

Green digital transformation and clean energy management in fashion companies: Circular economy and green innovation as pathways to sustainable performance

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Citation: Castro-Gómez, J., Jaramillo, N., & Sánchez-Torres, J. A. (2027). Green digital transformation and clean energy management in fashion companies: Circular economy and green innovation as pathways to sustainable performance. *European Journal of Sustainable Development Research*, 11(1), em0445. <https://doi.org/10.29333/ejosdr/19704>

ARTICLE INFO

Received: 06 Jul. 2026

Accepted: 01 Sep. 2026

ABSTRACT

The purpose of the present study is to analyze the capacity of green digital transformation and clean energy management to achieve sustainable performance in textile and fashion firms, considering circular economy and green innovation. Drawing on dynamic capabilities theory and the resource-based view, the study argues that green capabilities do not automatically improve sustainable performance; rather, they require internal organizational mechanisms that make them tangible. Based on a survey administered to 283 business managers in Colombia, the proposed theoretical relationships were analyzed using partial least squares structural equation modeling. The results showed that green digital transformation capability and clean energy readiness were positively associated with circular economy practices and green innovation capability, which were, in turn, positively associated with sustainable performance. The study identifies two internal organizational pathways consistent with corporate sustainability in a resource-intensive industry.

Keywords: green digital transformation, clean energy, circular economy, green innovation, sustainable performance, textile industry

INTRODUCTION

Firms devoted to the transformation of raw materials, such as those in the textile industry, face the challenge of establishing sustainable performance models that guarantee environmental care (Niinimäki et al., 2020). The apparel and fashion industry presents serious sustainability challenges, such as textile waste management, energy consumption, the intensive use of highly polluting materials, and the need for constant inventory turnover aimed at maintaining market competitiveness (Jia et al., 2020). This situation makes it urgent for the textile sector to implement a sustainable organizational model, not as a bureaucratic requirement, but as a genuine value-added proposition (Nguyen et al., 2026a). This approach requires demonstrating the ability to transform technological, organizational, and energy-related capabilities into concrete actions beyond advertising statements and commitments (Raman et al., 2025). Thus, commitment to socioeconomic well-being and environmental care becomes tangible through management forms that promote internal capabilities to achieve such objectives (Zhao et al., 2025).

This challenge is particularly relevant for small and medium-sized enterprises in the textile sector in emerging economies. The technological, financial, and managerial infrastructure possessed by these organizations is limited, which could restrict the adoption of technological resources and digital systems that favor circular practices and sustainable performance in their production and commercialization operations (Vidal-Ayuso et al., 2026). In addition, they face growing requirements from stakeholders, especially consumers, government agencies, and export processes in which international markets require evidence of their contribution to environmental care and circular economy practices, such as the use of sustainable materials, waste management, and clean production and commercial processes (Bedoya et al., 2025). In this sense, understanding how the green capabilities of these firms are transformed into sustainable performance constitutes a theoretical and managerial gap in sustainability (Huang & Huang, 2024).

Recent studies have shown that digital transformation contributes to the achievement of corporate sustainability goals by fostering operational efficiency, improving decision-making for environmental care, enabling traceability in

operational and administrative modes, and making data use more efficient (Connor-Crabb et al., 2026; Muhammad et al., 2025). Likewise, the literature has shown that the implementation of actions that prepare firms for clean energies—such as reducing conventional energy sources and increasing organizational awareness of energy costs and their environmental impact—also constitutes a set of actions implemented by the industry to ensure ecological care (Arsawan et al., 2026; Jia et al., 2020). However, an important part of these studies assumes approaches in which digitalization and orientation toward clean energies produce direct improvements in sustainable performance. This approach omits the internal mechanisms that allow the organization to strengthen strategic capabilities through observable innovations and sustainable practices. The adoption of technologies and clean energies does not, by itself, generate sustainability (Chowdhury et al., 2022; Rodríguez-Espíndola et al., 2022). Therefore, in the present study, green digital transformation capability and clean energy readiness are conceptually understood as organizational elements that underpin the firm's sustainable operation, and not as outcomes of sustainable practices (Nguyen et al., 2026a; Zarrouk et al., 2026). In this regard, they are understood as strategic elements for information management, resource allocation, process restructuring, and sustainability-related decision-making, whose relevance lies in becoming observable actions (Connor-Crabb et al., 2026; Vidal-Ayuso et al., 2026). These achievements must endure over time, generate a real impact on the way the organization operates and functions, and position a conscious and responsible market orientation (Morone et al., 2023). This is achieved through mechanisms that strengthen these initiatives as part of a true business transformation.

Considering these limitations, the present study argues that green digital transformation capability and clean energy readiness only achieve sustainable performance when internal mechanisms of circular economy and green innovation capability are established. This is because circular economy practices take advantage of organizational resources and capabilities for the reduction, recovery, reuse, and utilization of resources in production and commercial processes (Vidal-Ayuso et al., 2026). Similarly, green innovation is positively associated with the development of sustainable processes and products by considering the use of ecological materials and solutions with lower socioeconomic and environmental impact (Ooi & Memon, 2025; Yi et al., 2025). The study considers that these mechanisms help explain how digital capabilities and alternative energy approaches require circular economy practices and innovation management to achieve sustainable performance, understood not merely as environmental improvement, but as the result of integrating economic efficiency, social responsibility, and an environmental approach.

Accordingly, the study proposes a model in which circular economy practices function as an internal operational mechanism by intervening directly in materials management, waste, inventory management, input reuse, the implementation of biodegradable materials, and other aspects related to product management and commercialization (Merli et al., 2018). Likewise, the study argues that green innovation

capability is an internal mechanism of sustainable organizational renewal because it promotes the redesign of processes, products, and the use of materials that contribute to sustainable development (Yi et al., 2025). Consequently, the study addresses how both mechanisms explain the way in which green capabilities cease to be potential resources and become sustainable outcomes.

Although there are studies on corporate sustainability, green innovation, and circular economy, a theoretical gap persists regarding how these relationships are articulated and operate jointly to achieve tangible and real sustainability goals, especially in a sector as environmentally complex as the textile sector (Coppola et al., 2023; Vidal-Ayuso et al., 2026). Previous studies have focused on large manufacturing industries without specifying a sector. In addition, they address contexts of advanced economies, overlooking the fact that the socioeconomic environment of the organization affects its performance (Galli et al., 2024). Consequently, theoretical and managerial gaps remain that require exploring the dynamics of sustainability in Latin American SMEs linked to fashion and apparel. Thus, the gap is relevant because it contributes to the managerial performance of organizations facing competitiveness challenges due to the rise of digitalization, the alternative use of energy resources, sustainable waste management, and adaptation to expectations of sustainable consumption.

