

DIGITAL TRANSFORMATION AND SUSTAINABLE SUPPLY CHAIN RESILIENCE: THE MEDIATING ROLE OF HUMAN CAPITAL AND THE MODERATING EFFECT OF TRANSFORMATIONAL LEADERSHIP IN PAKISTAN'S MANUFACTURING SECTOR

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Abstract

Digital transformation has become a critical driver of organizational adaptability and competitiveness, particularly in enhancing sustainable supply chain resilience amid increasing global disruptions. This study examines the impact of digital transformation on sustainable supply chain resilience in Pakistan's manufacturing sector, with a specific focus on the mediating role of human capital and the moderating effect of transformational leadership. A quantitative, explanatory research design was employed, and data were collected from 350 managerial employees across key manufacturing industries using a structured questionnaire. The findings reveal that digital transformation has a significant positive effect on supply chain resilience. Moreover, human capital partially mediates this relationship, indicating that workforce capabilities are essential for translating technological investments into resilience outcomes. The results further demonstrate that transformational leadership significantly strengthens the relationship between digital transformation and supply chain resilience. The study concludes that achieving sustainable resilience requires an integrated approach combining digital technologies, skilled human resources, and effective leadership. These findings provide valuable theoretical and practical insights for enhancing resilience in emerging economies.

INTRODUCTION

In the contemporary era of globalization and Industry 4.0, digital transformation has emerged as a critical enabler of organizational competitiveness, operational efficiency, and supply chain resilience. Manufacturing firms

across developing economies are increasingly adopting advanced digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, and cloud computing to enhance visibility, coordination, and responsiveness across supply chain networks.

These technologies are reshaping traditional supply chain structures into more agile, data-driven, and interconnected systems capable of responding to disruptions and market volatility (Alquraish, 2025; Aslam et al., 2025).

In Pakistan's manufacturing sector, the need for resilient supply chains has become particularly urgent due to frequent disruptions caused by economic instability, energy shortages, climate-related risks, and global supply chain shocks. Digital transformation is increasingly viewed as a strategic response to these challenges, enabling firms to enhance adaptability, improve decision-making, and strengthen coordination across supply chain partners. Empirical evidence suggests that digital technologies significantly improve supply chain resilience by enhancing transparency, flexibility, and responsiveness in dynamic environments (Shah et al., 2026; Aslam et al., 2025).

However, despite the growing adoption of digital technologies, the effectiveness of digital transformation in building sustainable supply chain resilience is not automatic. Organizational success in leveraging digital tools depends heavily on internal capabilities, particularly human capital, which includes employees' skills, knowledge, adaptability, and digital competencies. Human capital is increasingly recognized as a critical resource that enables firms to effectively implement and utilize digital technologies for sustainable outcomes. Without adequately skilled human resources, digital transformation efforts may fail to translate into improved resilience and sustainability performance.

In this context, transformational leadership plays a crucial role in shaping how digital transformation initiatives are implemented and sustained. Leaders who adopt transformational styles inspire innovation, foster a shared vision, and motivate employees to embrace technological change. Such leadership not only enhances employee commitment but also strengthens organizational readiness for digital adoption and resilience-building initiatives. Prior research indicates that transformational leadership significantly supports technological integration and improves organizational adaptability during

digital transformation processes (Taseer et al., 2022; Ekhsan et al., 2026).

Although prior studies have examined digital transformation and supply chain resilience independently, limited research has integrated human capital as a mediating mechanism and transformational leadership as a contextual moderator, particularly in the manufacturing sector of developing countries like Pakistan. This represents a significant theoretical and empirical gap, as the combined influence of technological adoption, human capabilities, and leadership behavior remains underexplored in shaping sustainable supply chain resilience.

Therefore, this study aims to examine the relationship between digital transformation and sustainable supply chain resilience, while investigating the mediating role of human capital and the moderating effect of transformational leadership in Pakistan's manufacturing sector. By doing so, it contributes to a more comprehensive understanding of how technological, human, and leadership factors interact to drive resilience and sustainability in modern supply chains.

