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Transformational Leadership and Organizational Sustainability in Industry 4.0: The Mediating Role of Innovative Performance in Pakistan's Textile Sector

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Abstract

The present research seeks to examine how organizational sustainability is affected within the framework of Industry 4.0 in Pakistan's textile sector. This investigation combines the transformational leadership model with Industry 4.0 concepts to address disparities in sustainability practices. As digitalization, intelligent production, and rapid technological progress continue to reshape business operations, innovation has gained importance as a critical driver of performance enhancement. The study explores how transformational leadership and innovative performance contribute to organizational sustainability, especially under Industry 4.0 settings. A quantitative method was applied, gathering data through questionnaires from ISO-certified textile companies in Pakistan. The dataset was analyzed using Smart-PLS with a two-stage measurement and structural model assessment. The findings reveal that Industry 4.0 significantly moderates all observed relationships. Within the context of the Fourth Industrial Revolution, transformational leadership distinctly strengthens both innovation outcomes and organizational sustainability. The analysis further confirms that innovative performance more effectively supports sustainability when integrated with Industry 4.0 technologies. Additionally, mediation hypotheses were statistically supported. The results underscore the importance of adopting strategies to address sustainability concerns while integrating smart manufacturing practices to achieve operational innovation. The study provides a practical roadmap for Pakistan's textile sector to enhance productivity and efficiency. Moreover, the proposed framework contributes to future empirical exploration and guides other manufacturing industries in blending traditional management styles with advanced technological systems to maintain sustainable growth.

Keywords: Transformational leadership, Innovative performance, Industry 4.0, Fourth industrial revolution, Organizational sustainability

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Introduction

Business sustainability is a dynamic concept influenced by multiple global challenges, including climate change, limited resources, population growth, political unrest, economic instability, and technological innovation [1]. The key concern for organizations is not merely achieving superior performance but also maintaining it in a volatile global environment. The Fourth Industrial Revolution, initiated by Germany in 2011, has intensified uncertainty and competition among businesses [2].

Current literature defines sustainability as ensuring long-term competitiveness and success in international markets, where organizations invest in human capital, process optimization, product development, and value creation to sustain performance [3, 4]. However, many firms overlooked technological investment, adhering instead to traditional operational models. Consequently, the rise of Industry 4.0 introduced unprecedented challenges across industries such as manufacturing,

healthcare, banking, energy, and education [2, 5]. Thus, sustainability has become a multi-dimensional concern encompassing economic, environmental, and social dimensions.
Globalization has intensified competition, compelling leaders to pursue long-term sustainability through technological integration to gain a competitive advantage [6, 7]. The reliance on technology now defines performance and competitiveness in global markets. Industry 4.0 has accelerated the adoption of modern technologies in manufacturing, leading to the decline of traditional firms that failed to adapt to digital transformation.
In a recent analysis, companies such as Kodak, Nokia, Xerox, BlockBuster, Yahoo, Segway, Sears, Macy's, Hitachi, Polaroid, Toshiba, Circuit City, Hummer, Atari, and Nortel Telecom were identified as failed corporations due to their inability to innovate strategically [8]. The same report emphasized that successful firms achieved sustainability by digitally transforming their strategies through timely and visionary leadership decisions. Hence, leadership serves as a crucial element in securing a competitive position in the modern business environment. The survival of conventional enterprises has become increasingly difficult as Industry 4.0 has introduced unpredictable competition across the physical, digital, and biological domains [9]. Developing new business models and frameworks has become challenging for practitioners, scholars, and industry experts due to the complex technological integration within Industry 4.0 [10]. As noted by Carvalho *et al.* [11], only forward-thinking and innovative organizations can effectively handle this digital competition. Therefore, firms must continuously identify and adopt new innovation-oriented approaches to survive in the digital transformation age.
Likewise, Shi *et al.* [12], Schwab [9], and Zakaria *et al.* [13] highlighted the urgent need to reform conventional business models, leadership styles, and quality systems. They argued that traditional leadership practices lack alignment with the demands of digital transformation in the Fourth Industrial Revolution. This raises a critical question: who will guide organizations through this unending and unstoppable digitalization of Industry 4.0? With each moment, emerging technologies intensify global competition and pressure on companies to adapt [13].
A survey conducted by Salimova *et al.* [14] reported that 48% of professionals believe Industry 4.0 trends have heightened leadership challenges. Fifty top executives expressed a strong need to modernize business structures and policies through digital adoption. The contemporary business models must be integrated with the core pillars of Industry 4.0 to remain protected in this open-source era of rapid technological evolution. Consequently, this research serves as one of the initial attempts to explore the influence of redefined leadership approaches within the context of Industry 4.0.
In the same direction, several scholars have advocated for transforming conventional leadership to cope with the uncertain challenges of Industry 4.0 [15, 16]. Schwab [9] identified four major consequences of Industry 4.0: highly demanding customers, complex product design, accelerated innovation cycles, and the obsolescence of outdated business models. He asserted that modern technological progress threatens business sustainability. Similarly, Shan *et al.* [17] emphasized that innovation plays a vital role in achieving sustainability, while Edgeman and Eskildsen [18] stated that innovative performance requires implementing the latest technologies to counteract negative impacts and maintain consistent performance.
Furthermore, Adams *et al.* [19] argued that managing sustainability is unrealistic without embedding innovation across all stages of production. Therefore, this study introduces innovation performance as a mediating factor to analyze the impact of Industry 4.0-driven technologies on sustainability outcomes. It also examines the significance of transformational leadership when integrated with Industry 4.0 dynamics. In this era of technological disruption, re-evaluating managerial philosophies and restructuring business models are imperative for maintaining organizational sustainability.