The aim of this study is therefore to analyse the influence of green digital transformation capacity and readiness for clean energy on the sustainable performance of Colombian textile SMEs through the mediating effects of circular economy practices and green innovation capacity. The theoretical contribution lies in demonstrating that ecological capabilities do not automatically lead to sustainable performance. Rather, their value depends on the organisational mechanisms that convert digital and energy resources into circular practices, eco-innovation and sustainable outcomes. This approach offers a more accurate explanation of sustainability in fashion companies operating in an emerging economy.

LITERATURE REVIEW

Foundation From the Resource- and Capability-Based View

To address how green digital transformation and the use of clean energies achieve sustainable performance in organizations, considering the internal mechanisms of circular economy and innovation, the present study draws on the resource- and capability-based view to analyze their dynamics in textile firms. The administrative theory of resources and capabilities considers that resource management within an organization affects its strategic and market performance (Barney, 1991). Therefore, the way an organization manages its resources to achieve greater environmental and sustainable efficiency through innovation, preventive actions, and the reduction of negative impacts constitutes an organizational competitive advantage (Wang et al., 2010). Likewise, resource management must foster differentiated value in relation to competitors and be integrated into the firm's operations

(Coppola et al., 2023). In addition, the study argues that, in a complementary way, dynamic capabilities theory for sustainability makes competitive resource management possible.

Since resources do not create competitive advantages by themselves, learning, implementation, integration, adaptation, and redesign capabilities are required for both resources and processes in order to achieve sustainability goals (Hart & Dowell, 2011; Huang & Huang, 2024). Consequently, green digital transformation capability and the use of clean energies are understood as enabling capabilities. This means that they are not considered outcomes or achievements of sustainability, but strategic management conditions that allow the firm to use information, apply processes, manage resources, and make decisions that foster tangible sustainability outcomes (Bustanza et al., 2019). Regarding internal organizational mechanisms, green innovation is considered an organizational capability for sustainability with the ability to convert, redesign, and renew processes, products, and solutions with greater sustainable impact (Pitelis et al., 2023). As for circular economy, it is considered an operational practice that seeks the utilization, reuse, and reduction of resources, thereby constituting a conversion mechanism for digital performance capabilities and the use of clean energies to achieve sustainable performance (Chowdhury et al., 2022). Thus, the organizational theory of resources and capabilities applied to the objective of the present study makes it possible to understand that, in the textile and fashion sector, the adoption of digital technologies and a greater disposition toward clean energies do not by themselves achieve sustainable performance. The complexity of this industry requires transforming these capabilities into operational practices and tangible innovation processes for the achievement of sustainable objectives (Shamsuzzaman et al., 2025).

It should be noted that the capacity for green digital transformation and readiness for the transition to clean energy do not represent the same type of organisational attribute. From the perspective of dynamic capabilities, a capability refers to a firm's ability to integrate, mobilise and reconfigure resources and routines in response to changes in its environment (Teece et al., 1997). Consequently, the capacity for green digital transformation constitutes an organisational capability, as it reflects a company's current ability to utilise digital technologies, data, information systems and monitoring routines to support decisions relating to the environment and sustainability (Huang & Huang, 2024). By contrast, organisational readiness represents a pre-implementation state, associated with the commitment of the organisation's members, their perception of collective capacity, and the availability of the necessary conditions to carry out a specific change (Weiner, 2009). Readiness for the transition to clean energy therefore indicates the extent to which a company possesses managerial awareness, knowledge of costs and benefits, technical assessment and the initial conditions necessary to move gradually towards cleaner energy alternatives (Cavicchi et al., 2022; Segarra-Blasco & Jové-Llopis, 2019). Ontologically, capability reflects what a firm can currently achieve through mobilised resources and routines, whereas readiness reflects its preparedness for a

transition not yet fully implemented. Thus, the constructs are complementary but distinct: one is digital informational, and the other energy-transitional.

Green Digital Transformation Capabilities

Green digital transformation capabilities are the firm's abilities to implement and use digital technologies, management information systems, data management, and tools for monitoring efficiency in sustainable decisions (Alhaddar & Kummitha, 2025). In the fashion industry, this capability is evidenced in inventory management, the implementation of sustainable materials, clean production, monitoring water use and energy consumption, the digitalization of administrative and commercial processes, waste reduction, and the integration of planning with the firm's operations through technological means (Muhammad et al., 2025). Recent studies have shown that digitalization favors sustainable development in firms because it enables process coordination, efficient use of resources and energy sources, and better-quality information management (Connor-Crabb et al., 2026; Nguyen et al., 2026b). In addition, this capability is needed to make agile and precise decisions in an industry exposed to overproduction, inventory turnover, and permanent waste generation (Coppola et al., 2023). Therefore, this capability enables traceability, monitoring, and optimization of administrative, productive, and commercial processes. In this way, it is not understood as the mere adoption of technologies, but as a capability for orienting digital resources toward sustainability goals (Nguyen et al., 2026b).

Likewise, it can strengthen circular economy practices because it allows firms to identify waste accurately, manage recycling processes, recover inputs, optimize materials, reduce raw material surpluses, and coordinate production and commercial processes with greater precision in order to achieve competitive advantage (Jia et al., 2020; Raman et al., 2025). It can also promote green innovation by providing timely information for product production, process redesign, sustainable orientation of materials and packaging, and commercialization framed within sustainable marketing (García Guiliany & Paz Marcano, 2024). Therefore, the following hypothesis is proposed:

- H1:** Green digital transformation capability is positively associated with circular economy practices and green innovation capability in textile firms.

Clean Energy Readiness

Clean energy readiness is conceptualized as the firm's prospective state of organizational preparedness to assess, plan, and progressively implement energy-efficiency measures and cleaner energy alternatives, including renewable and lower-carbon energy sources (Cavicchi et al., 2022). In textile firms, Clean energy readiness is reflected in the organization's ability to assess the energy requirements of machinery, logistics, lighting and air-conditioning systems, storage facilities, and commercial operations (Shamsuzzaman et al., 2025). In this resource-intensive industry, such assessment is particularly relevant because energy use affects both operational efficiency and environmental impact. However, readiness does not imply that cleaner energy sources have

already been adopted. Rather, it represents an organizational condition preceding implementation, supported by managerial awareness, technical evaluation, knowledge of available alternatives, and the identification of processes suitable for energy transition (Hou et al., 2023; Segarra-Blasco & Jové-Llopis, 2019). When this preparedness is translated into concrete investments and operational changes, and integrated with circular economy and innovation processes, firms may improve resource efficiency, adopt cleaner technologies, redesign processes, and reduce their environmental impacts (Rodríguez & Camacho, 2026). Thus, Clean energy readiness provides the initial organizational conditions for the gradual implementation of energy-efficiency measures and cleaner energy solutions. (Segarra-Blasco & Jové-Llopis, 2019).