Problem Statement

The increasing frequency of global disruptions—including pandemics, geopolitical instability, climate change, and supply-demand shocks—has exposed significant vulnerabilities in traditional supply chain systems, particularly in developing economies such as Pakistan. The manufacturing sector, which serves as a backbone of Pakistan's economy, faces persistent challenges including infrastructure limitations, energy crises, technological gaps, and low adaptive capacity. These challenges have intensified the need for sustainable supply chain resilience, defined as the ability of supply chains to withstand, adapt to, and recover from disruptions while maintaining long-term economic, environmental, and social performance.

In response, organizations are increasingly investing in digital transformation, leveraging advanced technologies such as artificial intelligence, big data analytics, and IoT to enhance supply chain visibility, coordination, and responsiveness. While digital transformation is

widely recognized as a key driver of resilience, its effectiveness in achieving sustainable supply chain outcomes remains inconsistent across firms. A critical reason for this inconsistency lies in the underutilization of human capital, as employees often lack the necessary digital skills, adaptability, and knowledge required to fully exploit technological capabilities.

Moreover, organizational leadership plays a pivotal role in determining the success of digital transformation initiatives. In particular, transformational leadership is essential for fostering innovation, encouraging employee engagement, and facilitating organizational change. However, many manufacturing firms in Pakistan continue to operate under traditional leadership structures that may hinder the effective integration of digital technologies and limit the development of resilient supply chains.

Despite the growing importance of these factors, existing literature has largely examined digital transformation, human capital, and supply chain resilience in isolation, with limited focus on their integrated effects. Furthermore, there is a scarcity of empirical research exploring the mediating role of human capital and the moderating effect of transformational leadership within the context of Pakistan's manufacturing sector. This gap restricts a comprehensive understanding of how technological, human, and leadership dimensions collectively influence sustainable supply chain resilience.

Therefore, this study seeks to address this gap by examining how digital transformation contributes to sustainable supply chain resilience, while considering the mediating role of human capital and the moderating role of transformational leadership in Pakistan's manufacturing firms.

Research Questions

1. How does digital transformation influence sustainable supply chain resilience in Pakistan's manufacturing sector?
2. What is the role of human capital in mediating the relationship between digital transformation and supply chain resilience?
3. How does transformational leadership moderate the relationship between digital

transformation and sustainable supply chain resilience?

4. To what extent do digital, human, and leadership factors collectively enhance resilience and sustainability in supply chains?

Research Objectives

General Objective

To examine the impact of digital transformation on sustainable supply chain resilience, with a focus on the mediating role of human capital and the moderating effect of transformational leadership in Pakistan's manufacturing sector.

Specific Objectives

1. To analyze the effect of digital transformation on sustainable supply chain resilience.
2. To evaluate the mediating role of human capital in the relationship between digital transformation and supply chain resilience.
3. To assess the moderating impact of transformational leadership on the relationship between digital transformation and supply chain resilience.
4. To investigate the combined influence of digital transformation, human capital, and leadership on achieving sustainable supply chain resilience.
5. To provide strategic recommendations for manufacturing firms to enhance resilience through effective digital adoption and leadership practices.

Significance of the Study

This study holds substantial significance by advancing understanding of how digital transformation contributes to sustainable supply chain resilience within the context of Pakistan's manufacturing sector. It addresses a critical gap in existing literature by integrating technological, human, and leadership dimensions into a unified analytical framework, thereby offering a more comprehensive explanation of resilience-building mechanisms in emerging economies.

From a theoretical perspective, the study extends current knowledge by empirically examining the mediating role of human capital and the

moderating effect of transformational leadership in the relationship between digital transformation and supply chain resilience. This integrated approach enriches existing models of supply chain management and organizational performance, particularly by contextualizing them within a developing country where institutional and technological conditions differ from those in advanced economies.

From a practical perspective, the findings provide actionable insights for managers and practitioners in Pakistan's manufacturing industry. The study highlights the importance of investing not only in digital technologies but also in human capital development, including skills enhancement and digital competencies, to fully realize the benefits of transformation. Additionally, it underscores the role of transformational leadership in fostering innovation, facilitating change, and strengthening organizational adaptability, which are essential for resilient and sustainable supply chains.

