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The Mediating Role of Sustainability in the Relationship Between Digital Innovation And Environmental Performance Improvement: An Applied Study in the Jordanian Industrial Sector

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Abstract

This study investigates how digital innovation (DI) enhances environmental-performance improvement (EPI) in the Jordanian industrial sector and whether this relationship is channelled through sustainability (SUS). A structured questionnaire was administered to managers in large and medium-sized manufacturing firms, and the data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM). The results show that DI exerts a significant positive effect on both SUS and EPI, while SUS itself has a direct positive impact on EPI; moreover, sustainability partially mediates the DI → EPI pathway, confirming that technological upgrades yield meaningful ecological gains only when embedded in explicit sustainability programmes. The model explains 44 % of the variance in SUS and 46.7 % in EPI, indicating substantial explanatory power. These findings underline the strategic necessity of integrating ESG principles into digital-transformation roadmaps: real-time data capture and analytics equip firms to anticipate environmental risks, while sustainability frameworks ensure that digital tools are harnessed toward long-term economic, social and environmental objectives. By coupling digital innovation with institution-wide sustainability initiatives, industrial organisations can achieve resource efficiency, bolster regulatory compliance and strengthen competitive advantage in increasingly eco-conscious markets

Keywords

Digital innovation, sustainability, environmental performance, Jordanian industry, environmental management, sustainable development.

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Introduction

The proper management of environmental performance has emerged as a significant strategic issue for modern industrial organizations, particularly within dynamic and competitive markets. In the Jordanian industrial sector, organizations face multiple pressures exacerbating environmental concerns, including stringent regulatory frameworks, rapid technological evolution, and increasing competition both regionally and internationally. Effective management of environmental aspects within this context not only mitigates ecological impacts but also enhances competitive advantage through improved stakeholder perception and regulatory compliance (Beltrami et al., 2021).

Inability to align digital innovations with sustainability may lead to adverse operational and strategic consequences, such as inefficient resource utilization, increased environmental costs, and regulatory non-compliance. Bai et al. (2020) emphasize the importance of proactively embedding digital technologies into organizational processes to improve efficiency and reduce environmental harm, highlighting the necessity for a sustainability-oriented digital approach.

Defined as the adoption and utilization of novel digital technologies to optimize industrial processes, digital innovation is instrumental in environmental performance improvement (EPI). Technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics significantly enhance resource efficiency, waste reduction, and emissions control, especially when strategically aligned with sustainability frameworks (Culot et al., 2020).

Sustainability functions as a mediator by ensuring that digital transformation strategies align effectively with broader environmental objectives. Sustainability-driven management practices not only achieve short-term operational goals but also generate enduring environmental improvements, strengthening organizational adaptability and long-term resilience (Dyllick and Hockerts, 2002).

Despite the acknowledged significance of digital innovation and sustainability, existing literature reveals a research gap concerning the mediating role of sustainability in linking digital innovation with enhanced environmental performance within the Jordanian industrial sector. Previous research has predominantly examined these aspects separately, offering limited insights into their integrative potential to optimize environmental outcomes. Addressing this gap is crucial for formulating strategies that leverage both technological advancements and sustainable practices to meet environmental standards effectively.

Consequently, the aim of this research is to bridge this gap by examining the mediating role of sustainability in the relationship between digital innovation and EPIenvironmental performance improvement in the Jordanian industrial sector. Through this exploration, the study provides practical insights to industrial managers and policymakers, emphasizing the need to integrate sustainability within digital transformation initiatives. This research is especially pertinent given the global emphasis on achieving Sustainable Development Goals (SDGs), particularly Goal 9 on industry, innovation, and infrastructure, and Goal 12 on responsible consumption and production.

This introduction lays the groundwork for a comprehensive analysis of theoretical and practical implications concerning digital innovation, sustainability, and environmental performance management. Subsequent sections will include a detailed review of relevant literature, methodology description, results analysis, and discussion of implications beneficial to both academic and industry practitioners.

Furthermore, this study aligns with the scope of Agris On-line Papers in Economics and Informatics by examining the economic and environmental implications of digital transformation within industrial organizations. Specifically, it contributes to the understanding of how digital technologies such as data analytics, artificial intelligence, and IoT enhance operational efficiency and environmental performance. The study also highlights the role of sustainability as a strategic mechanism linking technological capabilities to economic and ecological outcomes, thereby providing insights relevant to both informatics and industrial economics.

Research problem

In recent years, the industrial sector in Jordan has been undergoing rapid changes driven by increasing environmental challenges, pressure from global sustainability commitments, and the accelerating adoption of digital technologies (Nambisan et al., 2017). Despite the growing awareness of the need for environmental responsibility, many industrial organizations still struggle to implement effective environmental performance strategies. These struggles are often linked to a lack of integration between digital innovation initiatives and sustainability frameworks (Frank et al., 2019).

Although digital innovation offers promising tools—such as big data analytics, automation, and AI—to optimize resource use and reduce environmental impact, the mere presence of these technologies does not guarantee improved environmental performance. According to Ghobakhloo (2020), without a strong mediating mechanism like sustainability, digital technologies may remain underutilized or misaligned with long-term ecological goals. This gap in alignment creates a significant problem in the Jordanian industrial sector, where efforts to modernize production are not always matched by environmental improvements.

