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ORIGINAL RESEARCH

Supply Chain Risk Management, Interpretive Structural Modeling (ISM), Resilience, Paper Industry

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Abstract

This study addresses a critical gap in supply chain risk management (SCRM) literature by developing a context-sensitive, hierarchical risk model for the paper and cardboard industry in Isfahan Province, Iran a sector operating under international economic sanctions, resource scarcity, and infrastructural constraints that render generic frameworks inadequate. A sequential exploratory mixed-methods design was employed. In the qualitative phase, semi-structured interviews were conducted with 14 purposively selected industry experts possessing minimum ten years of experience in supply chain, production, logistics, and risk management roles. Thematic analysis, following Braun and Clarke's six-phase framework supported by MAXQDA software, identified eight primary risk categories. In the quantitative-analytical phase, Interpretive Structural Modeling (ISM) established contextual relationships among these risks through dual-validation involving expert consensus and theoretical grounding. The resulting Structural Self-Interaction Matrix was converted into a reachability matrix, and iterative level partitioning generated a five-level hierarchical structure. The eight risk categories identified were: External, Strategic, Supplier, Information Technology (IT), Operational, Logistics, Human Resources (HR), and Market risks. ISM analysis positioned External risks (Level V) and Strategic risks (Level IV) as fundamental drivers with highest driving power and lowest dependence. Supplier and IT risks (Level III) functioned as critical enabling factors, Operational risks (Level II) as mediating variables, and Logistics, HR, and Market risks (Level I) as dependent outcomes visible symptoms of higher-level failures. MICMAC analysis corroborated this structure, revealing an intensely interconnected risk system. The model provides managers a diagnostic tool for prioritizing interventions based on causal influence, advocating proactive root-cause resilience through strategic flexibility, supplier diversification, digital infrastructure, and decentralized decision-making. For policymakers, findings underscore macroeconomic stabilization, public infrastructure investment, and sector-specific support mechanisms. This study contributes a contextualized, hierarchical SCRM framework for Iran's paper industry, providing a structured validation of risk propagation dynamics under economic sanctions and resource scarcity. While circular economy and lean principles informed the research context, the final model focuses on eight empirically derived risk categories, offering a practical diagnostic tool for managers and policymakers.

Keywords: Supply Chain Risk Management; Interpretive Structural Modeling (ISM); Thematic Analysis; Resilience; Paper Industry; Iran; Economic Sanctions; Mixed-Methods Research

1. Introduction

The global industrial landscape is undergoing a profound transformation, increasingly characterized by volatility, uncertainty, complexity, and ambiguity (VUCA). Within this challenging environment, supply chain management (SCM) has evolved from a supportive operational function into a critical strategic imperative for achieving competitive advantage and ensuring long-term organizational sustainability. The contemporary supply chain is no longer a linear sequence of procurement, production, and distribution but a dynamic, interconnected network whose resilience, agility, and efficiency determine a firm's capacity to navigate disruptions, meet evolving consumer demands, and adhere to escalating environmental and social governance standards. The neglect of the risk management domain in the past led to the bankruptcy of many large companies and caused severe damage to economies; consequently, risk management was introduced and has now become a hallmark of sound management [1]. Gradually, from the mid-twentieth century onwards, risk management gained the attention of business managers and regulatory bodies in developed countries; however, the world of management underwent a monumental transformation with the onset of the global financial crisis. During that crisis, major financial institutions were pushed to the brink of bankruptcy, and many banks and institutions were compelled to receive financial bailouts from governments. In the aftermath of the financial crisis, legislators and regulators mandated that financial institutions increase their capital and liquidity reserves, enhance transparency, constrain their risk appetite, and implement more stringent internal controls. Despite this success, many organizations still seek practical counsel regarding the implementation of risk management. The risk management process involves the definition of broad stages that are adaptable to various specialized fields. Therefore, the prerequisites for employing risk management encompass a wide spectrum of disciplines.

Business risk management is an effective approach to managing enterprise-wide risks that is gaining the attention of modern corporate leaders. Fundamental elements for survival in this dynamic modern economy include embracing business in light of market changes and capitalizing on prevailing opportunities, all while understanding that every choice from operational to strategic is accompanied by various types of risk. In the modern business world, enterprise risk management holds appeal as an effective risk management methodology, aiming to enhance long-term organizational resilience by creating and protecting value [2]. Firms that adopt enterprise risk management witness a reduction in their stock price volatility. This implies that enterprise risk management has the capacity to generate stability in profitability and sustain it [3].

A wide spectrum of risks present within the supply chain exert adverse effects on its performance; consequently, organizations must employ appropriate mitigation strategies to overcome these supply chain risks. Supply chain risk management constitutes a pivotal domain aimed at developing methodologies for identifying, assessing, analyzing, and mitigating risks within the supply chain. Researchers posit that factors such as globalization, increased outsourcing, a reduction in the number of suppliers, and heightened demand for timely product delivery have amplified risk levels, thereby accentuating the critical importance of supply chain risk management. Supply chain risk can be defined as a disruption in the linkages between various members of the supply chain. This disruption can potentially impact the flows of products, materials, and information [4].

A supply chain encompasses all the groups involved, directly or indirectly, in fulfilling a customer's request. The supply chain includes not only the manufacturer and supplier but also transporters, warehouses, retailers, and even the customers themselves. Within each organization, for instance, a manufacturer, the supply chain comprises all functions involved in receiving and fulfilling a customer request. These functions are not limited to but include new product development, marketing, operations, distribution, finance, and customer service [5]. Supply chain risks refer to a set of internal and external disruptions that interrupt the flow of goods and services. Examples of these risks include environmental risks, operational disruptions [6; 7; 8], shifts in customer preferences and needs, risks originating from suppliers [9; 10], and delays in product shipment and delivery [11].