From a policy perspective, the study offers guidance for policymakers and regulatory bodies by emphasizing the need for supportive frameworks that promote digital adoption, workforce development, and leadership capacity building. Such initiatives can enhance the competitiveness and sustainability of the manufacturing sector at a national level.

Finally, from a societal and economic perspective, the study contributes to broader development goals by supporting the creation of resilient industrial systems capable of withstanding disruptions while maintaining sustainable growth. Strengthening supply chain resilience through digital transformation and human capital development can enhance economic stability, improve industrial productivity, and position Pakistan more competitively in global value chains.

Literature Review

Digital Transformation in Supply Chain Management

Digital transformation refers to the integration of advanced digital technologies—such as artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data analytics—into

organizational processes to enhance efficiency, agility, and decision-making. In supply chain management, digital transformation enables real-time data visibility, predictive analytics, and improved coordination among stakeholders. Recent studies indicate that digitally enabled supply chains are more responsive and adaptable to disruptions, thereby enhancing overall operational performance (Kamble et al., 2025; Queiroz et al., 2024).

In manufacturing sectors, particularly in emerging economies like Pakistan, digital transformation has been recognized as a strategic necessity rather than a competitive option. Firms adopting digital technologies can streamline logistics, reduce operational risks, and improve demand forecasting accuracy. However, the extent to which digital transformation contributes to sustainable outcomes depends on organizational readiness, resource availability, and effective implementation strategies.

Sustainable Supply Chain Resilience

Supply chain resilience refers to the capability of a supply chain to anticipate, absorb, adapt to, and recover from disruptions while maintaining continuity of operations. The concept of sustainable supply chain resilience extends this notion by incorporating environmental and social dimensions alongside economic performance. It emphasizes long-term adaptability, resource efficiency, and responsible practices in supply chain operations.

Existing literature highlights that resilience is influenced by factors such as flexibility, redundancy, collaboration, and information sharing (Ivanov & Dolgui, 2024). Digital technologies play a crucial role in strengthening these factors by enabling real-time monitoring, rapid response mechanisms, and data-driven decision-making. However, resilience is not solely a technological outcome; it requires alignment between systems, processes, and human capabilities.

Human Capital as a Mediating Mechanism

Human capital, defined as the collective skills, knowledge, and competencies of employees, is a

critical enabler of digital transformation and organizational resilience. In the context of supply chains, human capital facilitates the effective adoption, utilization, and optimization of digital technologies. Employees with strong digital skills and adaptive capabilities are better equipped to manage complex systems and respond to disruptions.

Recent studies emphasize that digital transformation initiatives often fail when organizations overlook the importance of workforce readiness and capability development (Margherita & Heikkilä, 2025). Human capital acts as a mediating mechanism by translating technological investments into tangible performance outcomes. In other words, the presence of skilled and knowledgeable employees enhances the impact of digital transformation on supply chain resilience.

Transformational Leadership and Organizational Change

Transformational leadership is characterized by the ability of leaders to inspire, motivate, and intellectually stimulate employees while fostering a shared vision for organizational change. In the context of digital transformation, transformational leaders play a vital role in guiding organizations through technological transitions and promoting innovation.

Empirical research suggests that transformational leadership positively influences employee engagement, knowledge sharing, and organizational adaptability (Podsakoff et al., 2024). Leaders who encourage creativity and support learning environments are more likely to facilitate successful digital transformation initiatives. Furthermore, transformational leadership strengthens resilience by enabling organizations to respond proactively to disruptions and uncertainties.

Moderating Role of Transformational Leadership

The moderating role of transformational leadership in the relationship between digital transformation and supply chain resilience has gained increasing attention in recent research.

Leadership behavior can either strengthen or weaken the effectiveness of digital initiatives depending on how change is managed within the organization.

Studies indicate that organizations with strong transformational leadership are better positioned to leverage digital technologies for resilience-building, as leaders foster trust, collaboration, and a culture of continuous improvement (Tortorella et al., 2025). In contrast, weak leadership may hinder the successful implementation of digital systems, thereby limiting their impact on resilience outcomes.