Therefore, the following hypothesis is proposed:

H2: Clean energy readiness is positively associated with circular economy practices and green innovation capability in textile firms.

Circular Economy Practices

Circular economy practices comprise actions aimed at reducing, recycling, reusing, and recovering raw materials, resources, and products (Dissanayake & Weerasinghe, 2022). In the textile sector, these practices are relevant due to the intensive use of raw materials, pressure on packaging, short product life cycles, high waste generation, and growing consumer demands to mitigate environmental impacts (Shamsuzzaman et al., 2025). In addition, these practices foster operational efficiency, reduce costs, enhance corporate reputation, and favor product differentiation (Jia et al., 2020). Similarly, the present study conceptualizes circular economy practices as internal mechanisms for converting organizational capabilities into sustainability (Vidal-Ayuso et al., 2026). In this way, they transform green capabilities, such as green digitalization and energy readiness, into concrete actions for sustainable performance (Coppola et al., 2023). Therefore, the following hypothesis is proposed:

H3: Circular economy practices are positively associated with the sustainable performance of textile firms.

Green Innovation and Sustainable Performance

Green innovation is the organization's capability to plan, develop, and produce products and processes aimed at achieving sustainable development goals (Zhang, 2026). In the textile industry, green innovation is observed in the design of products with longer life cycles, the use of recyclable materials and clean energies, waste reduction, and production and commercialization methods with environmental and social criteria (Raman et al., 2025). Unlike circular economy practices, which are centered on the utilization of resources, green innovation acts as a mechanism for organizational redesign and renewal (Yi et al., 2025). This means that it acts as an organizational capability that guides and channels the strategic and operational levels of the organization so that it responds to socioeconomic and environmental criteria. In this way, green innovation improves sustainable performance through its environmental contributions, especially in the responsible management of resources (Dhir et al., 2023). This implies that supply chain processes must define clear

socioenvironmental guidelines that become part of the product's differentiated value (Luqmani et al., 2017). Sustainable performance, in turn, is defined as an outcome of the firm's actions in socioeconomic and environmental matters (Yadegaridehkordi et al., 2023). This outcome emerges from the integration of management and governance frameworks with the operational approaches of each functional area of the organization. Some studies indicate that sustainable performance is linked to the capacity for holistic integration of sustainability into the organization's structure and strategy (Connor-Crabb et al., 2026; Rehman et al., 2021). In the textile industry, the relationship between green innovation and sustainable performance is important because achieving sustainability requires a strategic approach that guides production and commercial goals toward social well-being and environmental care (Schlüter et al., 2023). This operational efficiency implies orienting the value proposition and adapting it to the expectations of more responsible markets committed to sustainability. Therefore, the following hypothesis is proposed:

H4: Green innovation capability is positively associated with the sustainable performance of textile firms.

Foundation of the Mediating Mechanisms

The central foundation of the present study is to analyze the mediation logic of the proposed model. Therefore, the exogenous variables are addressed as base capabilities for achieving sustainability goals. However, in order to make a tangible contribution to organizational sustainability objectives, internal mechanisms related to the organization's capabilities and resources are required (Zhao et al., 2025). Thus, the ability to establish concrete innovations and operational practices depends on the capacity to integrate, adapt, and reconfigure resources in response to technological changes and stakeholder requirements (Zimmermann et al., 2024). In this way, circular economy translates digitalization capabilities and the use of clean energies into waste management, thereby contributing to the environmental dimension of sustainability (Rodríguez-Espíndola et al., 2022). As for green innovation, it strengthens digital and energy capabilities in products and productive and commercial processes for the benefit of society and environmental care, and it may also foster a positive impact on the organization's economic sustainability (Wu et al., 2025). Green digitalization together with renewable energies may contribute to achieving sustainability. However, to ensure balance across the social, environmental, and economic dimensions of sustainability, mechanisms are required that promote its durability over time and operational materialization (Huang & Huang, 2024; Mahmood et al., 2024). In fashion firms in an emerging country where financial, technological, and managerial restrictions are present, this type of explanation is especially important because it allows us to understand how digital and energy capabilities lead to sustainable outcomes under a set of specific organizational conditions (Segarra-Blasco & Jové-Llopis, 2019). Considering that digitalization and energy capabilities do not generate sustainable performance automatically, but require organizational mediation mechanisms to produce sustainable outcomes, the following hypothesis is proposed:

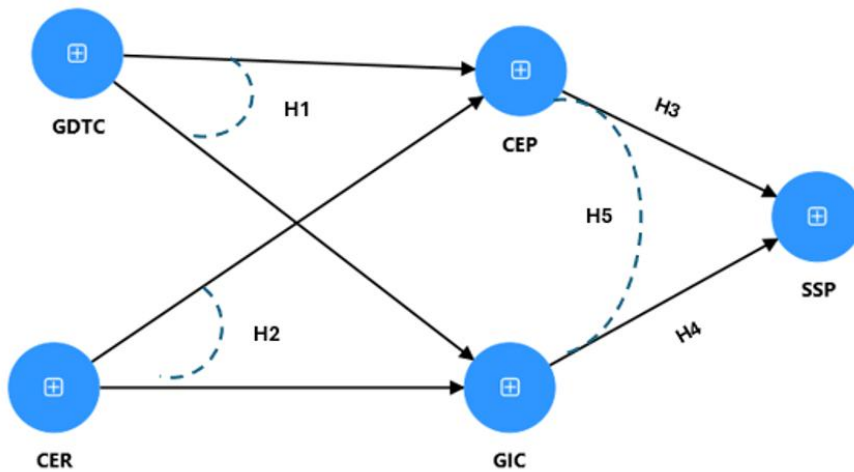


Figure 1. Theoretical model (Source: Authors' own elaboration based on theoretical model proposed in this study)

H5: Circular economy practices and green innovation capability mediate the relationship between green digital transformation capability, Clean energy readiness, and the sustainable performance of textile firms.

The theoretical model proposed in the present study can be observed in **Figure 1**.