Concerning risk, two primary concerns exist: on one hand, the issue of quantifying risk, and on the other, the issue of protection against risks [12]. Managing the supply chain without considering risk and its consequences within a structured framework and their impact on supply chain performance indicators leads to inefficient outcomes and misaligned processes. Identifying potential risk sources and implementing appropriate strategies to mitigate their detrimental effects through a set of coordinated actions among chain members is defined as supply chain risk management [13]. Like all processes, supply chain risk management involves steps that must be pursued and executed. Numerous researchers have described this process as comprising four stages: identification, assessment, mitigation, and control [14].

Supply chains connect manufacturers and customers, facilitating the exchange of goods, funds, and information [15]. With increasing competition among firms and the expanding complexities of supply chains, the catastrophes resulting from supply chain risks have placed significant pressure on companies [16]. Today, risk management is recognized as a critical factor in decision-making and an inherent component of management. By enhancing information processing and communication capabilities, and by improving decision-making, it reduces losses and costs. Furthermore, by increasing organizational efficiency, it enhances organizational performance [17].

In today's global market, companies increasingly rely on their supply chains to maintain competitiveness. Intense competition has driven firms to succeed by creating more complex supply chains through the development and expansion of their own supply networks [18]. To minimize costs and simultaneously optimize multiple expenses including procurement, production, and distribution costs across the supply chain it is first necessary to confront risks and disruptions within the supply chain [19].

Supply chain risk refers to the probability of occurrence of various events that have negative impacts on a company's supply chain and jeopardize its ability to fulfill its commitments [20]. This risk increases with both the likelihood of these events occurring and the severity of their effects [21]. Risk assessment within the supply chain is also complex, as a risk at a specific point can potentially affect all activities in the business process [22]. The strategic architecture of a resilient supply chain extends beyond internal process optimization to the critical domain of inter-organizational governance, particularly the selection and design of supply contracts. The efficacy of these contractual agreements in aligning incentives, distributing risks, and ensuring performance fidelity across the supply network is a determinant of overall chain robustness. Comprehensive meta-synthesis studies on contract selection have systematically cataloged a multifaceted array of influencing factors, encompassing cost structures, flexibility clauses, information sharing protocols, and quality enforcement mechanisms [23]. Furthermore, the inherent uncertainty characterizing the operational environment of Iranian industries demands that such contractual frameworks be explicitly designed to manage ambiguity and flux. The challenge, therefore, is not merely the identification of critical factors but the development of a robust decision-making model capable of operating with imperfect and dynamic data. Methodological precedents, such as those established in gas supply chain management within Khuzestan province, demonstrate the potent synergy of Multi-Criteria Decision-Making (MCDM) methods integrated with formal uncertainty modeling techniques. These hybrid approaches provide a structured, analytical foundation for evaluating and ranking complex contractual alternatives against often conflicting criteria such as cost containment, supply security, and adaptability to regulatory change under conditions of information scarcity [24].

The theoretical and scientific necessity of this study lies in the fact that many aspects of supply chain risk management remain ambiguous for researchers, and having a comprehensive model in this field can provide significant clarification. From a practical and applied perspective, the issue of supply chain risk management gains greater importance daily. For companies facing sanctions that still wish to remain competitive, this matter must be pursued with heightened sensitivity. Consequently, the results of this study can be highly beneficial for researchers working in this area and related fields such as supply chains, supply chain management, risk, supply chain risk, and supply chain risk management, illuminating new dimensions for their work.

2. Literature Review

Supply chain management (SCM) evolved from a supportive operational function into a critical strategic imperative for achieving competitive advantage and ensuring long-term organizational sustainability [25; 26]. Contemporary supply chains were recognized as dynamic, interconnected networks rather than linear sequences, where resilience, agility, and efficiency determined a firm's capacity to navigate disruptions [27; 28]. The fundamental objective of SCM was to maximize value and optimize performance across the entire network, from suppliers to end customers [5; 29]. However, the increasing volatility, uncertainty, complexity, and ambiguity (VUCA) of the global industrial landscape exposed these networks to a wide spectrum of disruptions, elevating supply chain risk management (SCRM) to a central concern for both academics and practitioners 30; 31].

Supply chain risk was broadly defined as the probability of occurrence of events that had negative impacts on the supply chain and jeopardized its ability to fulfill commitments [12; 21]. These risks originated from a multitude of sources, which researchers categorized into various typologies, including environmental, operational, financial, and strategic risks [32; 33]. The interconnected nature of modern supply chains meant that a disruption at one node, such as a supplier failure or a logistical bottleneck, could propagate rapidly, creating a "ripple effect" throughout the network [27; 34]. This realization prompted a paradigm shift from a traditional, reactive risk management approach towards building proactive supply chain resilience [35; 36]. Resilience referred to the ability of a supply chain to anticipate, prepare for, respond to, and recover from disruptive events to return to its original state or even a more competitive one [13; 37]. Studies demonstrated that resilience was achieved through strategic capabilities such as flexibility, agility, redundancy, and collaboration [38; 39; 40].

The literature identified several macro-trends that amplified supply chain risk. Globalization and lean practices, while driving efficiency, often led to extended and more fragile supply networks with reduced buffers [41; 42]. Furthermore, the emergence of Industry 4.0 technologies presented a dual-edged sword. On one hand, technologies like Big Data Analytics, the Internet of Things (IoT), Blockchain, and Artificial Intelligence (AI) were shown to significantly enhance supply chain visibility, traceability, and risk forecasting capabilities [30; 27; 43]. For instance, big data analytics enabled better demand sensing and risk prediction [44], while blockchain promised greater transparency and security [45]. On the other hand, the increasing digitalization of supply chains introduced new vulnerabilities, such as cybersecurity risks and a dependence on complex, interconnected digital infrastructure [46].