Literature Review and Hypothesis Development

Overview of the textile industry in pakistan
Pakistan, primarily an agricultural nation, has approximately 22.1 million hectares of cultivated land. Its main crops include rice, wheat, cotton, sugarcane, fruits, and vegetables, which together contribute over 75% of the country's total crop output value. Within Asia, Pakistan ranks eighth as a textile exporter [20]. The textile sector is often regarded as the backbone of the national economy, accounting for 62% of total exports and employing nearly 39% of the workforce. According to Shafiq [21], Pakistan's cotton quality surpasses that of India and China. However, Taneja [22] and Arshad *et al.* [23] contended that textiles from China, India, and Bangladesh outperform Pakistan's in terms of quality, design, and pricing.
Globalization, digitalization, and rapid innovation have become unavoidable realities worldwide. Developing economies like Pakistan must restructure their industries to align with global technological trends [24]. The swift adoption of Industry 4.0 technologies globally has intensified challenges in manufacturing [25]. Maintaining market stability without technological upgrades is no longer feasible, as product design, quality, and consistency now depend on smart innovations. Thus, textile firms must undertake major managerial and operational reforms to retain market share in this era of intelligent manufacturing.
According to a report by the All Pakistan Textile Mills Association [26], the textile sector's export value declined to PKR 266,540 in 2019—a 6% drop from 2018. This decrease reflects the industry's technological shortcomings. Dad and Karim [27] further explained that Pakistan's textile sector struggles to adapt to technological change because most companies still operate with outdated machinery, obsolete software, and low-cost equipment. Consequently, nations like India, Vietnam, and

China continue to capture export opportunities due to their advanced technologies [24, 28]. The future viability of Pakistan's textile industry thus relies heavily on aligning innovation practices, production technologies, and leadership strategies with the principles of Industry 4.0.

Transformational leadership and organizational sustainability in the context of industry 4.0

Organizational sustainability is generally viewed as a blend of three dimensions—economic, environmental, and social [29]. The economic component focuses on financial growth and market share; the social dimension relates to public welfare, safety, human rights, and customer protection; and the environmental aspect addresses ecological impacts such as waste management, product-related emissions, and the organization's carbon footprint [30-33]. Importantly, sustainability cannot be achieved by concentrating on only one of these aspects [34]. According to Purvis *et al.* [34], Industry 4.0 has profoundly affected the economic, social, and environmental pillars of sustainability worldwide. In this interconnected digital age, consumers participate from the conception to the delivery of products, often using online platforms for sharing and obtaining information. Advanced technological tools and software have also enhanced transparency in manufacturing functions, including marketing, sales, and logistics. Manufacturers now receive real-time feedback on product quality, pricing, and design, reducing potential losses. However, Purvis *et al.* [34] emphasized that even minor changes in Industry 4.0 can exert significant positive or negative impacts on an organization's sustainability. Hence, Oberer and Erkollar [35] recommended that organizations must reassess and reform their leadership approaches to effectively manage technological uncertainties.

Why leadership 4.0 is necessary

Industry 4.0 represents an integration of multiple technologies that render traditional leadership models, organizational structures, and outdated business systems ineffective [36]. Vlasov and Chromjaková [37] pointed out the obsolescence of conventional leadership characteristics and stressed the necessity of adopting new perspectives suited for the Industry 4.0 environment. Similarly, Xu *et al.* (2018) observed that previous leadership models have failed to cope with smart technologies, as the impact of Industry 4.0 transcends individual or departmental levels. Thus, aligning leadership strategies with Industry 4.0 principles has become essential.

In this context, leaders must dismantle outdated work practices, digitally redesign production, and reimagine products to sustain competitiveness in the global marketplace [38]. Prominent corporations such as Accenture, McKinsey & Company, and Boston Consulting Group have successfully integrated new business models through the adoption of "smart leadership" [39].

In today's rapidly shifting landscape, leadership based on knowledge and intellectual foresight has been discussed by various researchers [13, 40]. Drawing from previous literature, this study connects transformational leadership to Industry 4.0, as it fosters creativity, openness to new ideas, and adaptability within organizations [13, 41-43]. Transformational leadership encompasses four core dimensions: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration [41].

- Idealized influence reflects leaders' charisma, moral integrity, and clear strategic vision to enhance organizational performance.
- Inspirational motivation represents leaders' enthusiasm and positive attitude in motivating teams to accomplish shared objectives.
- Intellectual stimulation highlights the leader's encouragement of creativity, innovation, and adaptability to change.
- Individualized consideration involves empowering employees by offering timely skill development and aligning their personal growth with organizational goals.

These elements illustrate why transformational leadership fits the Industry 4.0 framework—leaders with vision and risk tolerance can steer organizations confidently through technological disruption. Roux [44] defined Leadership 4.0 as a digitally integrated, technology-driven approach that empowers employees through clarity of direction and purpose. Therefore, this study explores a revised leadership paradigm by aligning transformational leadership with the principles of Industry 4.0.

Research indicates that leaders lacking vision or adaptability often hinder digital transformation. Nearly 49% of executives admitted uncertainty about initiating digital transformation, even while allocating an annual investment of £500,000 toward technological advancement. This demonstrates the urgent need for leadership retraining and strategic realignment to navigate the digital revolution. Furthermore, leadership incompetence has been found to negatively affect sustainability performance [45, 46]. Poor leadership manifests in product quality issues, high production costs, outdated technologies, and inefficient design [47-49]. Conversely, several empirical studies have shown that effective leadership enhances sustainability outcomes [50, 51].

H1: *Transformational leadership positively affects organizational sustainability.*

Innovative performance and organizational sustainability in the context of industry 4.0

The rise of global competition—coupled with cultural, technical, financial, human, and digital advancements—has driven nations to strengthen collaborative industrial relations [52]. Industry 4.0, first conceptualized by the German government, aims to integrate information technologies with traditional manufacturing systems, fundamentally redefining production processes. In technology-intensive smart factories, organizations develop innovations through in-house R&D as well as through external technological collaborations [53].

Technological progress has redefined cost structures, production efficiency, and marketing paradigms—placing new emphasis on speed, creativity, and performance-based value. On one hand, it promotes agile manufacturing systems capable of rapidly adapting to changing consumer demands; on the other, it facilitates interconnected automation networks operating in synchronization. These dynamic processes of innovation and technology have fundamentally reshaped global organizational performance and competitiveness [54].

The notion of sustainability reflects an ever-evolving condition in business, shaped by numerous global forces including cultural diversity, technological evolution, political volatility, and globalization. Prior scholarship has stressed that to remain competitive at the international level, firms must pursue more progressive and inventive operational approaches [55-59]. In a related vein, Venema and Anger Bergström [60] viewed innovation as a core driver of sustainable outcomes, yet they questioned its universal applicability given the rapidly changing global environment. Consequently, the emergence of Industry 4.0 has redefined business sustainability through the introduction of advanced digital technologies in the production landscape [54, 57-59].