Moreover, while environmental performance has become a critical concern—especially in terms of carbon emissions, waste management, and energy efficiency—industries often face institutional and organizational barriers in turning innovation into sustainable action (Zhang et al., 2022). These challenges highlight a key research gap: the unclear role that sustainability plays in translating digital innovation into measurable environmental outcomes.

Therefore, this study investigates how sustainability can mediate the relationship between digital innovation and environmental performance. It seeks to determine whether sustainability acts as a necessary conduit that aligns technological initiatives with environmental goals, especially in the context of Jordan's industrial landscape. The lack of empirical studies exploring this mediating role within emerging markets like Jordan underscores the need for this research.

Practically, the findings of this study are expected to provide actionable insights for industrial managers, policymakers, and sustainability professionals. By understanding how digital innovation and sustainability interact, organizations can develop more coherent strategies that not only meet efficiency goals but also address pressing environmental issues. Theoretically, this study contributes to the growing body of literature on digital sustainability by providing a model that contextualizes this relationship within a developing country framework, addressing both technological and ecological dimensions of industrial development.

Materials and methods

Research design

In alignment with the outlined objectives, this research adopts a quantitative approach to explore the mediating role of sustainability in the relationship between digital innovation and EPIenvironmental performance improvement within the Jordanian industrial sector. The study employs a cross-sectional design, collecting data at a single point in time to comprehensively assess the hypothesized relationships among study variables.

Sample selection

Participants were managerial-level employees from companies operating within the Jordanian industrial sector, selected due to their direct involvement in strategic decision-making, environmental management, and digital technology implementation. Structured questionnaires were distributed to ensure adequate representation from diverse industrial subsectors. The optimal sample size was determined using statistical power analysis to achieve accurate and generalizable results.

A non-probability convenience sampling technique was adopted due to accessibility constraints within industrial firms.

Data collection

A total of 400 questionnaires were sent to medium and large manufacturing companies in Jordan. Of these, 312 were valid responses (78% response rate). The sample encompassed a wide range of subsectors such as food products, chemicals, textiles, construction materials, and electronics, and the sample represented the industrial sector. All cases with more than 10% missing data were excluded and minor missing data were imputed using mean imputation to assure the statistical robustness of the data. This method resulted in a reliable data set that represented the industrial sector in Jordan more broadly.

Variables and measures

Independent variable: Digital Innovation: Digital innovation was assessed through dimensions such as technological infrastructure, adoption of advanced digital tools, data integration capabilities, and organizational readiness for digital change.

Mediator variable: Sustainability: Sustainability practices were measured by assessing the degree of organizational implementation of sustainable practices across economic, social, and environmental dimensions. This included resource management, social responsibility initiatives, and long-term environmental planning.

Dependent variable: Environmental Performance: Environmental performance was evaluated through indicators such as reductions in waste, emissions, resource conservation efficiency, and adherence to environmental regulatory compliance. This provided a comprehensive overview of organizational commitment to environmental responsibility.

Econometric technique

The relationships among the variables were analyzed using Structural Equation Modeling (SEM), which is widely recognized for its effectiveness in testing complex interrelations among variables simultaneously. SEM also facilitates the identification of direct and indirect (mediating) effects, providing comprehensive insights into the mediating role of sustainability. Indirect mediation effects were specifically assessed using bootstrap procedures for enhanced robustness.

To assess the potential presence of common method bias (CMB), Harman's single-factor test was conducted. The results indicated that a single factor did not account for the majority of the total variance, suggesting that common method bias is not a significant concern in this study. In addition, several procedural remedies were implemented, including ensuring anonymity of respondents, using clear and concise questionnaire items, and reducing evaluation apprehension, which further minimized the likelihood of bias.

Ethical considerations

Ethical approval for this research was obtained from the Institutional Review Board (IRB) at Al-Ahliyya Amman University, Jordan. Confidentiality and anonymity of participants' information were strictly ensured, adhering to ethical research standards throughout data collection and analysis.

Rationale for methodology

The quantitative SEM approach was selected due to its superior capacity for elucidating causal and mediating relationships among multiple variables. Additionally, the cross-sectional design effectively captures current dynamics within Jordanian industrial firms, producing practical insights beneficial for both academic researchers and industry practitioners.

This methodology section clearly outlines the operational definitions for the independent variable (digital innovation), the mediator variable (sustainability), and the dependent variable (environmental performance). These variables are central to understanding how digital innovation, coupled with sustainability practices, enhances environmental outcomes within Jordan's industrial organizations.

Independent variable: digital innovation

Digital innovation encompasses the organizational capacity to adopt advanced digital solutions to enhance operational processes and strategic decision-making. This involves deploying technology infrastructures that support comprehensive digitalization, automation, and real-time data utilization, significantly enhancing environmental management capabilities (Nambisan et al., 2017).

Dependent variable: environmental performance

Environmental performance refers to the effectiveness of an organization's environmental management practices, reflected in improved resource efficiency, decreased environmental footprint, compliance with regulatory standards, and overall sustainable environmental outcomes. It serves as a vital indicator of an organization's environmental responsibility and long-term competitive positioning (Hartmann and Vachon, 2018).

Mediator variable: sustainability

In this research, sustainability is conceptualized as the integration of practices that promote long-term viability through balancing environmental, social, and economic objectives. Sustainability acts as a mediator, ensuring that digital transformation efforts effectively align with broader environmental and societal goals, thereby enabling sustained improvements in environmental performance (Epstein, 2018).

