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Explaining and Structuring a Smart Supply Chain Resilience Model in the Face of Global Market Turbulence: A Case Study of the Carpet Industry

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ABSTRACT

Global market turbulence, technological change, and competitive pressure have exposed the Iranian carpet industry's supply chain to significant structural and operational vulnerabilities. In this context, a smart resilience model is needed to preserve competitiveness, improve adaptability, and support data-driven decision-making. This study aimed to explain and structure a localized model of smart supply chain resilience in the carpet industry. The study used an applied, exploratory mixed-methods design combining grounded theory and interpretive structural modeling (ISM). In the qualitative phase, data were collected through 15 semi-structured interviews with experts in the carpet industry, supply chain management, production management, and digital technologies. The interviews were analyzed through open, axial, and selective coding using MAXQDA. The qualitative analysis identified six main dimensions: causal conditions, core phenomenon, contextual conditions, intervening conditions, strategies, and consequences. In the structural phase, ISM and MICMAC analysis were used to determine hierarchical relationships and driving-dependence patterns among the extracted dimensions. The findings show that AI-enabled smart supply chain resilience in the carpet industry is shaped by global market turbulence, weak traditional structures, data limitations, digital maturity, technological acceptance, and coordinated data-driven strategies. The ISM results indicate a three-level structure in which causal conditions, the core phenomenon, and intervening conditions form the foundational level; strategies and consequences form the intermediate level; and contextual conditions emerge as the dependent outcome layer. MICMAC analysis shows that most dimensions operate as linkage variables with high driving power and medium dependence, while contextual conditions are highly dependent. The findings suggest that digitalization, predictive analytics, data governance, digital networking, supplier intelligence, and human-skill upgrading can strengthen resilience, agility, transparency, and sustainable competitive advantage in the carpet industry.

Keywords: *smart resilience; supply chain resilience; artificial intelligence; global market turbulence; carpet industry; interpretive structural modeling; grounded theory*

1. Introduction

The Iranian carpet industry is one of the country's most important cultural, artistic, and economic industries. It has historically contributed to non-oil exports, employment, craft entrepreneurship, and national cultural identity. However, rapid changes in global competition, consumer preferences, international trade conditions, technology, and market uncertainty have increased the vulnerability of this industry's supply chain. In export-oriented industries such as carpets, turbulence in demand, fragile supplier networks, limited market intelligence, and weak coordination among actors can rapidly undermine competitiveness and operational continuity. Supply chain resilience refers to the capacity of a system to anticipate disruptions, adapt to changing conditions, recover effectively after crises, and learn from previous shocks. Contemporary supply chain resilience research has moved beyond reactive recovery and increasingly emphasizes preparedness, digital visibility, collaboration, and adaptive capability (Ivanov, 2024; Rahman et al., 2022; Shishodia et al., 2023). Digital technologies have become particularly important because they can improve real-time visibility, risk sensing, demand forecasting, supplier monitoring, and coordinated decision-making (Alkhatib & Momani, 2023; Atieh et al., 2024; Shen & Sun, 2021).

The rise of artificial intelligence, big data analytics, the Internet of Things, blockchain, and machine learning has created new possibilities for supply chain resilience. AI-based tools can support demand planning, anomaly detection, risk forecasting, inventory optimization, and early-warning systems (Culot et al., 2024; Daios et al., 2025; Walter et al., 2025). Studies on AI in supply chain management suggest that digital systems can improve operational efficiency and strategic decision-making, but successful implementation requires data governance, organizational readiness, human skills, and inter-organizational trust (Culot et al., 2024; Samuels, 2025). Supply chain resilience has been widely examined in relation to disruption management, risk mitigation, flexibility, redundancy, agility, collaboration, and recovery capability. Systematic reviews show that resilience strategies can be classified into preparedness, response, and recovery initiatives, and that their effectiveness depends on the interaction between supply chain structure, environmental uncertainty, flexibility, and managerial capability (Gaudenzi et al., 2023; Piprani et al., 2022; Rahman et al., 2022; Shishodia et al., 2023). Ivanov (2024) argues that the COVID-19 pandemic transformed resilience research by shifting attention from static protection toward dynamic adaptation, network redesign, and digital technology-enabled disruption management (Ivanov, 2024).