Empirical evidence from recent research points to innovation's significant influence across the social, ecological, and economic pillars of organizations [7, 61, 62]. A firm's innovation capability strengthens its ability to craft diverse strategies and capitalize on new opportunities to enhance growth and survival prospects [63]. However, other studies have questioned the contribution of Industry 4.0 toward sustainability's environmental and social aspects [64]. Kickul *et al.* [65] further observed that if a manufacturing organization fails to gain tangible advantages from digitalization, it indicates inefficient resource utilization and a lack of growth-oriented vision.

The foundation of Industry 4.0 lies in technologies such as cyber-physical systems, artificial intelligence, virtualization, big data, the Internet of Things (IoT), simulation, and cloud computing. Constant innovation within the Fourth Industrial Revolution continues to expand these frontiers [66]. Because prior research highlights a close conceptual link between innovation and sustainability, this study examines whether the adoption of Industry 4.0 alters how innovative performance affects organizational sustainability. Accordingly, the following hypothesis is posited:

H2: *Innovative performance exerts a positive impact on organizational sustainability.*

Transformational leadership and innovative performance in the context of industry 4.0

Leadership serves as a critical element within quality management, shaping the strategic path and operational coherence of a firm. A competent leader addresses systemic weaknesses and steers organizational resilience. Scholars have long recognized leadership as a determining factor in sustaining a company's competitive edge [67-69]. Although various leadership models—transformational, transactional, and laissez-faire—are well documented, debates continue over which aligns best with innovation-oriented contexts. Nonetheless, several investigations have outlined distinguishing features across these styles [70-73]. Comparative analysis of past findings has identified transformational leadership as the most significant predictor of innovative performance [74-76].

A large number of enterprises have experienced decline or complete market withdrawal due to a failure in promoting innovation within their products, procedures, or organizational systems [8]. Illustratively, corporations such as Xerox, Blockbuster, Yahoo, Segway, Sears, Macy's, Hitachi, Polaroid, Toshiba, Circuit City, Hummer, Atari, and Nortel Telecom are cited as examples of firms that collapsed because of resistance to innovation [8]. Their executive teams undervalued the potential of innovation during the rise of digital transformation. In essence, innovation involves the adoption of novel ideas, techniques, or behaviors designed to increase operational effectiveness [77].

This study emphasizes three key areas of innovative performance within the manufacturing sector: product, process, and organizational innovation. Product innovation relates to refining or redesigning goods for improved performance; process innovation focuses on introducing advanced tools and streamlined systems for more efficient operations; and organizational innovation concerns administrative and procedural enhancements aimed at achieving higher productivity [78].

Moreover, innovation is recognized as a dynamic mechanism through which new methods and technologies are implemented [75, 79]. Leaders with visionary and inspirational qualities can use innovation as a lever to accelerate results and reinforce adaptability. Transformational leadership, in particular, has been found to positively affect organizational achievements by incorporating innovation into operational systems [80-82]. Conversely, traditional leadership patterns are becoming outdated under the pressures of digital transformation, which demands greater innovation [83]. Therefore, this study revisits the link between transformational leadership and innovative performance in the setting of Industry 4.0 and puts forth the following hypothesis:

H3: *Transformational leadership has a positive relationship with innovative performance.*

Mediating influence of innovative performance between leadership 4.0 and organizational sustainability within industry 4.0

Over recent decades, innovation has remained the dominant force transforming industrial production systems [84]. The integration of intelligent technologies within enterprises elevates their operational efficiency and simultaneously broadens environmental, social, and economic expectations from stakeholders [85]. Innovative performance is thus considered a strategic enabler for ensuring long-term sustainability [86]. In agreement, Eskildsen and Edgeman [87] argued that maintaining sustainability fundamentally requires innovation at all levels of business activity. In contrast, several studies disregarded the intermediate role of innovative performance in shaping competitive advantage [88, 89]. Conversely, other scholars emphasized that the implementation of smart and automated systems enables organizations to sustain superior results and performance standards [67, 90, 91].

Nevertheless, some researchers claimed that the benefits of digital transformation diminish when innovation strategies remain static or outdated [57-59, 66]. The emergence of Industry 4.0 has significantly reshaped almost every organizational dimension—ranging from business operations, productivity, human capital, and supply chains to sustainability frameworks [6, 9, 66, 92]. Adams *et al.* [19] further contended that innovation should be practiced at every stage within a company to maintain balance in organizational sustainability. Proper and strategic use of Industry 4.0 tools—covering products, processes, and administrative activities—leads businesses toward sustainable progress [66, 85]. In practical terms, China's industrial sector serves as an example, as it consistently links technological upgrades with enhanced innovative capacity to dominate the global export market [93].

As explained by Aguinis *et al.* [94], mediation helps clarify how one variable transmits its influence to another. Building on this notion, the present research examines transformational leadership's impact on organizational sustainability through innovative performance as a mediating variable. While Honarpour *et al.* [95] identified the collective mediating role of innovation within quality management systems, the specific contribution of leadership remains underexplored in manufacturing contexts. Furthermore, Zakaria *et al.* [79, 96] highlighted that organizational innovation enhances the link between entrepreneurial orientation and firm outcomes, positioning it as the essential connector in this relationship. Meanwhile, Firman and Thabrani [97] rejected innovation's mediating influence on economic sustainability, while overlooking its potential effects on social and environmental aspects. These mixed outcomes motivate the present study to re-examine innovative performance as a mediator. Thus, the hypothesis proposed is:

***H4:** Innovative performance mediates the relationship between transformational leadership and organizational sustainability.*

System management theory

This research model draws upon systems theory, which conceptualizes organizations as coordinated and purposeful systems that transform inputs into outputs through interlinked processes [98]. Based on this perspective, transformational leadership is treated as the input, innovative performance serves as the process, and organizational sustainability represents the output. The study contributes by introducing a restructured interpretation of transformational leadership, linking it with Industry 4.0-driven innovation, and emphasizing its role in preserving sustainability under accelerating digitalization.

Theoretical Framework

The comprehensive analysis of prior literature supports the formulation of the proposed conceptual framework. The framework **(Figure 1)** visually demonstrates the interrelation among the three core constructs of this study.