As outlined, digital innovation, sustainability, and environmental performance are not isolated concepts; their integration enhances industrial organizations' ability to achieve sustainable environmental goals. Investigating these relationships provides essential insights into effective industrial practices, offering valuable implications for policy development and organizational strategies within the Jordanian industrial sector.

Study model

The theoretical framework underpinning this study model was developed based on a thorough analysis of existing literature addressing digital innovation, sustainability, and environmental performance. The model specifically aims to examine the interrelations between these variables within the Jordanian industrial sector, offering both an academic and practical blueprint that illustrates how digital innovation initiatives can effectively enhance environmental performance through sustainability mediation. This aligns with previous research emphasizing that integrating innovative digital technologies significantly contributes to superior environmental outcomes when strategically embedded within sustainability practices (Fernando et al., 2019).

In the presented model, digital innovation is positioned as the independent variable, providing industrial firms with the technological tools and capabilities required to anticipate, address, and solve environmental challenges. Such technologies include IoT, artificial intelligence (AI), and advanced data analytics, all of which enable organizations to optimize resource usage and reduce negative environmental impacts proactively (Nambisan et al., 2017). Previous literature confirms that organizations possessing advanced digital innovation capabilities are better positioned to align operational practices with environmental sustainability goals, ensuring effective environmental management and performance (Fernando et al., 2019).

The model further highlights sustainability as a pivotal mediator variable. Sustainability serves to mediate the relationship between digital innovation and environmental performance by ensuring that technological advancements are implemented within a holistic approach that addresses economic, social, and environmental considerations concurrently. Epstein (2018) emphasizes that embedding sustainability practices within technological transformations enables industrial companies to effectively manage complex environmental issues, avoid short-termism, and maintain long-term strategic alignment with global sustainability objectives. As similarly indicated by Hartmann and Vachon (2018), adopting sustainability-driven digital strategies significantly improves resource efficiency, reduces emissions, and enhances overall environmental performance.

Consequently, environmental performance represents the dependent variable in the model. This variable captures the extent to which digital innovation strategies, mediated by sustainability practices, achieve tangible improvements in organizational environmental outcomes. The directional arrows depicted in the model indicate the flow of influence: digital innovation directly affects both sustainability and environmental performance, while sustainability in turn strengthens and mediates the effectiveness of digital innovation initiatives on achieving improved environmental results. Such an integrated framework is justified by evidence supporting that sustainable digital practices substantially enhance an organization's environmental outcomes, resilience, and overall competitive positioning (Epstein, 2018; Nambisan et al., 2017).

The theoretical model presented here provides a clear roadmap illustrating how Jordanian industrial organizations can leverage digital innovation within a sustainability framework to enhance their environmental performance. It further stresses the necessity for organizations to adopt proactive and integrative strategies, not only for immediate operational efficiency but also for ensuring sustainable environmental success factors in the long term, especially within dynamic and environmentally sensitive industrial contexts.

Study hypotheses

By developing several theoretical assumptions, this research aims to examine the relationships among digital innovation, sustainability, and environmental performance within the Jordanian industrial sector. These hypotheses investigate how digital innovation practices, when mediated by sustainability initiatives, can enhance environmental performance, ultimately leading to improved organizational outcomes.

Firms leveraging advanced digital technologies such as automation, IoT, and big data analytics are expected to enhance their resource efficiency, waste reduction, and overall environmental management effectiveness. According to Singh and El-Kassar (2019), organizations that actively engage in digital transformation efforts demonstrate significant improvements in managing environmental risks and complying with environmental regulations. Based on the this discussion, the following hypotheses are proposed:

- **H1**: Digital Innovation (DI) has a positive effect on Sustainability (SUS).
- **H2:** Digital Innovation (DI) has a positive effect on Environmental Performance (EPI).
- **H3:** Sustainability (SUS) has a positive effect on Environmental Performance (EPI).
- **H4:** Sustainability (SUS) mediates the relationship between Digital Innovation (DI) and Environmental Performance (EPI).

Tseng et al. (2020) stress that sustainability-focused solutions will lead to the technological developments that are relevant and have a lasting impact on the environment, and not just on operations. Ghobakhloo (2020) states that digital innovation can give firms access to tools that would enable them to have accurate data collection, efficient use of resources, and strategic sustainability planning, which would lead to long-term sustainable outcomes. Additionally Galpin and Whittington (2012) suggest that sustainability can be taken as an integral part of business operations and can have a positive impact on long-term competitive advantage, as well as environmental performance.

Literature review

Here, it is essential to clarify and elaborate upon the key variables—Digital Innovation, Sustainability, and Environmental Performance —to justify their relevance in enhancing environmental outcomes within the Jordanian industrial sector. Based on this conceptual framework, this section identifies clear definitions and explanations from existing literature, aiming to enhance understanding and applicability of these concepts within the context of this study.

Digital innovation (independent variable)

Digital innovation refers to the implementation and effective utilization of digital technologies within industrial organizations to improve processes, products, or business models, especially in contexts characterized by competitive pressures and rapid technological advancements. According to Nambisan et al. (2017), digital innovation encompasses the systematic adoption of technologies such as artificial intelligence (AI), the Internet of Things (IoT), automation, and advanced data analytics to enhance decision-making capabilities, operational efficiency, and competitive advantage.