To manage this complex risk landscape, a variety of quantitative and qualitative modeling techniques were employed. Multi-Criteria Decision-Making (MCDM) methods, such as the Analytic Network Process (ANP) and TOPSIS, were widely used for risk assessment and supplier selection, especially when dealing with multiple, conflicting criteria [47; 48]. Interpretive Structural Modeling (ISM) and its fuzzy extensions were particularly valuable for identifying and understanding the complex interrelationships and hierarchical structures among risk factors, distinguishing between driving risks and dependent risks [49; 50]. Moreover, advanced optimization models, including robust and possibilistic programming, were developed to design supply chain networks that could withstand disruptions under uncertainty [51; 52]. The integration of machine learning techniques further enhanced the predictive power of risk assessment models [53].

The paper and cardboard industry presented a quintessential example of a sector with an intrinsically complex and resource-intensive supply chain. Its operations were characterized by a high dependency on volatile raw material bases (wood pulp, recycled fiber), significant energy and water consumption, and substantial environmental footprints [54; 55]. This placed the industry at the nexus of economic necessity and environmental scrutiny, compelling a transition towards circular economy principles and closed-loop material flows [56]). While generic SCRM models were abundant, and studies existed on specific aspects like green supplier selection [57] or resilient sourcing [58], a significant research gap was identified. There was a conspicuous absence of an integrated, holistic SCM model that synergistically wove together resilience to economic shocks, adherence to circular economy principles, and operational leanness, specifically tailored to the unique, concurrent pressures faced by resource-based industries in emerging economies operating under duress, such as those in Iran. The Iranian context, particularly for industries in Isfahan Province, was exacerbated by distinct constraints including international economic sanctions, hyper-inflation, foreign currency fluctuations, water scarcity, and underdeveloped reverse logistics infrastructure [59; 60; 61]. Therefore, this research sought to address this critical gap by designing and validating a contextualized supply chain risk management model for the paper and cardboard industry in Isfahan Province. The model is grounded in resilience thinking, while the contextual challenges of circular material flows and lean operations are acknowledged as important background factors that shape the risk landscape but are not separately operationalized as risk categories.

2.1. Supply Chain Risk Management in the Paper and Cardboard Industry

The paper and cardboard industry constitutes a globally significant sector characterized by complex, resource-intensive supply chains with distinct vulnerability profiles. Unlike many manufacturing industries, paper production involves heavy dependence on continuous raw material flows (wood fiber, recycled paper), substantial energy and water consumption, and significant environmental compliance requirements, creating a unique risk landscape that demands industry-specific investigation [62, 63].

Recent international research has increasingly focused on supply chain disruptions in this sector. In European contexts, studies have identified raw material price volatility and supply continuity as primary concerns, particularly as global recycling markets fluctuate and virgin fiber sources face increasing regulatory pressure [64, 65]. The Nordic paper industry, traditionally reliant on sustainable forest management, has experienced growing supply chain risks from climate-induced changes in forest growth patterns and harvesting conditions, demonstrating how environmental factors directly impact material availability [66].

In North America, research has emphasized logistics and transportation risks, given the industry's reliance on rail and maritime freight for both inbound raw materials and outbound finished products. Infrastructure aging, capacity constraints, and fuel price volatility have been identified as critical risk factors affecting just-in-time delivery capabilities and inventory carrying costs [67, 68]. Additionally, studies have examined the vulnerability of North American paper mills to energy price shocks, given that energy constitutes up to 20-30% of total production costs in the sector [69].

Asian paper industries, particularly in China and India, face distinct risk profiles characterized by rapid demand growth, import dependence for virgin fiber, and environmental regulatory pressures. Research on Chinese paper supply chains has highlighted risks associated with cross-border material sourcing, quality control in recycled fiber imports, and compliance with increasingly stringent emissions standards [70, 71]. Indian studies have emphasized infrastructure bottlenecks, fragmented supplier bases, and water scarcity as critical constraints affecting supply chain performance [72].

The circular economy transition has introduced both opportunities and novel risks for the paper industry. While increased recycling rates reduce dependence on virgin fiber, they create new vulnerabilities related to recycled material quality, collection system reliability, and contamination management [73, 74]. Research demonstrates that circular supply chains require fundamentally different risk management approaches compared to linear models, with particular attention to reverse logistics infrastructure and quality assurance in secondary material streams [75].

In emerging economies and sanction-affected contexts, the paper industry faces compounded vulnerabilities. Studies examining Middle Eastern and North African paper industries have identified currency volatility, trade restrictions, and energy subsidies as macro-level factors that fundamentally reshape supply chain risk profiles [76, 77]. These contexts demonstrate that generic SCRM frameworks, developed primarily in stable Western industrial settings, fail to capture the systemic constraints operating in politically and economically volatile environments.

Despite growing international attention to paper industry supply chains, a significant research gap persists: the absence of integrated, hierarchical risk models that simultaneously address operational efficiency (lean principles), sustainable resource management (circular economy), and adaptive capacity (resilience) under conditions of extreme external constraint. This gap is particularly acute in sanction-affected economies where macro-level institutional factors interact with industry-specific vulnerabilities in ways not addressed by existing literature.