METHODOLOGY

The research adopted a quantitative approach. Based on the literature review, the measurement instruments were designed, and the dimensions of the constructs were operationalized through items assessed on a seven-point Likert scale, where 1 = strongly disagree and 7 = strongly agree. In the first stage, the instrument was subjected to content validation through expert judgment. Thus, five specialists evaluated the items according to criteria of conceptual clarity, sufficiency, relevance, neutrality, and absence of biased wording. Based on their recommendations, the corresponding adjustments were made. Subsequently, a pilot test was conducted with 9 area managers ($n = 9$) to verify the comprehensibility of the items and refine the precision of the instrument. The fieldwork was carried out between May 2025 and February 2026, and 295 responses were collected from managers, owners, or heads of functional areas of Colombian SMEs in the textile, fashion, and apparel sector. The form was disseminated through virtual platforms. After removing outliers, the sample consisted of 283 valid responses. Once the fieldwork was completed, the statistical analysis was performed. First, an Exploratory Factor Analysis (EFA) was conducted using SPSS software, and subsequently the hypothesised structural associations were estimated through partial least squares structural equation modeling (PLS-SEM) using SmartPLS 4.1.1.8.

Measurement Instruments

For green digital transformation capability, the instrument assessed the way in which the firm uses digital tools, data, information systems, and monitoring tools to support environmental decisions and improve sustainable efficiency.

This orientation was grounded in the literature that links green digital transformation with traceability, operational efficiency, and sustainable performance (Huang & Huang, 2024; Muhammad et al., 2025). The items considered the monitoring of energy, water, materials, and waste consumption, as well as the use of data to identify opportunities for waste reduction, aspects that are relevant for integrating digitalization with sustainability and circular economy goals (Arroyabe et al., 2024; Connor-Crabb et al., 2026). Indicators on technological integration, human digital capabilities, and investment in technologies aimed at reducing environmental impacts were also included, in line with studies on green digital capabilities and sustainable transition in manufacturing and fashion firms (Alhaddar & Kummitha, 2025; Huang & Huang, 2024).

The Clean energy readiness instrument estimated the firm's capacity to evaluate, plan, and implement energy efficiency alternatives and clean or renewable energy sources. This measurement was supported by studies that highlight the importance of energy management for moving toward more sustainable business models (Cavicchi et al., 2022; Segarra-Blasco & Jove-Llopis, 2019). The scale included indicators related to initial technical readiness, managerial commitment, and knowledge of the costs and benefits of the energy transition, given that the adoption of clean energies requires organizational capabilities, information, and strategic orientation (Hou et al., 2023; Salem et al., 2023). Likewise, items on the identification of processes susceptible to energy transition and the gradual implementation of cleaner solutions were considered, elements that are especially relevant for resource-intensive sectors such as textiles and apparel (Shamsuzzaman et al., 2025). This distinction was also preserved in the operationalization of the constructs. The indicators of green digital transformation capability measured actions currently performed through digital tools, data, information systems, monitoring, and technological integration. By contrast, the indicators of clean energy readiness assessed a prior or progressive state of preparedness, reflected in managerial commitment, knowledge of costs and benefits, evaluation of energy alternatives, identification of processes suitable for transition, and the feasibility of gradual implementation. Thus, the former indicators capture an

already mobilized digital capability, whereas the latter capture the organizational conditions available for undertaking a future energy transition.

The circular economy practices instrument assessed the firm's operational actions through which it reduces, reuses, recycles, recovers, and takes advantage of materials, inputs, packaging, and resources within its production and commercial processes (Arsawan et al., 2026). This conceptualization is based on studies that define circular economy as a set of practices aimed at extending the value of resources and reducing waste generation (Dissanayake & Weerasinghe, 2022; Jia et al., 2020). The indicators considered the reduction of raw material consumption, the reuse of materials, waste management, and process redesign to reduce waste, dimensions that are especially important in the textile industry due to its material intensity and waste generation (Raman et al., 2025; Vidal-Ayuso et al., 2026). Items on extending the useful life of resources and collaboration with suppliers or customers were also included, in line with studies that link circular economy with value chains, organizational capabilities, and sustainable performance in SMEs (Chowdhury et al., 2022).

The green innovation capability instrument measured the firm's ability to develop or improve products, services, processes, technologies, packaging, materials, and operating methods with lower environmental impact (Zhang, 2026). This measurement was based on the literature that conceives green innovation as an organizational capability aimed at reducing environmental impacts and strengthening sustainable performance (Al-Hakimi et al., 2022; Rehman et al., 2021). The scale addressed green product and process innovation, the adoption of clean technologies, and the generation of environmental ideas, aspects associated with the renewal of resources and capabilities to respond to environmental and competitive pressures (Pitelis et al., 2023; Yi et al., 2025). In addition, indicators on the transformation of environmental opportunities and sustainable improvements in packaging, materials, and forms of operation were included, elements that are relevant for textile and fashion firms seeking to differentiate themselves through sustainable solutions (Ooi & Memon, 2025).

Finally, the sustainable performance instrument assessed the economic, environmental, and social results achieved by the firm during the last three years. This measurement was based on studies indicating that sustainable performance does not refer only to environmental results, but to the integration of economic efficiency, social responsibility, and the reduction of negative impacts (Rodríguez-Espíndola et al., 2022; Yadegaridehkordi et al., 2023). The items considered the reduction of costs associated with energy, water, or materials use, the decrease in waste and emissions, and the improvement of operational efficiency, dimensions linked to the environmental and economic performance of SMEs (Al-Hakimi et al., 2022; Chowdhury et al., 2022). Indicators on image among stakeholders, worker well-being, customer attraction and retention, competitiveness, and balance among economic, social, and environmental outcomes were also incorporated. The above followed the recommendations of the literature indicating that the measurement of sustainable

performance should address the triple bottom line (Laskar, 2024; Montiel & Delgado-Ceballos, 2014; Shriberg, 2004).

The complete instrument is presented as supplementary material in **Appendix 1**.

Sample

The fieldwork was conducted with managers, owner-managers responsible for functional areas, and administrators of Colombian SMEs belonging to the textile, fashion, and apparel sector. This sector was selected because it is one of the main objects of study in the application of organizational sustainability, given its intensive use of energy resources, materials, and waste generation. Likewise, this sector currently requires the application of circular practices and green innovations (Raman et al., 2025). Non-probabilistic convenience sampling was used, considering the accessibility of the business population and the logistical limitations for constructing a random sampling frame of textile SMEs in Colombia.