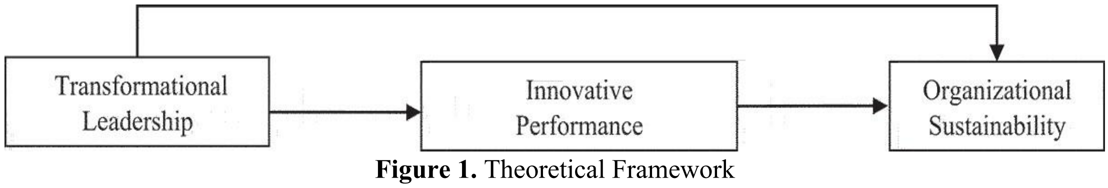

Figure 1. Theoretical Framework

The constructs were independently developed rather than derived from previous models, as the involvement of Industry 4.0 technologies presents a distinct contribution that fills an existing gap. To empirically assess the effects arising from the Fourth Industrial Revolution, the following hypotheses are proposed:

H1: Transformational leadership has a positive effect on organizational sustainability.

H2: Innovative performance positively affects organizational sustainability.

H3: Transformational leadership positively affects innovative performance.

H4: Innovative performance mediates the link between transformational leadership and organizational sustainability.

Research Methodology

Questionnaire design and data collection

This research employed a quantitative and cross-sectional approach, implying that data were collected at a single point in time. The dataset was obtained from ISO 9000-certified textile firms listed on Pakistan's Stock Exchange. Organizations holding ISO 9000 certification are known to engage actively in economic, environmental, and social initiatives [1]. Hence, chief executive officers (CEOs) and senior managers of these certified companies were identified as the most appropriate participants, considering the study's emphasis on organizational sustainability and transformational leadership.

A structured questionnaire was customized for this research, utilizing a five-point Likert scale to capture quantitative responses. The instrument was extensively refined based on prior literature. To ensure content and face validity, a focus group discussion was organized, involving four academic experts and three industry professionals from Pakistan's textile sector. The survey tool comprised two primary sections: one covering demographic details and the other containing measurement items **(Table 1)**.

Within the Karachi, Lahore, and Islamabad Stock Exchanges, 162 textile companies are listed, of which 129 possess ISO 9000 certification [99]. Consequently, the study's target population included these 129 firms. As the research aligns with the implementation of Industry 4.0 technologies, findings revealed that approximately 72% of Pakistan's textile firms have already begun integrating various Industry 4.0 systems, including cloud computing, cyber–physical systems, Internet of Things (IoT), big data analytics, and artificial intelligence [100].

Table 1. Demographic Characteristics of Respondents with Descriptive Statistics

Category	Sub-Category	Count	Percentage (%)
Position in Organization			
	CEO	34	31.1
	General Manager	13	11.9
	Quality Manager	21	19.2
	Operational Manager	23	21.1
	I.T Expert	18	16.5
	Total	**109**	**100**
Age of Respondent			
	20–30	22	20.1
	31–40	17	15.5
	41–50	32	29.3
	More than 50 years	38	34.8
	Total	**109**	**100.0**
Years of Experience			
	Less than 5 years	18	16.5
	5–10 years	22	20.1
	11–20 years	18	16.5
	21–30 years	20	18.3
	31–40 years	12	11.0
	More than 50 years	19	17.4
	Total	**109**	**100.0**
Organization Size (Employees)			
	Less than 50	15	13.7
	51–100	22	20.1
	101–500	41	37.6
	501–1000	12	11.0
	More than 1000	19	17.4
	Total	**109**	**100.0**
Organization Established (Years)			
	Less than 5 years	8	7.3
	5–10 years	27	24.7
	11–20 years	18	16.5
	21–30 years	27	24.7
	31–40 years	11	10.9
	More than 50 years	18	16.5
	Total	**109**	**100.0**
Textile Industry Segment			
	Textile Composite	31	28.4
	Textile Spinning	35	32.1
	Textile Weaving	43	39.4
	Total	**109**	**100.0**

A simple random sampling technique was applied. The G*Power tool was employed to determine the appropriate sample size, considering the number of predictors in the model. This software is widely recommended for use in PLS-SEM analyses when estimating sample adequacy. Based on the total population of 129 firms, the minimum required sample size was computed as 92 respondents [101]. To ensure sufficient representation, 122 questionnaires were distributed among ISO-certified textile organizations.

The data collection spanned six months, from November 2019 to April 2020. Some firms located in Karachi were unable to participate due to industrial strikes. Despite the logistical difficulties and the time-consuming nature of reaching CEOs and senior managers, the researcher successfully obtained 109 usable responses for analysis.

Measurement scale

To assess the core constructs, the study adopted validated measurement scales from established sources, all based on multi-item, five-point Likert scales.

The transformational leadership construct included four dimensions, each represented by four reflective indicators, adapted from AlOwais [102], Devie *et al.* [103] and Sadeghi & Pihie [104].

- Idealized Influence (4 items): Example – "Leadership demonstrates a shared vision aimed at enhancing quality through IR 4.0 technologies."
- Inspirational Motivation (4 items): Example – "Leaders consistently encourage employees to take independent action in improving quality."
- Intellectual Stimulation (4 items): Example – "Leaders critically reassess key assumptions to ensure alignment with organizational policies on IR 4.0 technologies."
- Individualized Consideration (4 items): Example – "Leaders dedicate more time and effort to train employees in using IR 4.0 technologies."

The mediating construct, innovative performance, was measured through 16 indicators covering three dimensions, derived from Gunday *et al.* [105] and Muhamad *et al.* [101]:

- Product Innovation (7 items): Example – "IR 4.0 implementation has enhanced the quality of current product materials."
- Process Innovation (4 items): Example – "IR 4.0 implementation helps eliminate non-value-added activities in production."
- Organizational Innovation (5 items): Example – "IR 4.0 implementation supports the development of better knowledge management systems."

The organizational sustainability variable was assessed using 27 items representing three pillars, adapted from Amrina & Yusof [106]; Dos Santos *et al.* [107]; and Hahn & Kühnen [108]:

- Economic Sustainability (11 items): Example – "IR 4.0 adoption contributes to higher organizational revenue growth."
- Environmental Sustainability (7 items): Example – "IR 4.0 technologies help reduce operational waste."
- Social Sustainability (9 items): Example – "IR 4.0 implementation promotes better training and skill development opportunities."

Table 1 further illustrates the respondents' demographic breakdown. Among the organizational positions, CEOs accounted for 31.1% of responses, representing the highest category, while general managers contributed 11.9%, the lowest. Regarding age, participants above 50 years constituted 34.8%, whereas the 31–40 age group was the least represented (15.5%). In terms of work experience, respondents with 5–10 years of experience formed the largest segment (20.1%), while those with 31–40 years accounted for 11.0%.