3. Methodology

This study employs a mixed-methods approach to design a supply chain risk management model for the paper and cardboard industry in Isfahan province. The research process is executed in two sequential Stages: a qualitative phase followed by a quantitative analytical phase. The qualitative phase aims to identify and conceptualize the risk components, while the subsequent phase utilizes an interpretive structural modeling approach to establish the relationships and hierarchical structure among these identified components.

3.1. Phase One: Qualitative Data Collection and Analysis via Thematic Analysis

The primary objective of the qualitative phase was to discover the constituent components and conceptual constructs of risk management within the supply chain of the paper and cardboard industry. To achieve this, semi-structured interviews were conducted with 14 experts active in the supply chain, production, logistics, and risk management sectors of the paper and cardboard industry in Isfahan province.

Participants were selected using a combination of purposive and snowball sampling techniques. The sampling process began with the identification of initial “seed” experts through professional networks, industry association directories, and participation records in paper industry conferences and workshops in Isfahan Province. Five initial experts were purposively selected based on meeting all of the following inclusion criteria: (1) minimum 10 years of professional experience in the paper and cardboard industry; (2) current or recent employment (within the last 5 years) in paper or cardboard manufacturing firms operating in Isfahan Province; (3) position at managerial or senior expert level in functions directly related to supply chain, production, logistics, procurement, or risk management; (4) direct involvement in strategic or operational decision-making affecting supply chain activities; and (5) willingness to participate in extended interviews and subsequent validation rounds.

These initial participants were then asked to nominate other qualified experts from their professional networks who met the same criteria (snowball sampling). This process continued iteratively until theoretical saturation was reached the point at which subsequent interviews yielded no new concepts, themes, or risk categories. Saturation was assessed using code frequency over time: after the 12th interview, no new codes appeared; interviews 13 and 14 confirmed existing codes only. Therefore, saturation was achieved after 14 interviews, which is consistent with methodological guidelines for qualitative research in supply chain management.

All participants held positions ranging from senior managers to directors and technical experts, ensuring representation across critical functions including procurement, production planning, logistics, quality assurance, maintenance, and general management. Table 1 presents the complete demographic profile of the expert panel.

Table 1. Demographic Profile of Expert Participants

Expert Code	Position/Role	Years of Experience	Education	Area of Expertise	Age Range	Gender
E1	Supply Chain Director	22	M.Sc. Industrial Management	Procurement, Logistics	45-50	Male
E2	Production Manager	18	B.Sc. Mechanical Engineering	Production Planning	40-45	Male

E3	Logistics Supervisor	15	B.Sc. Industrial Engineering	Transportation, Warehousing	35-40	Male
E4	Quality Assurance Manager	20	M.Sc. Chemical Engineering	Quality Control, Compliance	45-50	Female
E5	Procurement Specialist	12	B.Sc. Business Administration	Supplier Management	35-40	Male
E6	Plant Manager	25	M.Sc. Industrial Engineering	Operations Management	50-55	Male
E7	Maintenance Head	19	B.Sc. Mechanical Engineering	Equipment Reliability	40-45	Male
E8	Commercial Director	23	MBA	Sales, Market Analysis	45-50	Male
E9	Risk Management Officer	14	M.Sc. Risk Management	Risk Assessment	35-40	Female
E10	Production Supervisor	16	B.Sc. Industrial Technology	Production Operations	40-45	Male
E11	Warehouse Manager	13	B.Sc. Logistics Management	Inventory Management	35-40	Male
E12	Strategic Planning Manager	21	M.Sc. Strategic Management	Business Strategy	45-50	Male
E13	HR & Training Manager	17	M.Sc. Human Resources	Workforce Development	40-45	Female
E14	Senior Operations Advisor	28	Ph.D. Industrial Engineering	Process Optimization	55-60	Male

Source: Research findings

Data Analysis Procedure

Data analysis in this phase was conducted using the six-phase thematic analysis method proposed by Braun and Clarke [62]. This systematic process was facilitated by the use of MaxQDA software to organize, structure, and meticulously analyze the data obtained from the interviews. The six steps are as follows:

Step 1. *Familiarizing with the Data*

This initial step forms the foundation for all subsequent analysis, with the goal of developing a deep and comprehensive understanding of the content of the collected qualitative data. The researcher immersed themselves in the data through repeated and careful reading of the interview transcripts, textual review, and persistent engagement with the text. This process allowed the researcher to place themselves within the lived experience of the participants and become acquainted with the initial themes, signs, and meaningful indicators within the interviews. No formal coding was conducted at this stage; the focus was solely on grasping the overall implicit and explicit meanings within the data. Notes were taken regarding potential patterns and key ideas for use in later stages of coding and category formation. This engagement with the data gradually developed the researcher's theoretical sensitivity towards the research topic, preparing them for the next step.

Step 2. *Generating Initial Codes*

The researcher reviewed each interview line-by-line, assigning descriptive codes to meaningful segments. To reduce individual bias, two researchers independently coded the first five interviews using the same code list. Inter-coder agreement was calculated using Cohen’s kappa, yielding κ = 0.84 (substantial agreement). Disagreements were discussed and the codebook refined before coding the remaining nine interviews. The final codebook contained 87 unique codes. Table 2 presents examples of interview segments and their corresponding initial codes.

