digital and green technology adoption, tax benefits for environmentally sustainable investments, research and development funding, and stronger collaboration among government agencies, universities, and industry. Regulatory frameworks should also encourage organizations to incorporate Environmental, Social, and Governance (ESG) principles into corporate strategy while promoting digital solutions that improve resource efficiency and reduce environmental impacts. In addition, public programs aimed at enhancing digital literacy, technological capability, and sustainability awareness particularly among small and medium-sized enterprises (SMEs) can accelerate the transition toward a more sustainable and digitally enabled economy.

Finally, the findings provide implications for future research. The proposed framework may be extended by examining additional mediating or moderating variables, such as organizational culture, environmental strategy, digital leadership, organizational resilience, innovation capability, ESG implementation, or institutional pressure. Future studies may also employ longitudinal designs to

investigate how digital transformation and green innovation evolve over time, compare different industries or countries through multi-group analysis, or adopt mixed-methods approaches to obtain deeper insights into organizational sustainability practices. Such extensions would contribute to a more comprehensive understanding of the dynamic relationships among digital transformation, green innovation, and business sustainability in different organizational and institutional contexts.

Conclusion

This study examined the role of green innovation as a mediating mechanism between digital transformation and business sustainability. Specifically, it investigated the direct effects of digital transformation on business sustainability and green innovation, the influence of green innovation on business sustainability, and the mediating role of green innovation in explaining how digital transformation contributes to sustainable organizational performance. The findings indicate that digital transformation positively influences both green innovation and business sustainability, while green innovation also exerts a significant positive effect on business sustainability. Furthermore, green innovation serves as an important mediating mechanism, demonstrating that digital capabilities generate greater sustainability outcomes when they are translated into environmentally responsible innovations. This study contributes to the literature by developing an integrated framework that combines digital transformation, green innovation, and business sustainability within a single model. The integration of the Resource-Based View, Natural Resource-Based View, Dynamic Capability Theory, Stakeholder Theory, and the Technology–Organization–Environment framework provides a comprehensive theoretical explanation of sustainable digital transformation. These findings also offer practical implications by highlighting the importance of aligning digital transformation strategies with green innovation initiatives to improve economic, environmental, and social performance. From a managerial perspective, organizations should prioritize investments in digital capabilities that support environmentally sustainable innovation, cleaner production, and resource efficiency. Policymakers should encourage the adoption of digital and green technologies through supportive regulations, financial incentives, and sustainability-oriented industrial policies. Nevertheless, this study is limited by its cross-sectional design and reliance on self-reported survey data, which may restrict causal inference and generalizability. Future research should employ longitudinal or mixed-methods approaches, investigate different industrial sectors and national contexts, and incorporate additional mediating or moderating variables to further explain the relationship between digital transformation and business sustainability.

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