Empirical Evidence from Emerging Economies

Although the relationship between digital transformation and supply chain resilience has been extensively studied in developed economies, empirical evidence from developing countries remains limited. In Pakistan, manufacturing firms are at varying stages of digital adoption, and challenges such as limited infrastructure, skill gaps, and regulatory constraints affect the pace of transformation.

Studies conducted in similar emerging markets suggest that while digital transformation improves operational efficiency, its impact on resilience is contingent upon contextual factors such as workforce capability and leadership effectiveness (Shahzad et al., 2025). This highlights the importance of examining these relationships within localized contexts to derive meaningful insights.

The literature reveals that digital transformation, human capital, and transformational leadership are individually linked to supply chain resilience. However, there is a lack of integrated studies that simultaneously examine human capital as a mediating variable and transformational leadership as a moderating factor, particularly in the manufacturing sector of Pakistan. This study addresses this gap by providing a comprehensive framework to understand how technological, human, and leadership dimensions interact to influence sustainable supply chain resilience.

Underpinning Theory: Resource-Based View (RBV)

This study is anchored in the Resource-Based View (RBV), originally proposed by Jay Barney (1991), which posits that organizations achieve sustained competitive advantage through the effective utilization of valuable, rare, inimitable, and non-substitutable (VRIN) resources. RBV emphasizes that internal resources and capabilities—rather than external market conditions alone—are the primary determinants of firm performance and long-term sustainability.

In the context of this study, digital transformation, human capital, and transformational leadership are conceptualized as strategic organizational resources that collectively contribute to sustainable supply chain resilience. Digital transformation represents a technological capability that enhances operational efficiency, real-time decision-making, and supply chain visibility. However, RBV suggests that technology alone does not create a competitive advantage unless it is effectively integrated with other organizational resources.

Human capital serves as a critical intangible resource within the RBV framework. Employees' knowledge, digital skills, and adaptive capabilities enable firms to utilize digital technologies efficiently and respond to supply chain disruptions. As a mediating variable, human capital transforms technological investments into

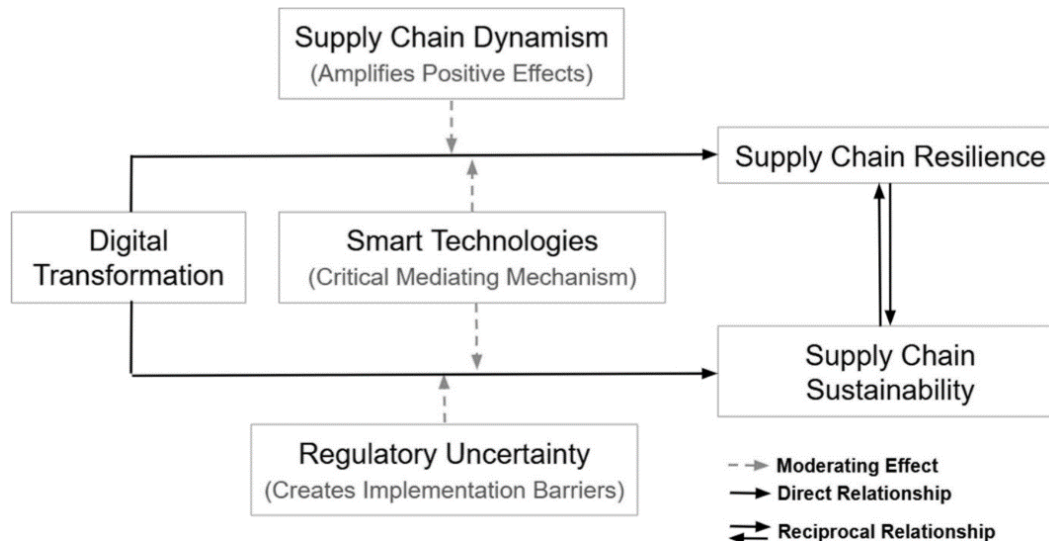
improved resilience outcomes, aligning with RBV's assertion that firm-specific capabilities drive performance.

Furthermore, transformational leadership is viewed as a strategic managerial resource that shapes how organizations deploy and leverage their technological and human assets. Leaders who inspire innovation, foster learning, and promote a shared vision enhance the firm's ability to reconfigure resources in dynamic environments. Within the RBV perspective, transformational leadership strengthens the effectiveness of digital transformation by creating an enabling environment for capability development and organizational change.