Table 2. Examples of Interview Segments and Initial Codes

Interview Page	Interview Segment (Text)	Initial Code
Senior Manager	"...We face a fundamental problem in the supply of raw materials. Dependence on specific suppliers and price fluctuations constantly challenge us."	Dependence on specific suppliers
Middle Manager	"The lack of a precise and digital warehouse management system is our main issue. Sometimes the supplier arrives, but because the goods entry isn't recorded in the system, we make mistakes in consumption prioritization."	Lack of sufficient digital infrastructure
Technical Expert	"The lack of coordination between the production and warehouse units causes many disruptions. The production schedule is not aligned with inventory levels."	Incoordination between production and warehouse units
Logistics Expert	"Fluctuations in fuel prices and traffic constraints on main routes directly cause delays in transporting our primary materials."	Delay in transporting primary materials
Human Resources Manager	"The constant turnover of specialized personnel and their demotivation due to salaries not keeping up with inflation has become a serious risk for us."	Demotivation and employee turnover

Step 3*. Searching for Themes*
The 87 codes were examined for semantic connections, repetitive patterns, and conceptual overlaps. Using MaxQDA, codes were grouped into larger conceptual categories, resulting in 23 preliminary themes.

Step 4*. Reviewing and Refining Themes*
The 23 preliminary themes were critically reviewed for coherence, overlap, and support from the data. Some themes were merged (e.g., "energy supply instability" and "water/electricity shortages" were combined into "External Risks"), others were split, and a few with weak support were removed. This process produced a refined set of 11 themes.

Step 5*. Defining and Naming Themes*
A concrete worked example demonstrates the iterative aggregation process. Two initial codes from Table 2 –"Dependence on specific suppliers" (from a senior manager) and "Delay in transporting primary materials" (from a logistics expert) were not directly grouped together. In Step 3, they were placed into two different preliminary sub-themes: "Supplier dependency" and "Transportation bottlenecks", respectively. In Step 4, "Supplier dependency" was merged with three related codes ("supplier's inability to supply on time", "receipt of low-quality materials", "delay in supplier delivery") to form a broader sub-theme called "Supplier-side failures". Meanwhile, "Transportation bottlenecks" was combined with "lack of alternative routes" and "fleet inefficiency" into a sub-theme "Logistics failures". In Step 5, after reviewing thematic coherence, "Supplier-side failures" became the main category Supplier Risks, and "Logistics failures" became part of Logistics and Transportation Risks (see Table 3). Thus, no single code directly became a final category; each passed through an iterative process of merging, splitting, and relabeling, involving multiple rounds of team discussion. A similar process was applied to all other codes, resulting in the final eight categories shown in Table 3.

Step 6. *Producing the Report and Conceptual Network*
The final thematic structure was extracted using MaxQDA and depicted as a conceptual model. A comprehensive table (Table 3) lists all main categories and their constituent indicators.
The thematic analysis culminated in the identification of eight primary risk categories essential to the supply chain of the paper and cardboard industry, as shown in Table 3.

Table 3. Extracted Main Components and their Indicators

Main Category	Indicators (Sub-codes)
Supplier Risks	Lack of effective communication with suppliers -Concentrated sourcing on a limited number of suppliers (Dependency Risk) -Supplier's inability to supply on time in critical conditions- Receipt of raw materials with low quality -Delay in supplier delivery of raw materials
Operational and Process Risks	In coordination between production and warehouse units -Lack of continuous quality control- Sudden stoppages in production lines- Weakness in production planning and scheduling -Human error in order registration
Information Technology Risks	Lack of sufficient digital infrastructure for supply chain support -Security threats such as cyber-attacks on supply chain data- Weakness in tracking order status- Disconnection between organizational units on the technology platform -Disruption in ERP systems
Logistics and Transportation Risks	Lack of suitable conditions in logistical infrastructure-Lack of alternative routes during main route blockage-Shortage or inefficiency of transportation fleet-Damage to materials during transport-Delay in transporting raw materials

Human Resource Risks	Demotivation and employee turnover due to salaries lagging behind inflation-Frequent turnover of human resources-High dependency on key individuals-Lack of training for employees in crisis conditions-Shortage of specialized personnel in the supply chain domain
Market and Demand Risks	Weakness in forecasting future demand-Entry of competing products into the market-Change in consumer tastes-Sudden increase in demand without supply readiness-Sudden decrease in customer order volume
External Factors Risks	Instability in the supply of critical energy resources (electricity, water, gas)-Environmental restrictions- Political or social instability-Sudden changes in regulations-Economic sanctions-Fluctuation in foreign exchange rates
Strategic and Structural Risks	Neglect of supply chain resilience in structural design-Concentration of decision-making at the senior management level-Incoordination between strategic objectives and executive operations-Weakness in participatory decision-making-Lack of alternative scenarios in the face of supply chain disruptions

3.2. Development of the Structural Self-Interaction Matrix (SSIM)

The Structural Self-Interaction Matrix (SSIM) was constructed through a formal group judgment process involving the same 14 experts who participated in the interviews. After the thematic analysis was completed, a two-round expert panel was convened (virtually) to determine the contextual relationships among the eight risk factors.

Round 1(Individual evaluation): Each expert received a questionnaire listing all 28 pairwise combinations of the eight factors. For each pair (i, j), they were asked to choose one of the four ISM relationship symbols:

- **V** : factor i influences factor j
- **A** : factor j influences factor i
- **X** : mutual influence (i and j influence each other)
- **O**: no direct influence

Round 2 (Consensus discussion): The aggregated results were shared with the panel. Where agreement exceeded 80% after the first round, the majority decision was accepted. Where disagreement was higher, a facilitated discussion was held, followed by a second vote. The final relationship was decided by simple majority (≥50%). The complete set of responses and meeting minutes are available from the corresponding author.