Digital supply chain resilience research emphasizes the role of real-time information, analytics, automation, and connectivity. Alkhatib and Momani (2023) found that digital technologies strengthen the relationship between resilience practices and operational performance (Alkhatib & Momani, 2023). Atieh et al. (2024) similarly showed that supply chain resilience and digital supply chain capabilities interact with supply chain dynamism to shape sustainability outcomes (Atieh et al., 2024). In AI-focused reviews, Culot et al. (2024), Daios et al. (2025), and Walter et al. (2025) demonstrate that AI contributes to supply chain planning, forecasting, customer relationship management, inventory control, procurement, transportation, and risk management (Culot et al., 2024; Daios et al., 2025; Walter et al., 2025).

Although the international literature increasingly links AI to resilience, most studies focus on industrial, retail, logistics, or manufacturing settings. Less attention has been paid to culturally embedded industries such as carpets and handicrafts, where supply chains combine craft knowledge, fragmented production networks, export dependence, and symbolic cultural value. This creates a specific research gap: the need for a localized model that integrates smart technologies, resilience logic, and the particular conditions of the carpet industry.

Despite this progress, traditional and culturally embedded industries face specific barriers to digital resilience. In the carpet industry, production is often fragmented, supply networks are dispersed, many producers operate through traditional management routines, and data infrastructure is weak. The challenge is not simply to import digital tools, but to design a context-sensitive model that links resilience capabilities with the cultural, economic, and technological realities of the industry. This issue is especially important because the carpet industry must preserve artistic authenticity while adapting to digital markets and global competitive pressure.

The problem addressed in this study is therefore not only technological. It concerns the structure of the whole supply chain: What conditions create the need for smart resilience? What is the core phenomenon that must be developed? What contextual and intervening factors shape the transformation process? What strategies can be used by industry actors? What outcomes can be expected if a smart resilience model is implemented? Accordingly, the central

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research question is: What dimensions, components, and mechanisms constitute a localized smart supply chain resilience model for the carpet industry in the face of global market turbulence, and how can this model contribute to sustainability and competitiveness?

2. Methods and Materials

This study was applied in purpose and exploratory in design. It used a mixed qualitative-structural approach by combining grounded theory and interpretive structural modeling (ISM). Grounded theory was used as a systematic qualitative strategy for building concepts from expert data (Glaser & Strauss, 1967; Strauss & Corbin, 1998), while ISM was used to structure the relationships among the main dimensions (Warfield, 1974). The grounded theory phase was used to extract the dimensions and components of smart supply chain resilience from expert interviews. The ISM phase was then used to structure the relationships among the extracted dimensions and identify their hierarchical levels.

Participants in the qualitative phase consisted of experts in supply chain management, carpet industry management, production management, and digital transformation. Purposeful and snowball sampling were used to identify experts with direct knowledge of the carpet industry and practical or academic experience in supply chain management. Semi-structured interviews continued until theoretical saturation. After 13 interviews, no substantially new concepts emerged; however, two additional interviews were conducted to confirm the stability of the codes. In total, 15 expert interviews were analyzed.

The interview protocol was developed based on the research aim and literature review. It included open-ended questions about supply chain resilience, smart technologies, global market turbulence, barriers in the carpet supply chain, and strategies for improving adaptability. The interviews were recorded with participants' consent and transcribed in full. Data were analyzed using the systematic grounded theory procedure, including open, axial, and selective coding. MAXQDA was used to support coding, classification, memo writing, and conceptual organization.

In the second phase, ISM was used to determine the structural relationships among the main dimensions extracted from grounded theory. Expert judgments were collected to evaluate the type and direction of relationships among the variables. A structural self-interaction matrix was developed and converted into an initial and final reachability matrix. Boolean logic was used to ensure transitivity, and the hierarchical levels were determined by comparing the reachability set, antecedent set, and intersection set for each variable. Finally, MICMAC analysis was used to classify the variables based on driving power and dependence power.

3. Findings and Results

3.1. *Grounded Theory Findings*

The grounded theory analysis generated six main paradigm dimensions: causal conditions, the core phenomenon, contextual conditions, intervening conditions, strategies, and consequences. Table 1 presents a condensed version of the extracted categories and concepts. The causal conditions show the pressures that create the need for smart resilience. The core phenomenon represents the AI-enabled smart resilience of the carpet supply chain. Contextual and intervening conditions shape the feasibility and direction of this transformation. Strategies indicate the actions required by supply chain actors, and consequences describe the expected outcomes of implementation.