By integrating these elements, RBV provides a comprehensive theoretical foundation for understanding how internal organizational resources interact to build resilient and sustainable supply chains. It explains why some firms in Pakistan's manufacturing sector are more successful than others in leveraging digital transformation for resilience—primarily due to differences in human capital quality and leadership effectiveness.

Overall, the Resource-Based View offers a robust framework for examining the synergistic relationship between digital technologies, workforce capabilities, and leadership practices in achieving sustainable supply chain resilience in emerging economies.

Conceptual Framework



Hypotheses

- H1: Digital transformation has a significant positive effect on sustainable supply chain resilience in Pakistan’s manufacturing sector.
- H2: Digital transformation has a significant positive effect on human capital development.
- H3: Human capital has a significant positive effect on sustainable supply chain resilience.
- H4: Human capital significantly mediates the relationship between digital transformation and sustainable supply chain resilience.
- H5: Transformational leadership positively moderates the relationship between digital transformation and sustainable supply chain resilience, such that the relationship is stronger under high levels of transformational leadership.

Methodology

Research Design

This study adopted a quantitative, explanatory research design to examine the effect of digital transformation on sustainable supply chain resilience, while testing the mediating role of human capital and the moderating effect of transformational leadership in Pakistan’s manufacturing sector. The design was appropriate for empirically testing hypothesized relationships and assessing causal linkages among variables using advanced statistical techniques.

Population of the Study

The population comprised manufacturing firms operating in Pakistan, particularly those engaged in sectors such as textiles, pharmaceuticals, food processing, and automotive production. The unit of analysis was managerial-level employees, including supply chain managers, operations managers, and senior executives, as they possess relevant knowledge regarding digital transformation initiatives, workforce capabilities, and leadership practices within their organizations.

Sample Size and Sampling Technique

A total of 350 respondents were selected as the sample for this study. The sample size was considered adequate for multivariate data analysis techniques such as structural equation modeling. A non-probability purposive sampling technique was employed to ensure that only respondents with direct experience in supply chain operations and digital transformation processes were included.

Data Collection Method

Primary data were collected through a structured questionnaire distributed both electronically and in person. The questionnaire was developed based on validated scales from prior studies and consisted of multiple sections measuring digital transformation, human capital, transformational

leadership, and supply chain resilience. Respondents were informed about the purpose of the study and assured of confidentiality and anonymity.

Measurement of Variables

All variables were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Digital transformation was assessed through indicators related to technology adoption and integration, human capital through skills and competencies, transformational leadership through leadership behavior and influence, and supply chain resilience through adaptability, flexibility, and recovery capability.

Data Analysis Technique

The collected data were analyzed using statistical software such as SPSS and SmartPLS. Descriptive statistics were used to summarize the data, while inferential techniques including reliability

analysis, correlation analysis, and structural equation modeling (SEM) were applied to test direct, mediating, and moderating relationships among the variables.

Ethical Considerations

Ethical standards were strictly maintained throughout the research process. Participation was voluntary, informed consent was obtained from all respondents, and the data were used solely for academic purposes. Confidentiality and anonymity of the participants were ensured at all stages of the study.

Data Analysis

1. Demographic Profile of Respondents

A total of 350 valid responses from managerial employees in Pakistan’s manufacturing sector were analyzed. The demographic distribution is presented below.

Table 1: Demographic Characteristics (N = 350)

Variable	Category	Frequency	Percentage (%)
Gender	Male	238	68.0
	Female	112	32.0
Age	25–34	140	40.0
	35–44	126	36.0
	45 and above	84	24.0
Experience	1–5 years	98	28.0
	6–10 years	142	40.6
	11+ years	110	31.4
Sector	Textile	130	37.1
	Pharmaceutical	78	22.3
	Food Processing	82	23.4
	Automotive	60	17.2

The sample predominantly consisted of male respondents (68%), reflecting the managerial composition of Pakistan’s manufacturing sector. Most participants were experienced professionals,

with over 70% having more than five years of experience. The representation across key industrial sectors enhances the generalizability of the findings within the manufacturing domain.