The resulting SSIM is summarized in Table 4. The conversion from the SSIM (V/A/X/O) to a binary reachability matrix followed standard ISM rules:

$$V \rightarrow (i,j)=1,(j,i)=0;\ A \rightarrow (i,j)=0,\ (j,i)=1;\ X \rightarrow (i,j)=1,(j,i)=1;\ O \rightarrow (i,j)=0,(j,i)=0.$$

Table 4. Structural Self-Interaction Matrix (SSIM) – Pairwise Relationships

Factor pair (i → j)	Relationship	Symbol
External → Strategic	External influences Strategic	V
External → Suppliers	External influences Suppliers	V
External → IT	External influences IT	V
External → Operations	External influences Operations	V
External → Logistics	External influences Logistics	V
External → HR	External influences HR	V
External → Market	External influences Market	V
Strategic → Suppliers	Strategic influences Suppliers	V
Strategic → IT	Strategic influences IT	V
Strategic → Operations	Strategic influences Operations	V
Strategic → Logistics	Strategic influences Logistics	V
Strategic → HR	Strategic influences HR	V
Strategic → Market	Strategic influences Market	V
Strategic → External	External influences Strategic (rev.)	A
Suppliers → Operations	Suppliers influences Operations	V
Suppliers → Logistics	Suppliers influences Logistics	V
Suppliers → HR	Suppliers influences HR	V
Suppliers → Market	Suppliers influences Market	V
Suppliers → IT	(No direct influence)	O
Suppliers → External	External influences Suppliers	A
Suppliers → Strategic	Strategic influences Suppliers	A
IT → Operations	IT influences Operations	V
IT → Logistics	IT influences Logistics	V
IT → HR	IT influences HR	V
IT → Market	IT influences Market	V
IT → External	External influences IT	A
IT → Strategic	Strategic influences IT	A
IT → Suppliers	(No direct influence)	O
Operations → HR	Operations influences HR	V
Operations → Market	Operations influences Market	V
Operations → Logistics	(No direct influence)	O
Operations → External	External influences Operations	A
Operations → Strategic	Strategic influences Operations	A
Operations → Suppliers	Suppliers influences Operations	A
Operations → IT	IT influences Operations	A
Logistics → (any other)	Logistics influences none (except itself)	O
HR → (any other)	HR influences none (except itself)	O
Market → (any other)	Market influences none (except itself)	O

Note: For brevity, only non-trivial pairs are listed. The full 28-pair matrix was used in the expert panel. Relationships marked **V** mean the row factor influences the column factor; **A** means the opposite direction; **X** (mutual) does not occur; **O** means no direct influence.

3.3. Phase Two: Interpretive Structural Modeling (ISM) Analysis

Following the identification of the eight core risk categories through thematic analysis, the research proceeded to the quantitative-analytical phase using Interpretive Structural Modeling (ISM). The

objective of this phase was to determine the hierarchical structure of these factors, their influential relationships, and their driving power and dependence, thereby identifying key factors and critical levels in managing supply chain resilience.
The process began with the development of a Structural Self-Interaction Matrix (SSIM) based on qualitative relationships between the factors, derived from supply chain and resilience theory and expert opinion. This SSIM was then converted into a binary (0/1) Reachability Matrix, where a value of 1 indicates a direct influence of the row factor on the column factor. The final Reachability Matrix is presented in Table 5.

Table 5. Final Reachability Matrix (0 and 1)

Factor	External	Strategic	Suppliers	IT	Operations	Logistics	HR	Market
External	1	1	1	1	1	1	1	1
Strategic	0	1	1	1	1	1	1	1
Suppliers	0	0	1	0	1	1	1	1
IT	0	0	0	1	1	1	1	1
Operations	0	0	0	0	1	0	1	1
Logistics	0	0	0	0	0	1	0	0
HR	0	0	0	0	0	0	1	0
Market	0	0	0	0	0	0	0	1

Subsequently, the driving power (influence) and dependence for each factor were calculated based on the sum of the row and column values of the Reachability Matrix, respectively. The results are shown in Table 6.

Table 6. Driving Power and Dependence of Factors

Factor	Driving Power (Influence)	Dependence	Level
External	8	1	5
Strategic	7	2	4
Suppliers	5	3	3
IT	5	3	3
Operations	3	5	2
Logistics	1	5	1
HR	1	6	1
Market	1	6	1

Using a standard ISM level partitioning algorithm, the factors were categorized into a five-level hierarchical structure:

1. Level 1 (Lowest): Logistics, Human Resources (HR), Market. These factors have the highest dependence and lowest driving power, representing the foundational elements most influenced by other factors.
2. Level 2: Operations. This factor has medium driving power and relatively high dependence, playing an intermediary role between lower and higher-level factors.
3. Level 3: Suppliers, Information Technology (IT). These factors have high driving power and medium dependence, acting as important drivers of the system.
4. Level 4: Strategic. This factor has very high driving power and low dependence, representing a strategic factor that influences many other factors.
5. Level 5 (Highest): External. This factor possesses the highest driving power and the lowest dependence, indicating that external environmental factors have the greatest influence on the system and are the least affected by others.

This ISM analysis provides a clear understanding of the interrelationships and hierarchy among the supply chain risk factors, establishing a solid foundation for proposing managerial insights and developing effective risk mitigation strategies within the studied industry.

4. Discussion

This section interprets the findings of the ISM analysis by situating the identified hierarchical structure of supply chain risks within established theoretical frameworks and by comparing the results with evidence from similar industrial and national contexts. Rather than restating the results, the discussion focuses on explaining why certain risks emerge as key drivers and how the proposed structure contributes to supply chain risk management and resilience theory.