Table 1

Condensed Paradigm Dimensions and Extracted Concepts of AI-Enabled Smart Supply Chain Resilience

Paradigm dimension	Condensed extracted concepts
Causal conditions	Market turbulence, competitive pressure, geopolitical uncertainty, demand volatility, fragile supplier networks, weak traditional structures, limited market intelligence, and competition from substitutes.
Core phenomenon	AI-enabled smart supply chain resilience; digital and data-driven renewal of the carpet supply chain; balance between technological innovation and cultural authenticity.
Contextual conditions	Fragmented production structure, weak data architecture, limited digital skills, traditional management routines, weak actor coordination, and uneven digital infrastructure.
Intervening conditions	Digital maturity, data quality, government policy, technological leadership, access to analytical technologies, cultural acceptance, and university-industry collaboration.
Strategies	Process digitalization, predictive analytics, data governance, smart supplier evaluation, digital networking, AI-based production and logistics optimization, workforce upskilling, early-warning systems, and traceability.
Consequences	Higher resilience, operational agility, export competitiveness, transparency, sustainability, organizational learning, dynamic coordination, preservation of authenticity, and long-term competitive advantage.

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After open and axial coding, selective coding integrated the categories around the core category of AI-enabled smart supply chain resilience in the carpet industry under global market turbulence. The final theoretical narrative indicates that the carpet supply chain requires a transition from a fragmented and reactive structure toward a digital, predictive, and learning-oriented system.

3.2. ISM Leveling Results

The six main dimensions extracted from grounded theory were used as the input variables for ISM. Based on expert judgments, the structural relationships were transformed into reachability and antecedent sets. Table 2 presents the hierarchical levels of the variables, and the corresponding ISM hierarchy is shown in Figure 1. The model has three levels. Causal conditions, the core phenomenon, and intervening conditions are located at the foundational level. Strategies and consequences are located at the second level. Contextual conditions occupy the first level, indicating that they are strongly influenced by the lower-level drivers and represent the contextual field in which the results of smart resilience are manifested.