When classified by organizational size, firms employing 101–500 workers represented the highest share (37.6%), and those with 501–1000 employees the lowest (11.0%). Regarding organizational age, 7.3% of companies were less than five years old, while the most represented groups were firms established 5–10 years and 21–30 years ago (24.7% each). Finally, in terms of textile sector specialization, the weaving segment produced the highest response rate (39.4%), and textile composites had the lowest (28.4%) **(Table 1)**.

Pilot study

For the pilot phase, 32 textile firms from the Punjab province were selected, which were not included in the main analysis. Out of 50 distributed questionnaires, 37 were returned, while 13 remained uncollected. Accordingly, 32 valid responses were analyzed using SPSS and Smart-PLS 3 to determine instrument reliability **(Table 2)**. The Cronbach's alpha coefficient served as the primary measure of internal consistency, a standard indicator of reliability within organizational research. Various scholars suggest that Cronbach's alpha should fall within the 0.70–0.95 range to indicate acceptable reliability [109, 110].

Table 2. Reliability Statistics of Measurement Items

Construct	Sub-Dimension	Items	Cronbach's α
Transformational Leadership			
	Ideal Influence (II)	04	0.862

	Inspirational Motivation (IM)	04	0.802
	Intellectual Stimulation (IS)	04	0.734
	Individual Consideration (IC)	04	0.811
Innovative Performance			
	IP_Product	07	0.921
	IP_Process	04	0.798
	IP_Organizational	05	0.709
Organizational Sustainability			
	OS_Economical	11	0.901
	OS_Environmental	07	0.857
	OS_Social	09	0.891

As displayed in **Table 2**, the Cronbach's alpha values for all measurement scales ranged between 0.709 and 0.921. These results confirmed that every construct met the reliability threshold, and therefore, no items were excluded from further analysis.

Analysis and Results

This section outlines the statistical examination of the collected data. The analysis was executed using Smart-PLS software, applying both the PLS algorithm and the bootstrapping technique. The initial stage involved evaluating the measurement model, focusing on reliability and validity to confirm the adequacy of the constructs. The first phase also included testing for convergent validity. The structural equation modeling (SEM) followed a two-step approach, using latent variable scores to conduct the bootstrapping procedure.

Measurement model

The measurement model was tested to establish the constructs' reliability and validity based on factor loadings, composite reliability (CR), and average variance extracted (AVE). According to Hair *et al.* [111], factor loadings above 0.40 should be retained, CR values exceeding 0.70 denote acceptable reliability, values over 0.80 suggest good reliability, and those greater than 0.90 indicate excellent reliability. Furthermore, an AVE value above 0.50 confirms the construct's convergent validity. The factor loadings, CR, AVE, and VIF results are summarized in **Table 3** and illustrated in **Figure 2**.

Table 3. Construct Reliability and Validity (Tabular View)

First-Order Reflective Constructs

First-Order	Second-Order	Scale	Indicator	Loading	CR	Alpha	AVE
Os_Eco		Reflective	OS 1	0.719	**0.931**	**0.918**	**0.550**
			OS 2	0.770			
			OS 3	0.773			
			OS 4	0.763			
			OS 5	0.699			
			OS 6	0.687			
			OS 7	0.731			
			OS 8	0.737			
			OS 9	0.808			
			OS 10	0.721			
			OS 11	0.740			
Os_Env		Reflective	OS 12	0.700	**0.872**	**0.826**	**0.532**
			OS 14	0.658			
			OS 15	0.796			
			OS 16	0.729			
			OS 17	0.749			
			OS 18	0.736			
Os_Soc		Reflective	OS 19	0.892	**0.919**	**0.893**	**0.657**
			OS 20	0.680			
			OS 21	0.738			
			OS 24	0.801			
			OS 25	0.885			
			OS 26	0.843			

Second-Order Formative Construct

Second-Order	Scale	Item	Weight	VIF	t-value
Organizational Sustainability (OS)	Formative	Os_Eco	0.510	4.982	8.597
		Os_Env	0.680	3.002	19.703
		Os_Soc	-0.159	4.881	2.801

Innovative Performance (IP)

First-Order Reflective Constructs

First-Order	Second-Order	Scale	Indicator	Loading	CR	Alpha	AVE
IP_Product		Reflective	IP 1	0.729	**0.936**	**0.920**	**0.679**
			IP 2	0.792			
			IP 3	0.895			
			IP 4	0.792			
			IP 5	0.871			
			IP 6	0.828			
			IP 7	0.850			
IP_Process		Reflective	IP 8	0.624	**0.864**	**0.786**	**0.617**
			IP 9	0.856			
			IP 10	0.829			
			IP 11	0.810			
IP_Org		Reflective	IP 12	0.688	**0.834**	**0.732**	**0.558**
			IP 13	0.669			
			IP 14	0.805			
			IP 15	0.814			

Second-Order Reflective Construct

Second-Order	Scale	Item	Loading	CR	AVE
Innovative Performance (IP)	Reflective	IP_Product	0.911	**0.922**	**0.797**
		IP_Process	0.901		
		IP_Org	0.866		

Transformational Leadership (TL)

First-Order Reflective Constructs

First-Order	Second-Order	Scale	Indicator	Loading	CR	Alpha	AVE
Ideal Influence (II)		Reflective	TL 1	0.846	**0.874**	**0.803**	**0.638**
			TL 2	0.883			
			TL 3	0.632			
			TL 4	0.811			
Inspirational Motivation (IM)		Reflective	TL 5	0.740	**0.847**	**0.757**	**0.584**
			TL 6	0.829			
			TL 7	0.634			
			TL 8	0.837			
Intellectual Stimulation (IS)		Reflective	TL 9	0.743	**0.801**	**0.701**	**0.502**
			TL 10	0.702			
			TL 11	0.695			
			TL 12	0.743			
Individual Consideration (IC)		Reflective	TL 13	0.879	**0.884**	**0.801**	**0.718**
			TL 14	0.760			
			TL 16	0.896			

Second-Order Formative Construct

Second-Order	Scale	Item	Weight	VIF	t-value
Transformational Leadership (TL)	Formative	II	0.341	4.021	1.688
		IM	0.055	4.785	0.222
		IS	0.406	4.771	1.978
		IC	0.287	3.273	1.133

Note: TL_II = Transformational Leadership—Idealized Influence; TL_IM = Inspirational Motivation; TL_IS = Intellectual Stimulation; TL_IC = Individualized Consideration;
IP_PI = Innovative Performance—Product Innovation; IP_Pro = Process Innovation; IP_OI = Organizational Innovation;
OS_Eco = Organizational Sustainability—Economic; OS_Evn = Environmental; OS_Soc = Social;
$p < 0.05$ ($t > 1.645$); $p < 0.01$ ($t > 1.96$)

The findings in **Table 3** confirm the reliability and validity of the constructs through their outer loadings. All items with factor loadings below 0.40 were discarded. Consequently, four items from organizational sustainability (OS13, OS22, OS23, and OS27), one item (IP16) from innovative performance, and one item (TL15) from transformational leadership were excluded due to low loadings. In total, 59 items were initially tested; after removing six, the remaining 53 items were retained for further analysis, satisfying the construct reliability and validity criteria.