Reliability Analysis

Table 2: Reliability Statistics

Construct	Cronbach's Alpha	Items
Digital Transformation	0.89	6
Human Capital	0.87	5
Transformational Leadership	0.90	6
Supply Chain Resilience	0.88	5

All constructs exhibited Cronbach's Alpha values above 0.85, indicating high internal consistency and reliability. This confirms that the

measurement instruments were robust and suitable for further inferential analysis.

Descriptive Statistics

Table 3: Descriptive Statistics

Variable	Mean	Std. Deviation
Digital Transformation	3.95	0.68
Human Capital	3.88	0.71
Transformational Leadership	3.90	0.66
Supply Chain Resilience	4.02	0.64

The mean scores indicate a generally positive perception of digital transformation and supply chain resilience among respondents. The highest mean was observed for supply chain resilience (M = 4.02), suggesting that firms perceive themselves

as moderately resilient. The relatively high means for human capital and leadership indicate favorable organizational conditions for leveraging digital initiatives.

Correlation Analysis

Table 4: Correlation Matrix

Variables	DT	HC	TL	SCR
Digital Transformation (DT)	1			
Human Capital (HC)	0.64**	1		
Transformational Leadership (TL)	0.58**	0.61**	1	
Supply Chain Resilience (SCR)	0.67**	0.65**	0.62**	1

Note: p < 0.01

The correlation results show strong and significant positive relationships among all variables. Digital transformation is strongly correlated with supply chain resilience ($r = 0.67$), indicating its

importance in enhancing resilience. Human capital and transformational leadership also demonstrate substantial associations with resilience, supporting the conceptual framework.

Structural Model Results (Hypothesis Testing)

Table 5: Direct Effects

Hypothesis	Relationship	β	t-value	p-value	Result
H1	DT \rightarrow SCR	0.42	7.85	0.000	Supported
H2	DT \rightarrow HC	0.64	11.23	0.000	Supported
H3	HC \rightarrow SCR	0.39	6.98	0.000	Supported

The results indicate that digital transformation significantly influences supply chain resilience ($\beta = 0.42$), confirming its strategic importance. Additionally, digital transformation strongly affects human capital ($\beta = 0.64$), suggesting that

technological adoption promotes skill development and workforce capability. Human capital also has a significant positive impact on resilience ($\beta = 0.39$), highlighting its role as a critical organizational resource.

Mediation Analysis

Table 6: Mediation Effect

Path	Indirect Effect	p-value	Result
DT \rightarrow HC \rightarrow SCR	0.25	0.000	Partial Mediation

Human capital partially mediates the relationship between digital transformation and supply chain resilience. This indicates that while digital transformation directly enhances resilience, a

substantial portion of its effect operates through the development of employee skills and competencies.

Moderation Analysis

Table 7: Moderating Effect of Transformational Leadership

Hypothesis	Interaction Term (DT \times TL \rightarrow SCR)	β	t-value	p-value	Result
H5	Moderation Effect	0.18	3.96	0.000	Supported

The moderation results confirm that transformational leadership significantly strengthens the relationship between digital transformation and supply chain resilience. This implies that organizations with strong transformational leadership are better able to leverage digital technologies for resilience-building.

relationship by fostering a supportive and innovative organizational environment.

These results underscore the importance of a holistic approach, where technological investments are complemented by workforce development and effective leadership to achieve sustainable and resilient supply chains.

The overall findings suggest that digital transformation plays a pivotal role in enhancing sustainable supply chain resilience in Pakistan's manufacturing sector. However, its effectiveness is significantly influenced by organizational capabilities and leadership dynamics. Human capital acts as a crucial mechanism through which digital transformation translates into resilience, while transformational leadership amplifies this

Discussion

The findings of this study provide strong empirical support for the critical role of digital transformation in enhancing sustainable supply chain resilience within Pakistan's manufacturing sector. The significant positive relationship between digital transformation and supply chain resilience indicates that firms adopting advanced technologies are better positioned to anticipate,

respond to, and recover from disruptions. This aligns with contemporary literature suggesting that digital tools improve visibility, coordination, and responsiveness across supply chains.