Digital innovation significantly contributes to improved environmental performance by enabling organizations to accurately monitor resource consumption, predict environmental impacts, and optimize operational processes. Singh and El-Kassar (2019) argue that advanced digital technologies, particularly big data analytics, provide comprehensive insights for sustainable management practices, enabling better prediction and management of environmental risks and resource efficiency.

Furthermore, digital innovation fosters cross-functional integration and communication within organizations, promoting a cohesive and collaborative environment necessary for effective environmental management. Ghobakhloo (2020) suggests that organizations employing digital innovation frameworks demonstrate higher adaptability and responsiveness to environmental challenges, particularly within volatile market conditions, enabling proactive resource allocation and waste minimization strategies.

Moreover, digital innovation enhances organizational alignment with long-term environmental and strategic goals, ensuring that technological advancements are not only adopted for short-term efficiency gains but also contribute meaningfully to broader sustainability objectives. A study by Frank et al. (2019) confirms that integrating digital tools significantly improves an organization's capability to implement strategic environmental initiatives, thus enhancing its overall environmental performance.

Additionally, digital innovation involves utilizing new technology tools such as predictive analytics and AI-driven forecasting systems. These tools enable organizations to systematically collect and analyze environmental data, anticipate potential environmental challenges, and implement proactive solutions effectively. According to de Sousa Jabbour et al. (2018), the incorporation of predictive environmental analytics significantly enhances managerial decision-making processes, ultimately reducing negative environmental impacts and improving compliance with regulatory standards.

In conclusion, digital innovation is critical to improving environmental management within the industrial sector. It serves as an effective enabler of sustainable organizational growth by enhancing resource optimization, fostering cross-functional collaboration, and aligning digital initiatives with strategic environmental goals, thereby contributing significantly to improved environmental outcomes and long-term competitive advantage.

Environmental performance (dependent variable)

Environmental performance in the context of this study is the capacity of industrial organizations to decrease the adverse environmental effects of their operations by using efficient and sustainable operating procedures. This involves reducing emissions, reducing waste, optimizing energy and water use, and adhering to environmental laws and regulations (Zhang et al., 2022). In industrial applications, environmental performance is increasingly linked to the use of technologies and optimisation of processes that reduce the pollution generated. Companies with a focus on environmental stewardship can enhance resource utilization and minimize environmental impacts. Improvements are vital to achieve competitiveness in markets where there are high environmental requirements and stakeholder pressure (Hartmann and Vachon, 2018).

Furthermore, by measuring environmental indicators like energy use rates, emissions, and waste minimisation metrics, organisations can evaluate their environmental footprint and work towards continual enhancements. These indicators offer actionable information which can inform strategic decisions and long-term sustainability goals (Jabbour and Santos, 2008).

From a broader perspective, environmental performance is a key outcome variable that captures the sustainability effectiveness of digital innovation and sustainability practices within industrial operations.

Sustainability (mediator variable)

Sustainability in the current study is defined as the ability to combine economic, environmental and social factors in a way that will maintain the viability of an organization and responsible use of its resources over time. It serves as a key link in making technological capability available to promote a wider environmental and social goal (Hussain et al., 2024; Dyllick and Hockerts, 2002).

In the industrial setting, sustainability entails implementing environmentally responsible production processes, effective management of resources, reducing waste, and complying with environmental standards. These practices maximise the focus on efficient delivery of digital innovation initiatives whilst also delivering long term ecological and economic value (Epstein, 2018).

Sustainability is a mediation factor, which turns digital innovation capabilities into real environmental impact. Digital technologies offer tools for data collection, monitoring and optimizing, but sustainability frameworks are the vehicles for putting these tools to work to make positive and productive environmental improvements. This alignment goes to a greater degree in the organization's capability of continuously improving its environmental performance.

Sustainability is therefore a very important instrument to combine digital innovation with environmental goals, so that technological innovation becomes sustainable and measurable environmental benefit.

Research gap

Despite the prior work focusing on digital innovation, sustainability, and environmental performance as separate themes, few studies have investigated the synergy among them. Most existing research tends to emphasize one-dimensional relationships—such as the impact of digital innovation on operational efficiency, or the role of sustainability in supporting long-term goals. However, the integrated framework linking these three variables, particularly in Jordan's industrial sector, remains underexplored.

To fill this gap, the present research aims to analyze the mediating role of sustainability in the relationship between digital innovation and EPI. Drawing on a multi-disciplinary literature base, this study seeks to offer both theoretical contributions and practical recommendations that support environmentally responsible innovation strategies in competitive industrial environments. The findings are expected to provide value not only to academic discussions but also to industry practitioners and policy makers aiming to enhance the environmental resilience and sustainability of industrial operations in Jordan.

Previous relevant studies

This section summarizes the most relevant literature that forms the conceptual basis for this study. These selected studies focus on digital innovation, sustainability, and environmental performance, with a particular emphasis on their integration in industrial or comparable organizational settings.

Study 1: digital innovation and environmental decision-making

Nambisan et al. (2017) provided a comprehensive understanding of how digital innovation—through tools such as artificial intelligence, automation, and data analytics—supports improved decision-making and operational efficiency. Their findings suggest that organizations adopting digital innovation can achieve enhanced environmental responsiveness, paving the way for improved ecological performance.

Study 2: big data and sustainable practices

Singh and El-Kassar (2019) examined the role of big data analytics in sustainable operations and environmental risk management. They found that data-driven innovation enables accurate prediction and mitigation of environmental impacts, confirming the direct role of digital innovation in EPIs.