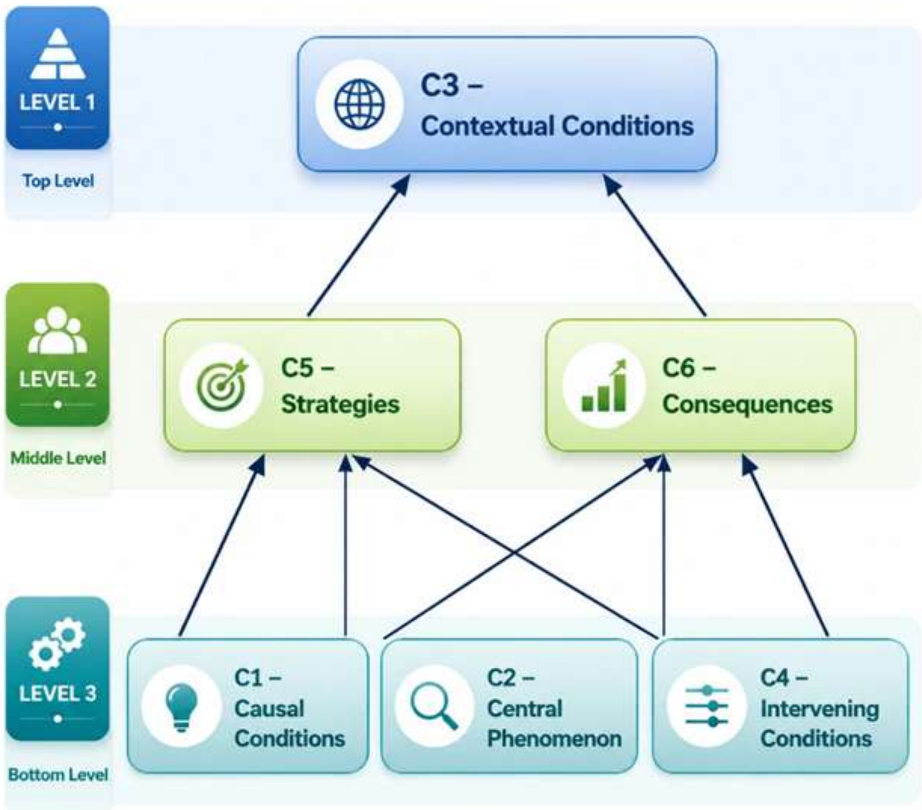
Table 2

Hierarchical Levels of Variables in the ISM Model

Code	Dimension	Reachability set	Antecedent set	Intersection	Level
C3	Contextual conditions	{C3}	{C1, C2, C3, C4}	{C3}	Level 1
C5	Strategies	{C2, C5, C6}	{C1, C2, C4, C5}	{C2, C5}	Level 2
C6	Consequences	{C1, C4, C6}	{C1, C2, C4, C5, C6}	{C1, C4, C6}	Level 2
C2	Core phenomenon	{C2, C3, C4, C5, C6}	{C1, C2, C4, C5}	{C2, C4, C5}	Level 3
C1	Causal conditions	{C1, C2, C3, C4, C5, C6}	{C1, C4, C6}	{C1, C4, C6}	Level 3
C4	Intervening conditions	{C1, C2, C3, C4, C5, C6}	{C1, C2, C4, C6}	{C1, C2, C4, C6}	Level 3

Figure 1

ISM hierarchy of the smart supply chain resilience model.



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3.3. MICMAC Analysis

MICMAC analysis was used to classify the variables according to driving power and dependence power. As shown in Figure 2 and summarized in Table 3, C1, C2, C4, C5, and C6 have high driving power and medium dependence and are therefore linkage variables. C3 has very low driving power and high dependence and is therefore a dependent variable. The results indicate that the smart resilience of the carpet supply chain is not driven by a single isolated factor; rather, it emerges from the interaction of structural, strategic, technological, and managerial dimensions.