The Variance Inflation Factor (VIF) values were all below 5, as recommended by Henseler *et al.* [112], indicating no multicollinearity issues among the constructs.

The composite reliability (CR) values for each dimension also confirmed strong internal consistency. Within the organizational sustainability construct, the economic, environmental, and social dimensions achieved CR values of 0.931, 0.872, and 0.919, respectively. The corresponding Cronbach's alpha coefficients were 0.918, 0.826, and 0.893.

For innovative performance, CR values were 0.936 for product innovation, 0.864 for process innovation, and 0.834 for organizational innovation, with Cronbach's alpha values of 0.920, 0.786, and 0.732, respectively.

Similarly, transformational leadership showed CR values of 0.874, 0.847, 0.801, and 0.884 across its four dimensions, with Cronbach's alpha coefficients of 0.803, 0.757, 0.701, and 0.801.

The average variance extracted (AVE) values also supported convergent validity. For organizational sustainability, AVE values were 0.550 (economic), 0.532 (environmental), and 0.657 (social). The innovative performance dimensions reported AVE values of 0.679, 0.617, and 0.558 for product, process, and organizational innovation, respectively. Finally, transformational leadership reported AVE values of 0.638, 0.584, 0.502, and 0.718.

All VIF scores remained below the cut-off value of 5, confirming that multicollinearity was not a concern in this study.

Heterotrait-Monotrait Ratio (HTMT)

The discriminant validity of the measurement model was evaluated using the Heterotrait-Monotrait (HTMT) ratio, as illustrated in **Table 4**. The HTMT represents the estimated correlations between constructs, similar to a correlated construct score. When this value exceeds the defined threshold, discriminant validity is considered inadequate. Several scholars propose different cut-off points: 0.85 according to Kline [113], and 0.90 as suggested by Teo *et al.* (2008). The generally accepted threshold of 0.90 has been supported by Henseler *et al.* [112] and Al Mamun *et al.* [114]. The HTMT values presented in **Table 4** verify that discriminant validity has been achieved.

Table 4. HTMT (Heterotrait–Monotrait)

	TL _II	TL _IM	TL _IS	TL _IC	IP_PI	IP_pro	IP_OI	OS_eco	OS_env	OS_sc
TL _II	——									
TL _IM	0.610	——								
TL _IS	0.551	0.634	——							
TL _IC	0.761	0.511	0.801	——						
IP_PI	0.761	0.612	0.792	0.692	——					
IP_pro	0.542	0.571	0.517	0.677	0.803	——				
IP_OI	0.491	0.529	0.412	0.741	0.625	0.801	——			
OS_eco	0.631	0.613	0.791	0.681	0.767	0.589	0.701	——		
OS_env	0.581	0.511	0.691	0.635	0.548	0.787	0.678	0.510	——	
OS_soc	0.782	0.565	0.671	0.614	0.443	0.671	0.547	0.423	0.618	——

Note: TL_II = leadership idealized influence; TL_IM = inspirational motivation; TL_IS = intellectual stimulation; TL_IC = individualized consideration; IP_PI = innovation performance (product innovation); IP_Pro = process innovation; IP_OI = organizational innovation; OS_Eco = organizational sustainability (economic); OS_env = environmental sustainability; OS_soc = social sustainability.

Development of higher-order constructs

To minimize the number of relationships within the conceptual model, this study utilized higher-order constructs. This technique simplifies the research framework and maintains theoretical clarity while preventing multicollinearity issues arising from multi-dimensional constructs [115]. As shown in **Table 3**, the path coefficients from the dimensions of organizational sustainability to the second-order construct were significant at $p < 0.01$. The respective weights were 0.510 (OS_eco), 0.680 (OS_env), and −0.159 (OS_soc), all statistically significant at the same level. The VIF values—4.982 (OS_eco), 3.002 (OS_env), and 4.881 (OS_soc)—indicate acceptable collinearity levels. The t-values for economic, environmental, and social sustainability were 8.597, 19.703, and 2.801, respectively.

Table 3 also demonstrates all first-order and second-order constructs for innovative performance with their corresponding reflective indicators. The strong intercorrelations among these dimensions imply the presence of a second-order construct [116]. Constructs containing reflective dimensions and reflective indicators are categorized as type I reflective–reflective models.

In the same way, transformational leadership was operationalized using four dimensions—idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration—each measured with reflective indicators. The model proposed by Byrne [116] includes reflective first-order constructs and a formative second-order construct, categorized as a type II reflective–formative model, following Wetzels *et al.* [117].

The path coefficients of transformational leadership dimensions were significant, as displayed in **Table 3**: 0.341 (TL_II), 0.055 (TL_IM), 0.406 (TL_IS), and 0.287 (TL_IC), all significant at $p < 0.01$. Corresponding VIF values—4.021, 4.785, 4.771, and 3.273—are below the acceptable limit of 5, confirming no serious multicollinearity. The t-values for these dimensions were 1.688 (TL_II), 0.222 (TL_IM), 1.978 (TL_IS), and 1.133 (TL_IC); the minimum required thresholds are 1.645 (5%) and 1.96 (1%). Therefore, TL_IM and TL_IC were not statistically significant. Nonetheless, since their outer loadings exceeded 0.5, they were retained in accordance with Sarstedt *et al.* [118], who noted that insignificant outer weights do not necessarily reduce model quality if the loadings meet acceptable levels for higher-order measurement models.