Study 3: organizational integration and innovation

Ghobakhloo (2020) argued that digital innovation enhances cross-functional collaboration and adaptability, especially in volatile market conditions. He demonstrated that such innovation facilitates the implementation of environmentally aligned strategies, which is essential for improving performance in industrial firms.

Study 4: digital tools and strategic environmental goals

Frank et al. (2019) highlighted the importance of aligning digital innovation with strategic environmental goals. Their study showed that firms using digital platforms to monitor environmental data experience enhanced sustainability outcomes and long-term performance improvements.

Study 5: predictive analytics and environmental compliance

De Sousa Jabbour et al. (2018) demonstrated that predictive environmental analytics help organizations identify challenges and proactively implement eco-efficient strategies. Their work confirms that advanced digital technologies positively influence regulatory compliance and environmental metrics.

Study 6: Environmental Metrics In Industrial Management

Zhang et al. (2022) defined key environmental performance indicators, such as energy use and waste reduction, and emphasized their relevance in evaluating environmental impact. The study supports the use of systematic measurement in linking innovation efforts to actual environmental outcomes.

Study 7: green finance and environmental performance

Thapliyal et al. (2024) examined the contribution of green banking and green finance initiatives to environmental performance. Their findings confirm that financial sustainability tools act as strategic enablers for environmental improvement, especially when integrated with technological innovation.

Study 8: sustainability as a mediator

Anser et al. (2025) explored how sustainability policies mediate the relationship between AI technologies and environmental outcomes in developing economies. Their findings confirm the mediating role of sustainability in translating innovation into measurable environmental benefits.

Study 9: theoretical framing of sustainability

Al Shawabkeh (2024) conceptualized sustainability as a balance of economic, social, and environmental goals. His work underlines the importance of embedding sustainability practices within organizational strategy to achieve long-term ecological resilience.

Results and discussion

Discussion and implications

This study contributes to a deeper understanding of how digital innovation and sustainability interact to enhance environmental performance in the industrial sector of Jordan. The findings extend both theoretical and practical insights by demonstrating that sustainability plays a significant mediating role in converting digital innovation efforts into tangible environmental improvements. This highlights that digital tools alone are insufficient unless coupled with sustainable practices and strategies aligned with long-term environmental goals.

From a theoretical standpoint, the study enriches literature by confirming that sustainability acts as a bridge between technology adoption and ecological impact. Practically, the findings provide industrial managers and policymakers with a framework for aligning technological investments with sustainability strategies, thereby ensuring better resource utilization, lower emissions, and improved compliance with environmental standards.

Data analysis

In this study, the partial least squares-structural equation modeling (PLS-SEM) was introduced as an analysis tool (Hair et al., 2019). PLS-SEM is considered an advanced analysis method that relies on multivariate techniques (Memon et al., 2021). This means the ability to simultaneously analyze causal relationships and increase predictive accuracy (Al-Khatib and Ramayah, 2025). Given that PLS-SEM is appropriate when the data are not normally distributed or lack one of the traditional assumptions assumed when relying on other analysis methods, PLS-SEM was relied upon and employed in this research.

The measurement model

In the first step of the PLS-SEM analysis, the measurement properties of the measurement tool are addressed (Ringle et al., 2020). Convergent validity, reliability, and discriminant validity are calculated (Hair et al., 2019). Table 1 shows the results for convergent validity and reliability. All statistical criteria were met, with AVE values above 0.5 and factor loadings, Cronbach alpha, and composite reliability above 0.7, indicating that these criteria were met.

First-order construct	Item	Factor loading	AVE	CR	α
Digital innovation	DI1	0.788	0.593	0.879	0.828
	DI2	0.826			
	DI3	0.819			
	DI4	0.673			
	DI5	0.733			
Sustainability	S1	0.852	0.674	0.912	0.878
	S2	0.859			
	S3	0.821			
	S4	0.806			
	S5	0.763			
EPI	EPI1	0.733	0.541	0.876	0.833
	EPI2	0.803			
	EPI3	0.708			
	EPI4	0.724			
	EPI5	0.740			
	EPI6	0.700			

Source: Adopted by authors based on data analysis

Table 1: Reliability and convergent validity.

The results summarized in Table 1 confirm that the measurement model for the three first-order constructs—digital innovation (DI), sustainability (SUS), and environmental-performance improvement (EPI)—possesses solid psychometric quality. All item loadings exceed the recommended threshold of 0.60 (lowest = 0.673; highest = 0.859), demonstrating strong item–construct alignment and supporting construct validity. Convergent validity is further verified by Average Variance Extracted (AVE) values of 0.593 (DI), 0.674 (SUS), and 0.541 (EPI), each surpassing the 0.50 benchmark, indicating that the indicators capture more shared variance than error variance within their respective constructs.

Reliability indicators likewise show excellent internal consistency. Cronbach's alpha coefficients are 0.828 (DI), 0.878 (SUS), and 0.833 (EPI), all comfortably above the 0.70 guideline. Composite Reliability (CR) values mirror this robustness—0.879, 0.912, and 0.876 respectively—confirming that the scales generate dependable and stable measurements suitable for subsequent structural analyses.