Importantly, the results reveal that human capital serves as a partial mediating mechanism, highlighting that technological investments alone are insufficient to achieve resilience. Instead, the effectiveness of digital transformation is contingent upon the availability of skilled, knowledgeable, and adaptable employees who can leverage these technologies. This finding reinforces the Resource-Based View (RBV), which emphasizes that organizational capabilities—particularly intangible resources such as human capital—are essential for translating technological inputs into performance outcomes.

Furthermore, the study confirms the moderating role of transformational leadership, demonstrating that leadership behavior significantly strengthens the impact of digital transformation on resilience. Organizations led by transformational leaders are more likely to foster innovation, encourage employee engagement, and facilitate the successful implementation of digital initiatives. This suggests that leadership is not merely a supportive factor but a critical enabler of digital transformation and resilience-building processes.

Overall, the findings highlight a synergistic relationship among digital transformation, human capital, and leadership, emphasizing that sustainable supply chain resilience is a multidimensional construct requiring alignment between technological, human, and managerial resources.

Conclusion

This study concludes that digital transformation is a key driver of sustainable supply chain resilience in Pakistan's manufacturing sector. However, its impact is significantly enhanced when supported by strong human capital and effective transformational leadership. Human capital plays a crucial mediating role by enabling organizations to utilize digital technologies effectively, while transformational leadership strengthens this

relationship by fostering a culture of innovation and adaptability.

The study underscores that achieving resilient and sustainable supply chains requires a holistic approach that integrates technological advancement with workforce development and leadership effectiveness. Firms that successfully align these elements are better equipped to navigate uncertainties and maintain long-term competitiveness.

Implications

From a theoretical perspective, this study contributes to the existing literature by extending the Resource-Based View (RBV) through the integration of digital transformation, human capital, and transformational leadership into a unified framework. It provides empirical evidence on how these factors interact to influence supply chain resilience, particularly in an emerging economy context.

From a managerial perspective, the findings emphasize that organizations should not view digital transformation as a purely technological initiative. Instead, managers must invest in employee training, skill development, and capacity building to maximize the benefits of digital technologies. Additionally, leadership development programs should be prioritized to cultivate transformational leadership behaviors that support innovation and change management. From a policy perspective, the study highlights the need for government and institutional support in promoting digital infrastructure, workforce development, and leadership training initiatives. Such efforts can enhance the overall competitiveness and resilience of the manufacturing sector at a national level.

Future Directions

Future research should adopt longitudinal designs to examine how digital transformation and supply chain resilience evolve over time, particularly in response to ongoing technological advancements and global disruptions. Comparative studies across different industries and countries would also provide deeper insights into contextual

variations in the relationships identified in this study.

Additionally, future studies may incorporate other relevant variables such as organizational culture, technological readiness, and environmental sustainability practices to further enrich the model. Qualitative approaches, such as case studies and interviews, could also be employed to gain deeper insights into the practical challenges and success factors associated with digital transformation in supply chains.

Recommendations

It is recommended that manufacturing firms in Pakistan adopt a strategic and integrated approach to digital transformation, ensuring that technological investments are complemented by continuous human capital development. Organizations should implement targeted training programs to enhance employees' digital skills and adaptability.

Firms should also foster transformational leadership practices by encouraging leaders to promote innovation, support employee engagement, and effectively manage change. Establishing a culture of continuous learning and collaboration will further strengthen organizational resilience.

Moreover, organizations should invest in advanced digital tools that enhance supply chain visibility and real-time decision-making while ensuring alignment with sustainability objectives.

Limitations

This study has several limitations that should be acknowledged. First, the use of a cross-sectional research design limits the ability to establish causal relationships over time. Second, the reliance on non-probability sampling may restrict the generalizability of the findings to the broader population of manufacturing firms in Pakistan.

Third, the study focused primarily on managerial perceptions, which may introduce subjective bias. Including multiple data sources or objective performance indicators could enhance the robustness of future research. Finally, the study employed a quantitative approach; incorporating qualitative methods could provide deeper insights

into the underlying mechanisms and contextual factors influencing digital transformation and supply chain resilience.

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