Structural Equation Modeling (SEM)

This section evaluates the relationships among the proposed constructs using the Partial Least Squares (PLS) bootstrapping method. Initially, f², R², and Q² were analyzed, followed by hypothesis testing. According to **Table 5**, Cohen's [119] f² values measure the influence of exogenous variables on endogenous variables: 0.35 = large, 0.15 = medium, and 0.02 = small effects. The results show that transformational leadership and innovative performance exhibited medium-to-large effect sizes.

Table 5. Effect Size (Cohen's f²), R², and Q² for TL, IP, and OS Constructs

Relation	f^2	R^2	Q²
Organizational sustainability (OS)	——	0.930	0.471
Transformational leadership (TL)	0.430	——	——
Innovative Performance (IP)	0.547	0.354	0.289

The R² values in the table indicate the proportion of variance explained in the dependent variables. Following Cohen [119], R² = 0.26 is considered high, 0.13 moderate, and 0.02 weak. In this study, the R² = 0.349, explaining approximately 34% of the variance in the dependent variable, which is deemed substantial. When dependent variables are influenced by three or more independent constructs, the R² should be at least moderate to substantial [120].

Additionally, predictive relevance (Q²) was tested using the blindfolding method as described by Hair *et al.* [115]. A Q² value greater than zero signifies acceptable predictive capability [121]. The blindfolding results presented in **Table 5** show Q² values for the endogenous constructs as TL = 0.289 and OS = 0.471, both exceeding the threshold, thereby confirming predictive validity.

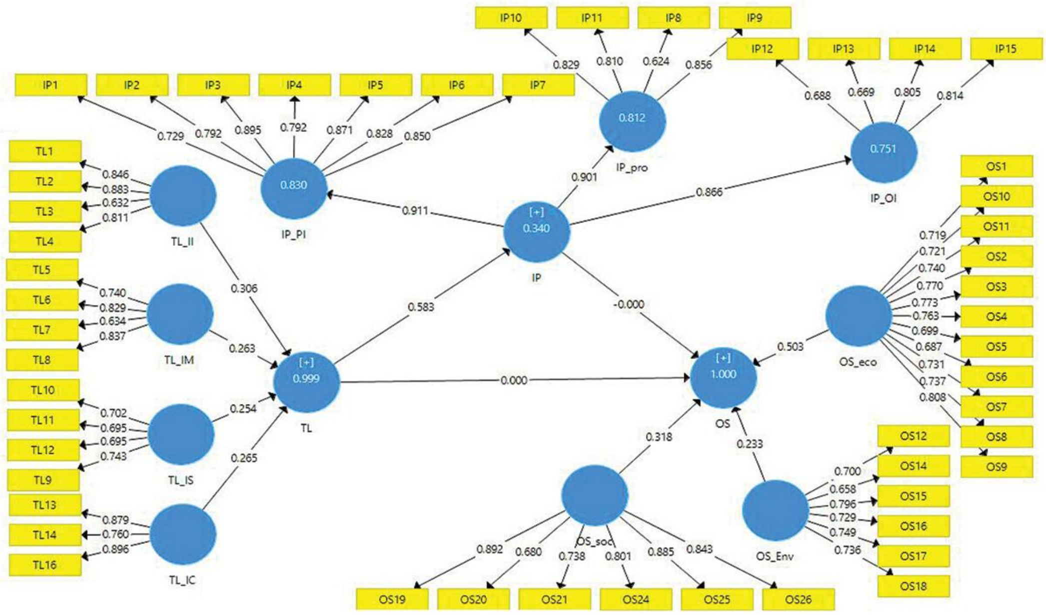

Figure 2. Measurement model of Transformational Leadership (TL), Innovative Performance (IP), and Organizational Sustainability (OS)

Findings

This section analyzes the interrelationships among the constructs based on the proposed hypotheses—H1, H2, H3 (direct relationships) and H4 (mediating relationship). Each relationship was examined through the β-value, which indicates direction, and the t-value and p-value, which determine significance. According to Hair *et al.* [111], a valid relationship requires a t-value above 1.96 at a 5% error level, and a p-value below 0.05. The corresponding outcomes for all hypotheses are listed in **Table 6**, while the structural equation model is shown in **Figure 3**.

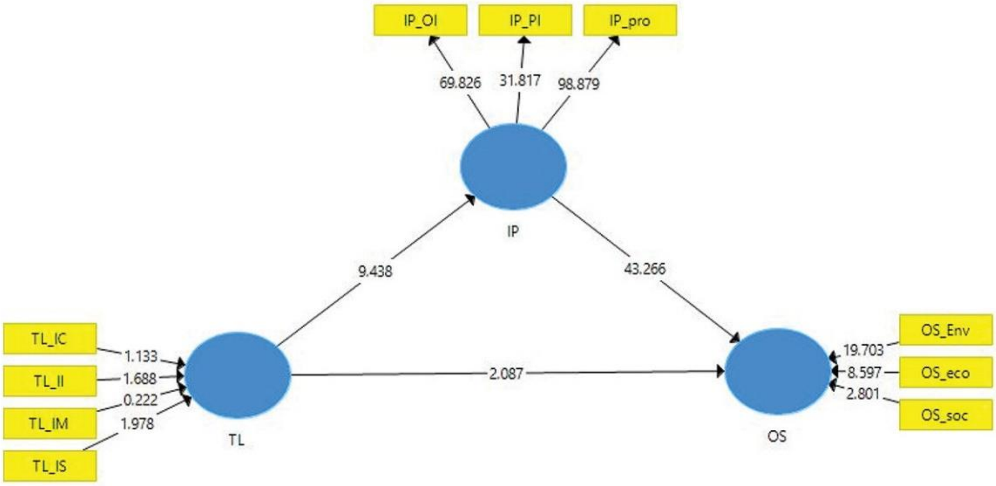

Figure 3. Structural equation model of Transformational Leadership (TL), Innovative Performance (IP), and Organizational Sustainability (OS)

Table 6. Results of Research Hypotheses

S#	Relationship	Std. Beta	Std. Error	t-value	p-value	LLCI	ULCI	Decision
H1	TL → OS	0.060	0.029	2.087	0.019	0.017	0.110	Supported
H2	IP → OS	0.927	0.021	43.266	0.000	0.885	0.958	Supported
H3	TL → IP	0.595	0.063	9.438	0.000	0.473	0.683	Supported
H4	TL → IP → OS	0.551	0.060	9.236	0.000	0.417	0.653	Supported

TL – Transformational Leadership; IP – Innovation Performance; OS – Organizational Sustainability
$p < 0.01$ ($t > 1.96$); $p < 0.05$ ($t > 1.645$)

The data presented in **Table 6** and illustrated in **Figure 3** summarize the outcomes of all tested hypotheses.