Turning to discriminant validity, the HTMT matrix in Table 2 reveals inter-construct ratios of 0.711 (DI–SUS), 0.771 (DI–EPI), and 0.709 (SUS–EPI), each well below the conservative 0.90 cut-off (Henseler et al., 2015). These results indicate that each latent variable is empirically distinct from the others, eliminating concerns of conceptual overlap. Collectively, the evidence from Tables 1 and 2 provides a robust measurement foundation, allowing the study to proceed with confidence to hypothesis testing and structural-equation modeling.

The results in Table 2 validate the discriminant validity of the three latent constructs—digital innovation (DI), sustainability (SUS), and environmental-performance improvement (EPI)—using the Heterotrait-Monotrait ratio (HTMT). Each HTMT coefficient falls well below the conservative 0.85 benchmark recommended by Henseler et al. (2015): 0.711 for DI–SUS, 0.771 for DI–EPI, and 0.709 for SUS–EPI.

	DI	SUS	EPI
DI			
SUS	0.711		
EPI	0.771	0.709	

Source: Adopted by authors based on data analysis

Table 2: Discriminant validity: HTMT criterion.

These values show that the constructs are empirically distinct; although conceptually related, they do not exhibit problematic overlap. Such clear separation reinforces confidence that each scale captures a unique dimension of the study's theoretical framework.

Accordingly, the evidence strongly supports the discriminant validity of the measurement model—an essential prerequisite for moving forward with structural equation modeling (SEM) and for drawing reliable inferences about how digital innovation and sustainability jointly influence environmental-performance improvement.

The structural model

This study aims to test the effect of DI on both SUS and EPI, in addition to testing the mediating effect. To achieve the above objectives, the bootstrapping technique was used via PLS-SEM. Before testing the hypotheses, R2 values were extracted, which were acceptable, with a value of 0.440 for SUS and 0.467 for EPI, which is considered a good value. All hypotheses were supported as shown in Table 3 where the effect of DI on both SUS and EPI was positive and statistically significant (H1: $\beta = 0.664$, $t = 15.161$, $p = 0.000$; H2: $\beta = 0.381$, $t = 7.741$, $p = 0.000$) while the effect of SUS on EPI was positive (H3: $\beta = 0.369$, $t = 6.878$, $p = 0.000$).

Table (3) shows that the results obtained indicate that the study hypotheses are supported empirically. The results of Hypothesis H1, which investigates the effect of Digital Innovation (DI) on Sustainability (SUS), demonstrate that there is a significant positive relationship between the two ($\beta = 0.664$; $t = 15.161$; $p = 0.000$).

Hypothesis H2 predicting the direct effect of Digital Innovation on EPI is supported as well ($\beta = 0.381$, $t = 7.741$, $p = 0.000$), indicating that digital technologies directly help to enhance environmental outcomes.

Last, the results of Hypothesis H3 justify a positive and significant association between Sustainability and EPI ($\beta = 0.369$, $t = 6.878$, $p = 0.000$), indicating the importance of sustainability in promoting EPI.

The results reported in Table (4) furnish compelling empirical support for the mediating role of sustainability (SUS) in the link between digital innovation (DI) and environmental-performance improvement (EPI). The indirect effect (DI → SUS → EPI) yields a standardized beta of 0.245, a standard error of 0.042, a robust t-value of 5.889, and a p-value of 0.000. In addition, the bootstrapped confidence interval ranges from 0.180 (LL) to 0.317 (UL) with no zero value falling between the limits, confirming the statistical significance of the mediation pathway.

These figures indicate that sustainability partially mediates the relationship between digital innovation and environmental performance. Put differently, a portion of the positive impact that digital-innovation initiatives exert on environmental outcomes is transmitted through improvements in sustainability practices. Thus, firms leveraging advanced digital tools not only achieve direct efficiencies but also bolster their environmental results by embedding sustainability more deeply into their operations.

This finding is noteworthy because it highlights sustainability as a pivotal mechanism that amplifies the effectiveness of digital innovation in driving ecological gains. It dovetails with the study's theoretical premise that integrating sustainability into organizational routines enhances overall resilience and strengthens environmental performance—especially vital for organizations striving to meet increasingly stringent green mandates and stakeholder expectations.

The structural model in Figure (1) visually confirms the hypothesized links among the study constructs. Digital innovation (DI) demonstrates a strong, positive influence on sustainability, as evidenced by a standardized path coefficient of 0.664.

Hypothesis	Relationship	Std. Beta	Std. Dev.	t-value	p-value	Decision
H1	DI → SUS	0.664	0.044	15.161	0.000	Supported
H2	DI → EPI	0.381	0.049	7.741	0.000	Supported
H3	SUS → EPI	0.369	0.054	6.878	0.000	Supported

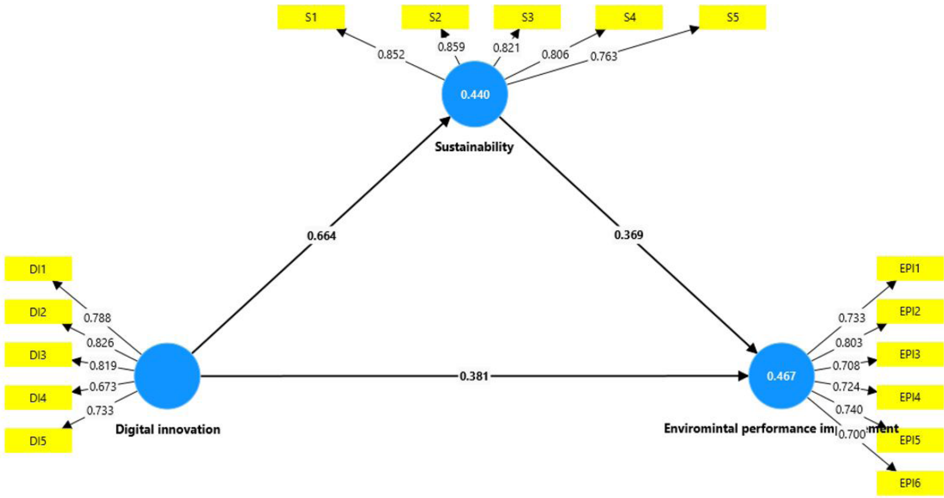
Source: Adopted by authors based on data analysis

Table 3: Hypotheses testing.