The data were collected through a structured questionnaire directed at people with knowledge of the firm's operational, commercial, energy, or sustainability management. The instrument was distributed through digital media and sectoral contacts, guaranteeing participant anonymity and the academic use of the information. Before responding, participants were informed about the study objective, the voluntary nature of their participation, and the confidentiality of the data collected. The sample size was justified considering the relationships in the model. Thus, the statistical power required for the PLS-SEM analysis addressed the five latent constructs and a maximum of two predictors per endogenous variable (Cohen, 1988). Accordingly, a sample of 283 managers exceeded the minimum recommended for models with this structure, considering a significance level of 0.05, statistical power of 0.80, and a small-to-moderate effect size indicating an approximate minimum of 196 cases; therefore, the final sample exceeded the required threshold (Hair & Alamer, 2022; Kock & Hadaya, 2018). Likewise, the ratio between cases and instrument indicators supported the sufficiency of the sample for multivariate analysis (Faul et al., 2009). The geographic characterization of the sample is shown in **Table 1**.

Because all constructs were measured through a single questionnaire completed by one managerial respondent from each firm, the design may be exposed to social desirability and common method variance. To reduce these risks, the surveys were anonymous, no information identifying the respondents or participating firms was collected, and participants were informed that the data would be used exclusively for academic purposes. During content validation, the experts also assessed item neutrality and the absence of biased wording. These procedural safeguards reduce evaluation apprehension and the tendency to provide socially desirable responses, although they do not completely eliminate the limitations inherent in single-source self-reported data.

FINDINGS

As a result of expert validation, adjustments were made to the measurement instrument. Initially, the questionnaire

Table 1. Geographic characterization of the sample

City	Region	Sectoral justification	Valid sample	Percentage
Medellín	Antioquia: Andean Region	Main center of textile and fashion production, design, manufacturing, and commercialization in the country.	115	40.64%
Bogotá D.C.	Capital District: Central Region	Business and commercial center with a high concentration of fashion, apparel, and distribution companies.	96	33.92%
Cali	Valle del Cauca: Pacific Region	Relevant center due to its participation in production, commercialization, and business dynamics in the sector.	72	25.44%
Total			283	100%

Note: The distribution was organized according to the greater or lesser concentration existing in each of the country's main production and commercialization centers. Company names remain anonymous to guarantee the privacy of the information.

Table 2. Reliability and convergent validity of the model

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
CEP	0.938	0.941	0.938	0.684
CER	0.951	0.952	0.951	0.795
GDTC	0.868	0.886	0.863	0.564
GIC	0.939	0.941	0.939	0.719
SSP	0.926	0.933	0.925	0.641

Table 3. Heterotrait-Monotrait Ratio Matrix (HTMT)

	CEP	CER	GDTC	GIC	SSP
CEP					
CER	0.671				
GDTC	0.443	0.287			
GIC	0.378	0.389	0.513		
SSP	0.490	0.621	0.397	0.429	

consisted of 32 items. Two items were eliminated: one from circular economy practices (CEP8) and one from sustainable performance (SSP6), due to conceptual redundancy and comprehension problems. After the refinement, the final instrument consisted of 30 items: six for green digital transformation capability, five for clean energy readiness, six for circular economy practices, six for green innovation capability, and seven for sustainable performance.

Results of Exploratory Factor Analysis (EFA)

For the initial validation of the instrument, an exploratory factor analysis was conducted in SPSS using principal axis factoring and Promax oblique rotation with Kaiser normalization. The results showed adequate suitability of the data for this type of analysis, with a KMO of 0.907 and a significant Bartlett's test of sphericity, $\chi^2 = 7,978.113$; $df = 496$; $p < 0.001$. The total variance explained by the five factors was 66.49%, exceeding the minimum recommended criterion of 60% (Hair et al., 2019). The factor loadings of the retained items ranged from 0.591 to 0.996, which is appropriate according to Hair et al. (2019). As a result of the analysis, only item GDTC6, corresponding to green digital transformation capability, was eliminated because it did not present an adequate factor estimate. In this way, the instrument was refined to 29 items.

Confirmatory Factor Analysis (CFA)

The confirmatory factor analysis estimated the reliability and validity of the measurement models. The factor loadings were adequate, with values between 0.595 and 0.976. In general, the indicators exceeded the 0.60 criterion (Hair et al., 2019). Only item GDTC3 presented a slightly lower loading (0.595), although it was close to the expected threshold. This

item was retained due to its theoretical relevance within the construct of green digital transformation capability. In addition, according to methodological recommendations for PLS-SEM, loadings between 0.40 and 0.70 may be retained when their elimination does not substantially improve composite reliability or average variance extracted (Hair et al., 2019; Shmueli et al., 2019). Likewise, its conceptual justification guided its retention. Internal reliability presented satisfactory results, with Cronbach's alpha values between 0.868 and 0.951, rho_A between 0.886 and 0.952, and composite reliability between 0.863 and 0.951, all above the minimum criterion of 0.70. Convergent validity was also confirmed, since the average variance extracted (AVE) presented values between 0.564 and 0.795, exceeding the 0.50 threshold (see Table 2).

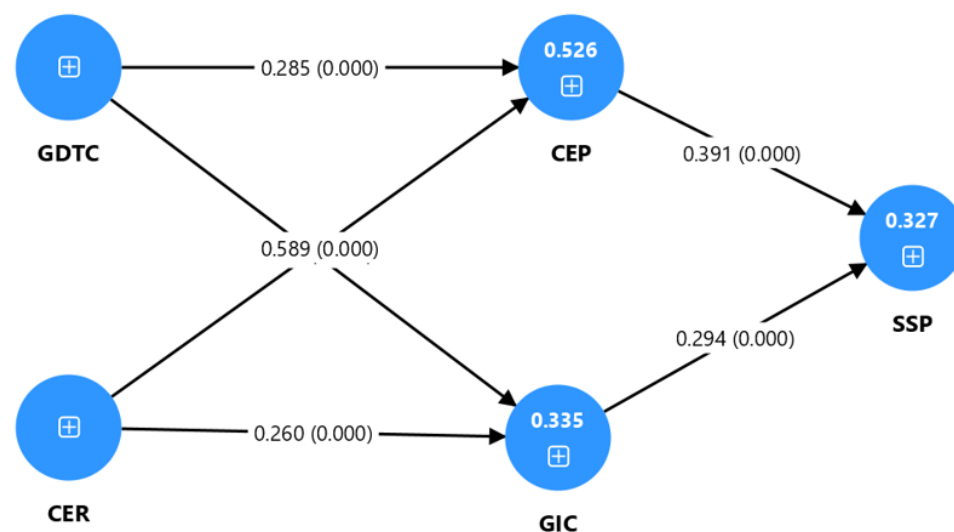
Discriminant validity was evaluated using the HTMT criterion and the Fornell-Larcker criterion. First, the HTMT values ranged between 0.287 and 0.671, below the conservative threshold of 0.85, which indicates that the constructs present adequate conceptual and statistical differentiation. The highest value was found between circular economy practices and clean energy readiness, with 0.671, remaining within acceptable ranges (see Table 3).