4.1 Theoretical Interpretation of ISM Levels

The ISM model developed in this study reveals a multi-level structure of supply chain risks in the Iranian paper industry, in which lower-level risks act as fundamental drivers and higher-level risks represent more visible operational outcomes. This hierarchical configuration is theoretically consistent with the core assumptions of systems theory, which conceptualizes supply chains as interdependent systems where disruptions propagate from structural causes to operational consequences.

At the lower levels of the ISM hierarchy, risks with strong driving power but low dependence emerge. These risks are largely external and structural in nature, shaping the operating environment of firms rather than originating from internal managerial decisions. In contrast, higher-level risks exhibit high dependence and lower driving power, indicating that they are symptoms rather than root causes. This distinction reinforces the analytical value of ISM by enabling managers and policymakers to distinguish between causal risks and resultant vulnerabilities.

4.2 External Risks and Institutional Theory

One of the most significant findings of this study is the dominant role of external risks at the foundational levels of the ISM model. This result can be theoretically explained through institutional theory, which emphasizes the influence of regulatory, political, and macro-economic environments on organizational behavior and performance.

In the context of the Iranian paper industry, factors such as sanctions, regulatory instability, and constraints on international trade exert a pervasive influence on supply chain configurations. These institutional pressures limit firms' access to global suppliers, restrict financial transactions, and increase uncertainty in procurement and logistics decisions. As a result, internal risk mitigation strategies often remain reactive and constrained, since firms have limited control over the institutional environment in which they operate.

The prominence of external risks in the ISM model suggests that supply chain vulnerability in this industry is not merely a consequence of inefficient management practices, but rather a systemic outcome shaped by broader institutional conditions. This finding highlights the necessity of incorporating macro-level considerations into supply chain risk analysis, particularly in economies facing persistent external constraints.

4.3 Comparison with International Evidence

The results of this study are broadly consistent with findings from research conducted in other countries and industries characterized by political instability, economic sanctions, or limited integration into global markets. Studies on manufacturing sectors in countries such as Russia, Venezuela, and certain African economies similarly report that external and institutional risks play a central role in shaping supply chain resilience.

However, a notable difference lies in the degree of flexibility available to firms. In relatively open economies, firms often respond to external shocks through supplier diversification, near-shoring, or financial hedging. In contrast, firms in the Iranian paper industry face structural limitations that significantly reduce these strategic options. Consequently, intermediate-level risks such as supplier dependency and logistics bottlenecks become more persistent and difficult to mitigate.

This comparison suggests that while the hierarchical logic of supply chain risk is globally relevant, the relative importance of specific risk categories is highly context-dependent. The ISM structure identified in this study therefore reflects not only industry characteristics but also the unique geopolitical and economic conditions affecting Iran.

4.4 Implications for Supply Chain Resilience Theory

From a theoretical perspective, the findings of this study contribute to the literature on supply chain resilience by reinforcing the distinction between resilience capabilities and resilience constraints. Much of the existing literature emphasizes organizational flexibility, redundancy, and agility as key resilience mechanisms. While these capabilities remain relevant, the ISM results demonstrate that their effectiveness is contingent upon the stability of underlying institutional and structural conditions.

The hierarchical risk structure suggests that resilience cannot be fully achieved through firm-level interventions alone when foundational risks originate outside the control of individual organizations. This insight supports a more multi-level conceptualization of resilience, in which firm-level capabilities must be complemented by policy-level and industry-level support mechanisms.

By explicitly linking ISM levels to established theories of risk and resilience, this study advances a more integrated understanding of supply chain vulnerability in constrained environments. It also demonstrates the value of ISM as a theory-building tool, capable of revealing causal structures that remain obscured in purely quantitative or descriptive analyses.

5. Conclusion

This study aimed to identify and structurally analyze supply chain risks in the Iranian paper industry by employing a qualitative approach combined with Interpretive Structural Modeling (ISM). By integrating expert interviews with a systematic modeling process, the research moved beyond simple risk listing and revealed the hierarchical and causal structure underlying supply chain vulnerabilities in this industry.

The ISM results demonstrate that supply chain risks are not independent or equally influential, but rather form a layered system in which external and institutional risks act as fundamental drivers, while operational risks emerge as dependent outcomes.

This finding underscores the importance of addressing root causes rather than focusing exclusively on surface-level disruptions. In environments characterized by regulatory constraints, sanctions, and limited access to global markets, such as Iran, firm-level risk management strategies alone are insufficient to ensure supply chain stability.

By linking the ISM hierarchy to established theories of supply chain risk management and resilience, this study contributes to the literature in several ways. First, it provides empirical support for a multi-level understanding of resilience, where organizational capabilities are constrained and shaped by broader institutional conditions. Second, it highlights the role of contextual factors in determining the relative importance of different risk categories, reinforcing the argument that resilience strategies must be tailored to specific economic and geopolitical environments.

From a practical perspective, the findings suggest that effective risk mitigation in the paper industry requires a prioritization framework based on causal influence rather than immediate visibility. Managers can use the ISM model to identify leverage points within the supply chain and to allocate resources more strategically. At the same time, policymakers and industry stakeholders play a critical role in addressing foundational risks that lie beyond the control of individual firms.

Despite its contributions, this study is subject to certain limitations. The qualitative nature of the research and the focus on a single industry and national context may limit the generalizability of the findings. Future research could extend this work by applying hybrid methods, such as integrating ISM with quantitative techniques, or by conducting comparative studies across industries or countries facing different institutional conditions.

In conclusion, this research demonstrates that understanding supply chain risk in constrained environments requires both structural analysis and theoretical grounding. By uncovering the causal architecture of risks in the Iranian paper industry, the study provides a robust analytical foundation for developing more effective, context-sensitive resilience strategies and offers a methodological template for similar investigations in other industries and regions.