Hypothesis	Relationship	Std. Beta	Std. Dev.	t-value	p-value	BCI LL	BCI UL
H4	DI → SUS → EPI	0.245	0.042	5.889	0.000	0.180	0.317

Source: Adopted by authors based on data analysis

Table 4: Mediation testing.



Source: Adopted by authors based on data analysis

Figure 1: Hypothesized relationships.

This finding suggests that investments in digital technologies substantially foster the adoption and enhancement of sustainable practices across the surveyed organizations. In addition, digital innovation exerts a direct, albeit more moderate, effect on environmental-performance improvement (EPI) with a coefficient of 0.381, indicating that technology-driven efficiencies translate into measurable environmental gains.

Turning to the mediating construct, sustainability itself shows a meaningful positive impact on environmental-performance improvement, reflected in a standardized coefficient of 0.369. The simultaneous significance of the DI → EPI path and the indirect DI → Sustainability → EPI route implies a partial-mediation pattern: firms benefit environmentally both directly through digital tools and indirectly by embedding sustainability practices enabled by those tools.

The model's explanatory strength is further supported by the R^2 values of the endogenous variables. Sustainability records an R^2 of 0.440, indicating that digital innovation accounts for roughly 44 % of its variance—a substantial share in organizational research. Likewise, environmental-performance improvement attains an R^2 of 0.467, showing that digital innovation and sustainability together explain about 46.7 % of its variance. These figures underscore a robust predictive capacity and affirm the strategic value of integrating digital-innovation initiatives with sustainability efforts to achieve superior environmental outcomes.

Theoretical contributions

This study advances the literature on digital transformation and sustainable development by integrating Digital Innovation (DI) with Sustainability (SUS) to explain Environmental-Performance Improvement (EPI) in the Jordanian industrial sector. Building on Dyllick and Hockerts' (2002) triple-bottom-line view and recent digital-sustainability frameworks (e.g., Nambisan et al., 2017), the research develops and empirically tests a mediated model in which sustainability channels the effects of digital innovation onto environmental outcomes. Unlike prior work that has typically assessed these constructs in isolation, the current study synthesizes them into a single model and empirically validates all direct and indirect paths via PLS-SEM. By confirming sustainability's partial-mediation role, the findings fill a noted gap in emerging-market contexts and provide a richer explanation of how technological capabilities translate into measurable ecological gains.

Practical implications

For industrial managers, the findings make it clear that investing in technology is necessary but not sufficient: meaningful environmental gains emerge only when digital initiatives are woven into explicit, organization-wide sustainability programmes. To realise these gains, executives should first align their digital roadmaps with ESG targets—linking IoT, AI and data-analytics projects to measurable environmental KPIs such as energy intensity and waste-to-landfill. They must also bolster cross-functional sustainability teams capable of converting digital insights into actionable resource-efficiency plans, while simultaneously investing in employee upskilling—particularly in data-driven environmental management and life-cycle thinking—so that staff can fully leverage digital tools for ongoing ecological improvement. Collectively, these practices enhance regulatory compliance, generate resource savings and strengthen competitive advantage by demonstrating credible environmental stewardship.

Policy recommendations

To accelerate green industrial growth in Jordan, policy-makers should introduce fiscal incentives—such as tax credits and green grants—for firms that combine advanced digital technologies with certified sustainability standards (e.g., ISO 14001, GRI reporting); require sector-specific disclosure of digital-enabled environmental metrics to heighten transparency and peer benchmarking; facilitate public-private training programmes that build digital-sustainability skills among operations and environmental managers; and establish national "Green Tech Hubs," where manufacturers, technology providers and regulators co-create zero-waste and circular-economy solutions—all of which will lift the digital-sustainability readiness of Jordanian industry and speed progress toward the country's SDG commitments.

Future research

Although the present study yields valuable insights, it is constrained by several limitations. Chief among these is its cross-sectional design, which prevents firm causal inference and restricts the generalisability of the findings beyond the Jordanian industrial sector. Future work should adopt longitudinal or panel approaches to capture the dynamic, time-lagged effects of digital innovation and sustainability on environmental-performance improvement, as well as to test the model's robustness across other industries and cultural settings.

Notwithstanding these constraints, the results offer compelling evidence that digital innovation—when embedded in explicit sustainability programmes—constitutes a powerful driver of environmental gains. The two constructs operate in tandem: digital tools provide the data, automation and process efficiencies, while sustainability frameworks ensure these tools are harnessed toward long-term ecological objectives. Together they furnish organisations with a resilient platform for addressing environmental challenges, ensuring that performance improvements are both immediate and aligned with strategic, future-oriented goals.