Particularly relevant to the conceptual distinction addressed in this study, the HTMT value between green digital transformation capability and Clean energy readiness was 0.287, while their latent-variable correlation was 0.293. These results indicate that respondents empirically differentiated the firm's mobilized digital capability from its preparedness to undertake a Clean energy readiness.

Second, the Fornell-Larcker criterion also confirmed discriminant validity, given that the square root of the AVE of

Table 4. Fornell-Larcker criterion

	CEP	CER	GDTC	GIC	SSP
CEP	0.827				
CER	0.672	0.892			
GDTC	0.452	0.293	0.751		
GIC	0.383	0.390	0.523	0.848	
SSP	0.495	0.625	0.397	0.433	0.801

**Figure 2.** Inner model (Source: Authors' own elaboration, using Smart PLS 4.1.1.8)

Note: Significant at 5%. Bootstrap samples = 5000 and confidence level = 95%.

each construct was higher than its correlations with the other constructs. The diagonal values ranged between 0.751 and 0.892, exceeding the corresponding external correlations in all cases. These results make it possible to state that the model variables retain their own identity and do not present problems of empirical overlap (see **Table 4**).

Common Method Bias

Because the data were obtained from single-source self-reports, the presence of common method variance cannot be completely ruled out. As a supplementary diagnostic, the VIF values of the measurement model were examined and ranged from 1.010 to 3.341. All values were below the general threshold of 5.0, although one was marginally above the conservative criterion of 3.3. These results suggest that severe collinearity is unlikely; however, the VIF values are interpreted only as a supplementary diagnostic and not as definitive evidence that common method bias is absent. The findings are therefore interpreted considering the limitations associated with self-reported and single-informant data (Kock, 2015; MacKenzie & Podsakoff, 2012).

Structural Model

After confirming the quality of the measurement models, the structural model was estimated through PLS-SEM and bootstrapping. The results made it possible to contrast the proposed hypotheses and verify the relationship among the base green capabilities, the organizational conversion mechanisms, and the sustainable performance of textile firms. Overall, the model showed effects consistent with the theoretical foundation proposed, as observed in **Figure 2**.

The structural model supported all the proposed direct associations. Clean energy readiness showed the strongest association with circular economy practices ($\beta = 0.589$; $p < 0.001$), followed by the association between green digital transformation capability and green innovation capability ($\beta = 0.447$; $p < 0.001$). Circular economy practices ($\beta = 0.391$; $p < 0.001$) and green innovation capability ($\beta = 0.294$; $p < 0.001$) were positively associated with sustainable performance. The associations between green digital transformation capability and circular economy practices ($\beta = 0.285$; $p < 0.001$), and between clean energy readiness and green innovation capability ($\beta = 0.260$; $p < 0.001$), were also significant.

The indirect effects were also significant, providing evidence consistent with the proposed mediation of circular economy practices and green innovation capability in the relationship between the green organizational antecedents and sustainable performance. In particular, the routes CER mediated by CEP ($\beta = 0.230$; $p < 0.001$), GDTC mediated by GIC ($\beta = 0.131$; $p = 0.001$), GDTC mediated by CEP ($\beta = 0.111$; $p < 0.001$), and CER mediated by GIC ($\beta = 0.076$; $p = 0.008$) stood out. These results support the logic of the present study, which argues that green digital transformation and clean energy readiness contribute to sustainable performance when they are translated into circular practices and green innovation. The structural model confirmed all the direct structural routes proposed in the mediation model, as shown in **Table 5**.

Likewise, the 95% confidence intervals supported the stability of the estimated effects, since none of the direct relationships presented values that included zero. The intervals remained within positive ranges; for example, CEP and SSP [0.256; 0.524], CER and CEP [0.456; 0.722], GDTC and GIC [0.341; 0.555], and GIC and SSP [0.148; 0.432]. Similarly,

Table 5. Path coefficients

	Original sample (O)	t statistics (O/STDEV)	p values
CEP -> SSP	0.391	5.673	0.000
CER -> CEP	0.589	8.619	0.000
CER -> GIC	0.260	4.121	0.000
GDTC -> CEP	0.285	4.369	0.000
GDTC -> GIC	0.447	8.103	0.000
GIC -> SSP	0.294	4.142	0.000
CER -> GIC -> SSP	0.076	2.637	0.008
GDTC -> GIC -> SSP	0.131	3.224	0.001
CER -> CEP -> SSP	0.230	4.247	0.000
GDTC -> CEP -> SSP	0.111	3.486	0.000

the indirect effects maintained positive intervals, which confirms the significance of the proposed mediating routes.

Indicators of the Structural Model

The R^2 values indicated differentiated levels of explanatory power across the endogenous constructs. Circular economy practices presented an R^2 of 0.526, while green innovation capability showed an R^2 of 0.335. Sustainable performance presented an R^2 of 0.327, indicating that circular economy practices and green innovation capability jointly accounted for 32.7% of its variance. This represents a meaningful, although partial, level of explanatory power. The result supports the relevance of the two organizational conversion mechanisms examined, while also indicating that sustainable performance is shaped by additional internal and external factors not included in the proposed model. Regarding f^2 effect sizes, differentiated contributions were observed among the predictors. Clean energy readiness had a high effect on circular economy practices ($f^2 = 0.669$; $p = 0.008$), while green digital transformation showed small-to-moderate effects on circular economy ($f^2 = 0.157$; $p = 0.033$) and green innovation ($f^2 = 0.275$; $p = 0.002$). In turn, circular economy practices ($f^2 = 0.193$; $p = 0.018$) and green innovation ($f^2 = 0.178$; $p = 0.021$) presented relevant effects on sustainable performance. Finally, the SRMR of the saturated model was 0.055, which indicates adequate model fit. The NFI value was also 0.93, exceeding the reference criterion of 0.90, which supports an adequate global fit of the estimated model (Hair & Alamer, 2022).