4.5. Acknowledged limitations regarding circular economy and lean principles

The reviewer correctly noted that the final eight risk categories do not explicitly include distinct factors such as “reverse logistics inefficiency” or “waste in production processes”. While the interview data contained references to recycling quality issues and production waste, these did not emerge as standalone themes with sufficient frequency and causal distinctness to justify separate ISM factors. Instead, they were subsumed under “External Factors Risks” (e.g., environmental restrictions affecting recycled material imports) and “Operational and Process Risks” (e.g., sudden stoppages, planning weaknesses). Thus, the present model does not claim to fully operationalize circular economy or lean management. Future research could extend this work by specifically designing instruments to capture those dimensions as separate risk categories.

6. Executive and Managerial Implications of the ISM-Based Risk Model

While the proposed ISM framework provides a structural–causal understanding of supply chain risks in the paper and cardboard industry, its practical value ultimately depends on its applicability for managerial decision-making. This section translates the hierarchical risk structure into concrete executive-level actions by proposing targeted intervention strategies aligned with each ISM level. The recommendations are explicitly derived from the causal positioning of risks within the model and are intended to support proactive, root-cause-oriented risk mitigation rather than reactive operational responses.

Level 5: External Risks (Highest Driving Power, Lowest Dependence)

External risks, including economic sanctions, regulatory instability, energy supply disruptions, and currency fluctuations, constitute the most influential drivers in the system. As these risks are largely beyond the direct control of individual firms, managerial interventions should focus on adaptation and buffering strategies rather than elimination.

Executives are advised to:

- ❖ Develop scenario-based contingency plans for energy shortages, regulatory changes, and foreign exchange volatility.
- ❖ Establish institutional monitoring mechanisms to continuously track policy, regulatory, and macroeconomic developments.
- ❖ Strengthen industry-level collaboration through associations or consortia to collectively negotiate energy access, logistics permissions, or regulatory accommodations.
- ❖ Increase the use of local sourcing and substitution strategies to reduce exposure to international sanctions and import constraints.
- ❖ These actions aim to reduce the transmission intensity of external shocks to

lower ISM levels rather than attempting direct control over external factors.

Level 4: Strategic and Structural Risks

Strategic risks occupy a critical position as high-driving internal factors that translate external pressures into organizational vulnerabilities. Weak alignment between strategy and operations, centralized decision-making, and lack of alternative scenarios significantly amplify downstream risks.

- ❖ Recommended executive actions include:
- ❖ Embedding supply chain resilience explicitly into corporate strategy, rather than treating it as an operational concern.
- ❖ Decentralizing decision-making authority to enable faster local responses during disruptions.
- ❖ Designing and periodically updating alternative supply chain configurations (e.g., backup suppliers, alternative logistics routes).
- ❖ Establishing cross-functional risk committees to improve strategic–operational alignment.

Addressing strategic risks enhances the organization's ability to absorb external shocks before they manifest as supplier, operational, or logistics failures.

Level 3: Supplier and Information Technology Risks

Supplier dependency and information technology weaknesses emerge as key mid-level drivers that operationalize higher-level strategic and external constraints. Their position indicates that improvements at this level can significantly reduce cascading failures.

To reduce supplier dependency, managers should:

- ❖ Implement supplier diversification policies, particularly for critical raw materials.
- ❖ Develop long-term relational contracts with performance and flexibility clauses.
- ❖ Support supplier capability development through technical assistance or information sharing.

To mitigate information technology risks, organizations should:

- ❖ Invest in integrated digital platforms (e.g., ERP, inventory tracking systems) that enhance visibility across the supply chain.
- ❖ Strengthen cybersecurity protocols to protect sensitive supply chain data.
- ❖ Ensure interoperability between production, warehouse, procurement, and logistics systems.

These interventions directly reduce uncertainty propagation and improve coordination across supply chain actors.

Level 2: Operational and Process Risks

Operational risks function as transmission mechanisms through which upstream vulnerabilities materialize into tangible disruptions. Weak production planning, coordination failures, and quality issues are therefore symptoms of higher-level deficiencies.

Practical actions include:

- ❖ Enhancing production planning and scheduling systems to better align inventory levels with demand and supply constraints.
- ❖ Establishing standard operating procedures for disruption scenarios, including rapid rescheduling and inventory reallocation.
- ❖ Implementing continuous improvement programs focused on process stability and error reduction.

Improving operational robustness increases the system's capacity to respond effectively once disruptions occur.

Level 1: Logistics, Human Resources, and Market Risks (Highest Dependence)

Risks at this level represent the most visible and immediate consequences of upstream failures. Although they have low driving power, they strongly affect short-term performance and service levels.

Managers should:

- ❖ Improve logistics flexibility by identifying alternative transport routes and backup carriers.
- ❖ Invest in human capital retention and training, particularly for supply chain-critical roles.
- ❖ Strengthen demand forecasting and market intelligence to reduce exposure to sudden demand fluctuations.

While interventions at this level are necessary for operational continuity, the ISM results indicate that isolated actions here will have limited effectiveness unless higher-level risks are simultaneously addressed.

Integrated Use of the Model as a Practical Tool

Taken together, the ISM-based hierarchy can function as a managerial prioritization checklist, guiding executives to allocate resources according to causal impact rather than symptom severity. The model supports:

- ❖ Sequential risk mitigation planning,
- ❖ Identification of leverage points for investment,
- ❖ Continuous monitoring of risk propagation paths.

By operationalizing the structural–causal relationships, the proposed framework bridges the gap between theoretical modeling and executive decision-making, thereby enhancing its practical relevance for firms operating under constrained and volatile environments.

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