Recommendations

To translate the study's evidence into practice, Jordanian industrial firms should first deploy an integrated digital-intelligence architecture—linking IoT sensors, AI-driven analytics and cloud dashboards to real-time environmental KPIs—so managers can detect sustainability risks early and act proactively (Nambisan et al., 2017; Frank et al., 2019). Targeted upskilling in data analytics and life-cycle thinking is therefore essential for turning digital signals into resource-efficiency actions (Beltrami et al., 2021).

Second, companies need to embed ESG principles throughout their digital projects. Aligning every initiative with economic, social and environmental goals strengthens internal cooperation and productivity, reflecting the triple-bottom-line logic of corporate sustainability (Dyllick and Hockerts, 2002) and the supply-chain integration benefits highlighted by Hartmann and Vachon (2018).

Third, environmental-performance strategies must be framed with a long-term horizon. Integrating multi-year sustainability roadmaps with successive waves of digital upgrades enhances organisational flexibility and stimulates continuous innovation —an advantage confirmed in emerging-economy settings (Chowdhury et al., 2025; Anser et al., 2025).

Fourth, leadership sponsorship is critical. Senior executives must champion change, allocate resources and reward learning; firms led by digitally savvy, sustainability-minded managers implement more stable, forward-looking strategies (Culot et al., 2020; Beltrami et al., 2021).

Fifth, robust interdepartmental collaboration prevents siloed decisions and ensures unified environmental responses. Enterprise-wide business-intelligence systems improve data sharing and teamwork across production, logistics and sustainability units, reducing escalation potential and reinforcing internal cohesion (Zhang et al., 2022; Jabbour and Santos, 2008).

Sixth, industrial firms should embed continuous feedback loops—regular audits, dashboard reviews and peer benchmarking—to keep conflict policies responsive to changing personnel dynamics and external conditions (Jarsh, 2025; Al-Oun and Al-Khasawneh, 2025). Structured feedback mechanisms enable rapid refinement and sustained effectiveness.

Finally, all digital-intelligence frameworks must embed regulatory compliance. Aligning environmental metrics with national and international standards bolsters governance and public trust, safeguarding organisational integrity in the face of evolving legal requirements (Epstein, 2018; Al-Khatib and Ramayah, 2025).

Conclusion

The structural-equation analysis confirms that digital innovation (DI) is a pivotal driver of environmental-performance improvement (EPI) in Jordan's industrial sector and that its impact is significantly channelled through sustainability (SUS), which acts as a partial mediator in the model. This finding aligns with Frank et al. (2019), who underscore how Industry 4.0 technologies create environmental value only when embedded in explicit sustainability programmes. By enabling real-time data capture and analytics, DI equips firms to anticipate ecological risks and implement proactive mitigation measures, while SUS ensures that these actions remain anchored to broader economic, social, and environmental objectives (Beltrami et al., 2021).

The strongest statistical support emerges for the mediating path DI → SUS → EPI, indicating that technology alone is insufficient; tangible ecological gains materialise when digital tools are integrated into long-term ESG roadmaps (Culot et al., 2020). This synthesis of technology and sustainability not only delivers short-term efficiency benefits but also reinforces organisational resilience by fostering continuous learning and adaptation, a dynamic particularly vital in emerging-market contexts (Chowdhury et al., 2025). Collectively, the results highlight the strategic necessity of coupling digital-innovation investments with institution-wide sustainability frameworks to secure enduring environmental performance and competitive advantage.

Declaration of AI Use

AI-based tools were used solely for language refinement and improving the clarity of expression. The authors are fully responsible for the content, analysis, and originality of the manuscript.

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Appendix A: Measurement items

All items were measured using a five-point Likert scale ranging from (1) strongly disagree to (5) strongly agree.

Construct	Code	Measurement Item	1	2	3	4	5
Digital Innovation (DI)	DI1	Our organization utilizes advanced digital technologies (e.g., AI, IoT, big data) in its operations.	□	□	□	□	□
	DI2	Digital tools are actively used to enhance efficiency in production and operational processes.	□	□	□	□	□
	DI3	The organization integrates digital systems across multiple functional areas.	□	□	□	□	□
	DI4	We continuously invest in upgrading digital infrastructure and technologies.	□	□	□	□	□
	DI5	Employees are encouraged to adopt and effectively use digital technologies.	□	□	□	□	□
Sustainability (SUS)	S1	The organization incorporates environmental considerations into operational decisions.	□	□	□	□	□
	S2	We actively implement practices aimed at reducing environmental impact.	□	□	□	□	□
	S3	Sustainability principles are integrated into long-term strategic planning.	□	□	□	□	□
	S4	The organization effectively manages resources (energy, water, materials).	□	□	□	□	□
	S5	Social and environmental responsibility are key organizational priorities.	□	□	□	□	□
Environmental Performance Improvement (EPI)	EPI1	The organization has reduced waste generation over time.	□	□	□	□	□
	EPI2	Emissions have decreased due to improved operational practices.	□	□	□	□	□
	EPI3	Energy efficiency has improved within the organization.	□	□	□	□	□
	EPI4	The organization has achieved better efficiency in resource utilization.	□	□	□	□	□
	EPI5	Compliance with environmental regulations has improved.	□	□	□	□	□
	EPI6	The overall environmental impact has been reduced.	□	□	□	□	□

Source: Authors

Table A1: Measurement items.