DISCUSSION

The objective of the present study was to analyze the capacity of green digital transformation and clean energy management to achieve sustainable performance in textile and fashion firms, considering circular economy and green innovation. The results presented a demanding and complex panorama of corporate sustainability in resource-intensive organizations by showing that green capabilities (product redesign, use of sustainable materials, waste reduction, inventory control, energy management, and stakeholder management) do not operate automatically in sustainable performance. However, the study found that such capabilities materialize when they are reflected in operational practices, innovation processes, and sustainable managerial decisions. These findings are relevant because they question previous studies that argue that digitalization and environmental

management processes automatically have the capacity to generate sustainable performance (Huang & Huang, 2024; J. Xu et al., 2023; Zaid et al., 2018). Thus, the proposed model confirmed a logic of organizational translation of internal processes to achieve sustainable performance.

The results supported H1, showing that green digital transformation capability was positively associated with circular economy practices and green innovation capability. This finding makes it possible to observe that digitalization should not be reduced to the adoption of technological tools (Zimmermann et al., 2024). On the contrary, its organizational value depends on obtaining information, managing resources, identifying waste and optimizing raw materials, redesigning processes, and developing sustainable capabilities to operate and commercialize (Alabdali et al., 2024; Yi et al., 2025). In addition, the textile industry operates under a logic of high inventory turnover, associated with short product cycles, changes in consumer preferences, and constant competitive pressure (Mahmood et al., 2024). This dynamic increases material use and waste generation, making circular practices and green innovation necessary to reduce impacts and sustain business competitiveness. In this case, digitalization acquires important value by favoring decision-making in resource use and achieving effective coordination of the proposed process (Connor-Crabb et al., 2026).

This finding coincides with previous studies that relate digital transformation to efficiency, traceability, and sustainability (Alabdali et al., 2024; Escoz Barragan & Becker, 2025). However, its contribution goes further by demonstrating that these links are not generated directly, but are channeled by internal organizational mechanisms such as circular economy and green innovation. Likewise, the study found a strong relationship between digital transformation and green innovation (Hu et al., 2024). This finding indicates that digitalization plays an especially important role in the renewal of products and processes to achieve sustainable solutions (Escoz Barragan & Becker, 2025). In addition, information systems and technological integration more intensely activate the capability to plan, design, and create the firm's structure and strategy for circular operational improvement (Arroyabe et al., 2024). In this way, the instrumental interpretation of technology is displaced, indicating that green digital transformation not only allows firms to manage and monitor waste and resources, but also constitutes a starting point for the creation and design of sustainable solutions. Therefore, digitalization moves from

being an administrative instrument to becoming a sustainable capability (Alabdali et al., 2024; Amin et al., 2025).

Likewise, the results supported H2, showing that Clean energy readiness was positively associated with circular economy practices and green innovation capability in textile firms. It is noteworthy that the strongest effect of this variable occurred on circular economy practices. Therefore, this finding is consistent with the literature indicating that the firm's operational activities are strongly linked to energy readiness management (Raman et al., 2025). This means that a firm identifies processes to achieve efficiency and evaluates clean alternatives when it manages to incorporate awareness at the managerial and operational levels. Similarly, energy readiness functions as a starting point toward circular economy practices and not as a direct driver of innovation (Cavicchi et al., 2022). This finding does not invalidate the hypothesis, but rather specifies it and circumscribes it to an operational logic for achieving efficiency, while innovation requires additional capabilities of design, learning, experimentation, and market orientation (Segarra-Blasco & Jove-Llopis, 2019). The importance of this finding lies in the fact that the energy transition is not focused only on renewable energy investments. It also involves prior organizational capabilities related to diagnosis, managerial awareness, infrastructure evaluation, and gradual process improvement (Ortiz-Avram et al., 2024). In this way, Clean energy readiness is understood as a progressive organizational capability (Rodríguez & Camacho, 2026). This is significant in emerging contexts where firms face technological and financial restrictions, which is why they approach energy readiness as a route to efficiency in circular practices (Cavicchi et al., 2022).

Regarding H3, the results showed that circular economy practices were positively associated with sustainable performance, thereby supporting the proposed hypothesis. This result is consistent with the literature on corporate environmental sustainability (Al-Hakimi et al., 2022; Yadegaridehkordi et al., 2023). Likewise, the empirical context showed that this relationship supports the importance of the finding. In textile and fashion firms, circular economy does not function as a cosmetic or promotional element, but as an operational mechanism that intervenes in the management of materials, waste, inventories, packaging, input reuse, and production and commercial processes (Jia et al., 2020). These operational actions make organizational sustainability visible by optimizing the product life cycle and establishing a sustainable commercialization approach (Vidal-Ayuso et al., 2026). Similarly, this result should be read with caution. The reason is that circular economy, although it improves sustainable performance, does not constitute its ultimate goal. This is because circular economy can contribute to reducing the environmental impact and operating costs of firms, but when it is disconnected from innovation, organizational culture, and the market, it becomes an isolated practice (Raman et al., 2025; Xia et al., 2026).

Regarding H4, the results showed that green innovation capability was positively associated with the sustainable performance of textile firms, thereby supporting the proposed hypothesis. This discovery supports the idea that textile firms do not achieve sustainability only through waste

minimization. They must also renew products and market approaches (Yi et al., 2025). This is because green innovation has an objective different from that of circular economy. While circularity seeks resource optimization, green innovation allows the firm to modify its value proposition (Rehman et al., 2021). This distinction supports the theoretical contribution of the study, which considers the proposed mediating mechanisms as differentiated processes (Xia et al., 2026). The first concerns waste reduction, and the second concerns the redesign of products and market approaches. Both have different organizational logics (Nhi & Khoi, 2026). Therefore, in the fashion sector, sustainability cannot be based only on practices that are corrective at the end of the process (Cheng et al., 2026). If the firm only manages waste and does not foster innovation, sustainability will be partial. This is because green innovation allows firms to act proactively to achieve the desired performance impact through the articulation of the supply chain around sustainability goals (Nhi & Khoi, 2026; Rehman et al., 2021).