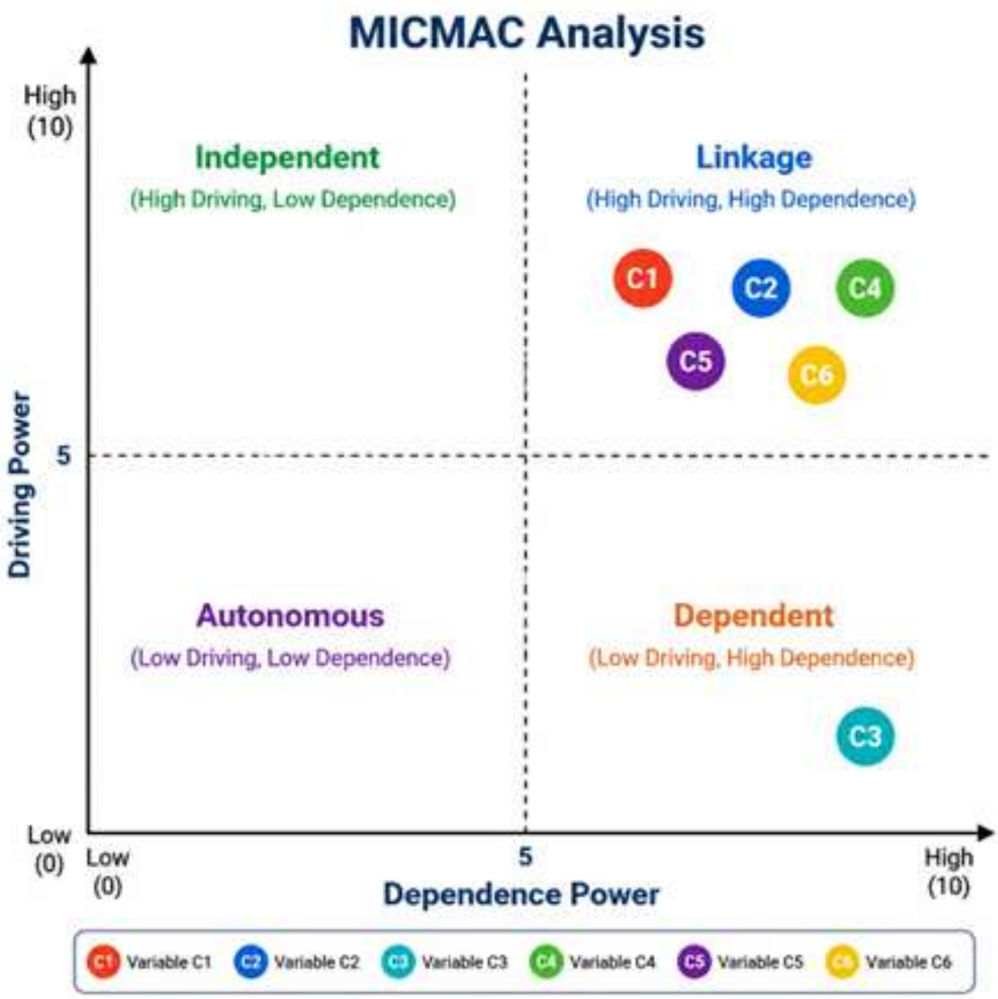
Table 3

MICMAC Results: Driving Power, Dependence Power, and Classification

Variable	Driving power	Dependence power	MICMAC class	Status
C1	6	5	Linkage	High-medium
C2	6	5	Linkage	High-medium
C3	1	5	Dependent	Very low-high
C4	6	5	Linkage	High-medium
C5	6	5	Linkage	High-medium
C6	6	5	Linkage	High-medium

Figure 2

MICMAC driving-dependence map of the model variables.



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4. Discussion

The findings show that smart supply chain resilience in the carpet industry is a dynamic, multi-layered, and technology-enabled capability. The grounded theory results indicate that the need for resilience arises from global market turbulence, competitive pressure, geopolitical risks, demand volatility, weak information transparency, and fragile supply networks. These findings are consistent with the broader literature, which emphasizes that supply chain resilience emerges when organizations face uncertain environments and must develop preparedness, response, recovery, and adaptation capabilities (Ivanov, 2024; Rahman et al., 2022; Shishodia et al., 2023). The results also show that AI and digitalization should not be understood only as technical tools. In the model, AI-enabled resilience requires data governance, predictive analytics, human-skill development, digital networking, and trust among actors. This interpretation is consistent with research showing that AI improves supply chain performance when it is supported by organizational readiness, process redesign, and data integration (Culot et al., 2024; Daios et al., 2025; Samuels, 2025; Walter et al., 2025). In traditional industries, however, the cultural and organizational barriers to digital adoption may be as important as the technologies themselves.

The ISM results indicate that causal conditions, the core phenomenon, and intervening conditions form the foundational level of the model. This suggests that the initial drivers of change and the system's enabling or constraining conditions must be addressed before strategies can become effective. Strategies such as digitalization, predictive analytics, supplier intelligence, and early-warning systems are located at the intermediate level because they translate structural pressures into practical responses. The consequences, including agility, transparency, export development, and sustainable competitive advantage, depend on the implementation of these strategies. MICMAC analysis further shows that most variables are linkage variables. This is important because linkage variables are unstable and strategically sensitive: changes in one dimension can create feedback effects across the system. For managers and policymakers in the carpet industry, this means that isolated interventions are unlikely to be sufficient. Improving resilience requires coordinated action across policy support, digital infrastructure, data quality, managerial readiness, supplier evaluation, and inter-organizational collaboration.

The findings have practical implications. Industry policymakers should prioritize integrated data infrastructure, shared digital platforms, and targeted support for small producers. Carpet producers and exporters should invest in predictive demand analysis, digital traceability, supplier monitoring, and scenario planning. Training programs are also essential because AI adoption depends on human capabilities and trust in data-driven decision-making. Finally, the model shows that digital transformation should not undermine the cultural authenticity of Iranian carpets; rather, smart technologies should be used to protect and communicate authenticity in global digital markets. Several limitations should be acknowledged. First, the data were collected through expert interviews, and the findings reflect the judgments of a specialized group of participants. Future studies may validate the model using survey data from a larger sample of producers, exporters, suppliers, and policymakers. Second, the study focused on the Iranian carpet industry; comparative studies across traditional and cultural industries could clarify the transferability of the model. Third, the ISM and MICMAC analyses are based on expert judgment and should be complemented by quantitative structural modeling in future research. Future studies may also test the role of specific technologies, such as blockchain, IoT-enabled traceability, machine-learning demand forecasting, and digital export platforms.

5. Conclusion

This study explained and structured a localized model of AI-enabled smart supply chain resilience for the carpet industry in the face of global market turbulence. Using grounded theory, the study identified six main dimensions: causal conditions, the core phenomenon, contextual conditions, intervening conditions, strategies, and consequences. Using ISM, the study determined a three-level hierarchy among these dimensions, and MICMAC analysis showed that most variables operate as linkage variables with high driving power and medium dependence. Overall, the findings suggest that the carpet industry can improve its resilience and competitiveness through a coordinated transition toward digital, data-driven, and AI-supported supply chain management.

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Authors' Contributions

All authors equally contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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