• The first hypothesis (H1) yielded results of $\beta = 0.060$, $t = 2.087$, and $p < 0.05$, confirming statistical significance, since the t-value exceeds 1.96; hence, H1 is supported.

• The second hypothesis (H2) reported $\beta = 0.927$, $t = 43.266$, and $p < 0.01$. As the t-value is far above the 1.96 threshold, H2 is also accepted.

• For the third hypothesis (H3), the results were $\beta = 0.595$, $t = 9.438$, and $p < 0.05$, meaning H3 meets the significance criteria and is therefore accepted.

• The fourth hypothesis (H4) examined the mediating role of IP between exogenous and endogenous constructs. The mediation effect was confirmed with $\beta = 0.551$, $t = 9.236$, and $p < 0.01$, supporting H4 as statistically significant.

In summary, both the direct and mediated hypotheses of this research were found to be statistically validated.

Summary of Hypotheses Results

S#	Hypothesis	Result
1	Transformational leadership positively influences organizational sustainability	Sig
2	Innovative performance positively influences organizational sustainability	Sig
3	Transformational leadership positively influences innovative performance	Sig
4	Innovative performance mediates the relationship between transformational leadership and organizational sustainability	Sig

Discussion and Conclusion

The current results are consistent with earlier studies that identified a positive association between transformational leadership and organizational sustainability [35, 51, 85]. This study confirms that the integration of Industry 4.0 (IR 4.0) technologies enhances leadership's contribution toward organizational sustainability. Similarly, prior research found that innovative performance significantly strengthens organizational sustainability [57-59, 62], indicating that the incorporation of IR 4.0 tools within innovation processes boosts sustainable outcomes [95].

The study suggests that leaders should actively adopt and promote IR 4.0 technologies to achieve sustainable growth through innovation. It also demonstrates that the redefined transformational leadership framework, aligned with Industry 4.0 demands, is particularly effective for Pakistan's textile sector. The emerging smart era poses major challenges that can be managed only if leadership competencies evolve and advanced technologies are strategically implemented [122].

Findings reveal that organizational sustainability benefits positively from a transformational leadership style, particularly when addressing Industry 4.0-related issues. For textile manufacturers, deploying smart technologies improves innovation performance, which in turn strengthens sustainability outcomes. Leadership grounded in creativity and innovation enables firms to modernize both products and processes.

However, the Fourth Industrial Revolution has also caused significant disruptions in developing economies [20, 28, 54]. The study emphasizes that innovation remains essential for ensuring the survival of firms in competitive global markets. Long-term sustainability will depend heavily on how effectively companies integrate smart and automated technologies associated with Industry 4.0. While manufacturing in this era is increasingly automated, flexible, and data-driven, it also reduces human labor needs, potentially contributing to global unemployment.

Future research may therefore explore the interaction between human resource management, quality practices, and Industry 4.0 technologies, as these relationships still require more empirical examination.

This investigation specifically focused on the textile sector of Pakistan, which faces significant challenges from rapid digital transformation. Many organizations remain unprepared for Industry 4.0 adoption due to an underdeveloped technological infrastructure. To successfully compete, firms must enhance their capacity to manage IoT systems, cyber-physical networks, artificial intelligence, big data, and cloud computing.

Elements such as big data analytics, IoT, and smart factory systems are reshaping the future of manufacturing. According to Moktadir *et al.* [123] and Siddique [28], technological and human-related barriers remain the primary challenges to achieving sustainable industrial performance. Similarly, Ali *et al.* [122] identified inadequate infrastructure as a major obstacle to implementing Industry 4.0 technologies in Pakistan's textile industry.

Theoretical implication

This research contributes significantly to the understanding of quality management, innovation performance, and organizational sustainability, while embedding the concepts of Industry 4.0 technologies and the ISO framework. Primarily, the leadership principle, a central element of quality management, has been reconceptualized in the context of Industry 4.0. More specifically, the transformational leadership approach has been revisited through its four dimensions from a digitalization-oriented perspective of the Fourth Industrial Revolution. This advancement offers a novel path for achieving organizational sustainability, supported by a quantitative assessment framework designed to guide senior management in effectively implementing Industry 4.0 technologies.

Methodological implication

This empirical investigation stands among the early studies emphasizing the critical role of leadership within management principles that foster sustainability through the adoption of Industry 4.0 components. The study introduces a methodological innovation by extensively refining and modifying the indicators within the core framework. It provides empirical support for integrating technological collaboration under the ISO 9000 system to ensure sustainable development. Moreover, the findings emphasize that leadership and innovation at multiple organizational tiers are essential for the comprehensive realization of economic, social, and environmental sustainability objectives.

Practical implication

The findings offer valuable insights for the textile sector, enabling firms to build strategic initiatives that align sustainability goals with Industry 4.0 advancements to achieve operational innovation. The research outcomes serve as a practical guide for Pakistan's textile industry, enhancing efficiency and productivity. Manufacturers in developing economies can adopt the conceptual framework proposed in this study as a strategic roadmap, integrating sustainability into their corporate priorities based on local operational contexts.

For policy developers, the study provides guidance in identifying and ranking sustainable manufacturing activities that need support through legislation, infrastructure development, and financial or technical resources. As noted by Fatima *et al. [24],* Pakistan's textile manufacturers lag in global markets due to outdated technological systems; hence, this research provides a directional framework for executives to realign their operations with Industry 4.0 principles. Overall, the study's contributions can assist top management in formulating and executing strategic and operational actions that effectively respond to the digital transformation era.

Limitation of the study

The proposed framework provides a foundation for future empirical work and can support other manufacturing industries in transitioning from traditional approaches to technology-driven strategies for sustainable outcomes. The respondents in this study consisted primarily of senior executives from ISO-certified textile firms. For broader applicability and validation, future research should incorporate cross-industry and cross-national analyses to generalize the findings more effectively.

Recommendations for future research

This empirical investigation focused on ISO-certified textile companies; however, future studies could replicate it across varied manufacturing sectors. It is also recommended to conduct comparative analyses across industries facing different technological and managerial challenges to explore interrelationships more deeply. Additionally, interviews with a wider range of stakeholders and executives could help expand the study's scope, providing a broader and more holistic understanding of sustainability and leadership under Industry 4.0 dynamics.

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