The results supported H5, as significant indirect associations were observed through circular economy practices and green innovation capability. The findings showed significant indirect effects through circular economy practices and green innovation capability. This is the main finding of the study. Green digital transformation and clean energy readiness are not presented as direct paths toward sustainable performance. On the contrary, they are addressed as base capabilities whose contribution depends on organizational conversion mechanisms (Cheng et al., 2026). Therefore, based on the respective findings, the study proposes that green capabilities and energy readiness do not automatically generate sustainable performance, but need to be translated into circular practices and green innovation. Thus, the indirect effects make it possible to rank the importance of the mechanisms. The strongest route was the one connecting clean energy readiness with sustainable performance through circular economy. This indicates that energy readiness acquires greater sustainable value when it materializes in operational practices of reduction, reuse, utilization, and resource efficiency (H. Xu et al., 2024). For its part, green digital transformation showed a relevant indirect route through green innovation, confirming its role as a renewal capability. Thus, the model makes it possible to differentiate two sustainability pathways: an energy and operational pathway centered on circular economy, and a digital and innovative pathway centered on green innovation (Mahmood et al., 2024; Yi et al., 2025). The model explained 32.7% of the variance in sustainable performance, indicating meaningful but partial explanatory power. This result is consistent with the multidetermined nature of sustainable performance, which may also depend on regulatory pressure, stakeholder demands, green culture, environmental leadership, financial resources, supply-chain conditions, and market factors. Thus, the mediators represent two specific organizational pathways rather than an exhaustive explanation of sustainable performance.

Finally, the study found that sustainable performance in organizational terms is not the consequence of an autonomous environmental action but depends on an integrated system in which basic green capabilities are transformed into

operational and strategic practices that generate social, environmental, and economic value. Although the direction of the proposed relationships was grounded in the resource-based view and dynamic capabilities theory, the cross-sectional design does not establish temporal precedence or identify causal effects. Consequently, the structural coefficients and indirect effects should be interpreted as statistical associations consistent with the proposed theoretical model. Reverse causality cannot be ruled out, as firms with stronger sustainable performance may possess greater resources to invest in green digitalisation, energy readiness, circular economy practices, and green innovation. The findings therefore support the plausibility of the proposed theoretical ordering but do not demonstrate that it represents the only possible causal mechanism.

CONCLUSIONS

The findings of the present study allow us to conclude that green capabilities do not determine sustainable performance automatically. Sustainable performance is possible based on the firm's ability to transform digital and energy capabilities into practices suitable for operations, the innovation process, and sustainable decision-making. The model confirmed that green digital transformation and clean energy readiness strengthen circular economy practices and green innovation. In turn, both mechanisms positively influence sustainable performance. This evidence supports the central idea of the study: corporate sustainability does not depend solely on adopting technologies or showing orientation toward clean energies, but on transforming such capabilities into routines and concrete solutions that modify the way the firm manages materials, waste, inventories, packaging, production processes, and commercial decisions.

Therefore, the main theoretical contribution of the study lies in establishing a reading of sustainability mediated by internal organizational mechanisms in textile firms. Based on the resource- and capability-based view and dynamic capabilities theory, the results show that technological and energy resources only have sustainable value when they are integrated, reconfigured, and introduced as organizational mechanisms for action. Likewise, the study argues for a non-linear approach to sustainability and incorporates an explanatory framework more consistent with SMEs in emerging economies, where financial, technological, and managerial limitations lead firms to convert existing capabilities into practices with high operational and strategic impact.

Managerial Implications

The study provides important implications for the management of textile and fashion firms. First, it proposes that leaders must rethink the ambiguous vision of sustainability. Digitalizing processes, implementing information systems, or taking steps toward incorporating cleaner energy sources do not, by themselves, allow firms to obtain better sustainable results. These actions must be articulated with specific decisions related to waste reduction, material reuse, energy efficiency, inventory management,

packaging, sustainable repackaging, and process redesign. Second, firms must understand circular economy as an operational conversion mechanism. This means moving from carrying out individual environmental actions to implementing management routines that fully enter the use of raw materials, textile waste, input recovery, product life cycle, and collaboration with suppliers or customers. For SMEs in the fashion sector, circularity should not be undertaken as an action that sustains reputation, but to increase efficiency, reduce costs, address sensitive market demands, and maintain competitive advantages. Finally, the results suggest that managers should manage sustainability as an integrated system. Green digital transformation and clean energy readiness should act as base capabilities; circular economy and green innovation as conversion mechanisms; and sustainable performance as an economic, social, and environmental result.

Limitations and Future Research Lines

The study presents several methodological limitations. All constructs were measured through self-reports provided by a single managerial respondent from each firm; therefore, despite the use of anonymity, neutral wording, and acceptable collinearity diagnostics, social desirability, informant subjectivity, and common method variance cannot be completely ruled out. Future research should adopt multi-informant designs and combine managerial perceptions with objective indicators of energy consumption, waste, technological investment, innovation, sales, and financial performance. In addition, the cross-sectional design prevents the establishment of temporal precedence, the exclusion of reverse causality, and the interpretation of indirect effects as causal mechanisms; longitudinal, panel, or time-lagged designs are therefore recommended. The R^2 for sustainable performance also indicates that the model provides a partial rather than comprehensive explanation, suggesting that regulatory pressure, stakeholder demands, green organisational culture, environmental leadership, financial resources, and sustainable supply-chain capabilities may provide additional explanatory value. Finally, because the study focused on Colombian SMEs in the textile, fashion, and apparel sector, the findings cannot be automatically generalised to other industries or national contexts.

Author contributions: JC-G: conceptualization, methodology, literature review, formal analysis, writing - original draft, writing - review & editing; NJ: methodology, critical review, validation, writing - review & editing; JAS-T: data collection, data curation, literature review, writing - review & editing. All authors agreed with the results and conclusions.

Funding: The authors declare that this research received no external funding.

Acknowledgements: The authors gratefully acknowledge the managers, owners, and functional area supervisors of the participating companies for their valuable collaboration during the data collection process.

Ethical statement: The authors stated that participation in this study was voluntary, anonymous, and confidential. Data were collected through anonymous surveys, and all participants were informed about the academic purpose of the research before completing the questionnaire. The authors further stated that informed consent was obtained from all participants prior to data collection. No sensitive personal data or information that could identify individual respondents or participating companies were

collected, stored, or reported. This study was reviewed and approved by the Ethics Committee of Tecnológico de Antioquia, approval number 02 dated semester 2025-02.

AI statement: The authors stated that they used OpenAI's ChatGPT exclusively to improve the clarity, readability, grammar, and academic style of the manuscript. The artificial intelligence tool was not used to generate, analyze, or interpret the research data, nor to develop the study design, results, or conclusions. All scientific content, methodological decisions, analyses, interpretations, and final responsibility for the manuscript remain entirely with the authors, who carefully reviewed and validated the final version before submission.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from corresponding author.

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