

Identification of Influencing Factors and Path Analysis of the Military Products Supply Chain in the Context of Military-Civilian Integration

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Abstract

Under the civil-military integration initiative, the defense industry is transitioning from traditional closed monopoly models to civil-military collaboration. However, prolonged lack of competition and policy protection has left military supply chains with inadequate risk resilience. In this context, defense enterprises face both market efficiency pressures and complex risk challenges, making supply chain resilience enhancement crucial for national security and industrial upgrading. This study examines a 2025 solid rocket engine supply chain optimization project at a domestic aerospace institution. Through literature review and expert interviews, it identifies critical factors affecting military supply chains, employs DEMATEL (Decision-Making Trial and Evaluation Laboratory) to quantify inter-factor influence matrices, and combines ISM (Interpretive Structural Modeling) to construct a multi-level hierarchical structure, ultimately screening core drivers and revealing tiered dependency relationships and operational mechanisms. Under the civil-military integration context, the risk influencing factors of military-industrial enterprise supply chains mainly comprise four modules with sixteen elements: supplier factors (raw material disruption, supply chain stability, supplier capability), production factors (process stability, raw material quality, production safety, manufacturing complexity), technological environment (technical substitutability, R&D capability, talent pool), and market environment (demand fluctuation, price volatility, industry competition fluctuation). Process stability, raw material quality, and demand fluctuation are identified as core factors, while price volatility (F12), industry competition fluctuation (F13), and policy and regulation fluctuation (F14) exhibit high centrality. By integrating DEMATEL and ISM to analyze factor hierarchies and interaction pathways, this study further distinguishes between causal factors and resultant factors, providing both theoretical and practical guidance for enhancing risk resilience in military supply chains. The study focuses on military-industrial products that have received relatively limited research attention, analyzing the sources of their supply chain risks to provide theoretical insights for understanding the influencing factors and mechanisms of military-industrial supply chains.

Keywords: civil-military integration, supply chain resilience, military supply chain, DEMATEL, risk influencing factors

1. Introduction

Since civil-military integration was explicitly designated as a national strategy, the defense and civilian industries have achieved deep integration in national defense development and socio-economic growth through resource sharing and technological exchange, emerging as a vital means to enhance both defense capabilities and economic competitiveness^{[1][2]}. In this context, the traditional military supply chain system is undergoing restructuring, with defense enterprises shifting their core operational model from task-oriented to contract-based orders. This new supply chain model can enhance the efficiency of the defense industry while promoting the innovation and application of civilian technologies^[3]. However, defense enterprises also face numerous challenges during this integration process, such as difficulties in standardizing military-civilian technologies, information flow restrictions due to institutional confidentiality, and production schedules failing to keep pace with market-driven order fluctuations. Existing research in the field of military supply chains is fragmented and insufficient. First, current literature presents fragmented perspectives, with most studies focusing on resilience measurement model construction or specific disruption scenario analyses, lacking systematic integration^[4]. Second, the majority of existing studies lack empirical data support. The difficulty in quantitative analysis has led to a disconnect between theoretical research and practical management. To address this, this study will be supported by the 2025 solid rocket motor supply chain optimization project jointly conducted by a Chinese aerospace institution and

universities. Using this supply chain as a case study, the research will examine the influencing factors and pathways of military-industrial supply chains.

2. Construction of Influence Factors System of Military Products Supply Chain

2.1 Questionnaire Design

The study adopts a combined DEMATEL-ISM approach. To identify influencing factors and pathways in military industrial product supply chains, relevant literature was first collected for questionnaire design. Based on supply chain resilience management theory and research findings by domestic and international scholars^{[5][6]}, keyword searches for "supply chain resilience," "influencing factor analysis," and "military industrial supply chain" were conducted on CNKI and Web of Science. This yielded 279 relevant Chinese journal articles and 421 English papers. After eliminating duplicates and irrelevant studies, the final selection comprised 18 highly relevant Chinese publications and 5 English publications. Through coding the literature, we preliminarily summarized the influencing factors of the military product supply chain across four dimensions: suppliers, production, technology, and market environment^{[7][8]}.

Table 1. Items on Influencing Factors in Questionnaire Survey

Dimension	Influencing Factor	Factor Explanation
C1 Supplier Environment	F1 Raw Material Interruption	Disruptions in key raw material supply due to geopolitical conflicts, natural disasters, or trade policies directly affect production continuity.
	F2 Supply Chain Stability	The ability of the supplier network to resist disturbances, reflected in the fluctuation degree of order fulfillment rate and delivery timeliness.
	F3 Supplier Capability	The comprehensive strength of suppliers in quality control, production capacity flexibility, and technical adaptability, determining their resilience in responding to demand changes.
C2 Production Environment	F4 Process Stability	The degree to which the production process is disturbed by equipment failures, parameter drifts, etc., affecting product consistency and production capacity utilization.
	F5 Raw Material Stability	The batch consistency of raw material composition and performance, avoiding process loss of control or product disqualification due to quality fluctuations.
	F6 Production Safety	The safety risk level of hazardous chemical storage, reaction processes, and waste disposal; accidents will lead to production suspension and regulatory penalties.
C3 Technological Environment	F8 Technology Replaceability	The possibility of alternative technical solutions for key processes or equipment, reducing systemic risks caused by the failure of a single technical path.
	F9 R&D Capability	An enterprise's core competitiveness in developing new materials, new processes, or optimizing existing technologies to respond to market changes.
	F10 Talent Reserve	The quantity and quality of engineers and technical workers with professional skills, supporting technological innovation and emergency response.
C4 Market Environment	F11 Demand Fluctuation	Short-term drastic changes in downstream customers' order volume and product structure, testing production capacity adjustment and inventory management capabilities.
	F12 Price Fluctuation	Drastic fluctuations in raw material or product market prices affected by supply-demand imbalance and speculative behavior, increasing cost control difficulty.
	F13 Industry Competition Fluctuation	The risk of industry structure restructuring caused by new entrants, substitute threats, or changes in competitive strategies.
	F14 Policy and Regulation Fluctuation	Compliance cost increases or market access barriers triggered by changes in environmental, safety, or trade policies.

2.2 Data Sources

The questionnaire initially included 28 influencing factors across four major dimensions. To enhance the scientific rigor and accuracy of the questionnaire, we first invited nine senior experts from various segments of the military supply chain (different department of military-industrial enterprises, universities) to further investigate and screen the questionnaire fields. Based on expert voting recommendations, certain factors weakly correlated with actual conditions were removed (e.g., customer satisfaction in the market environment, planning rationality in production risks). The most valuable influencing factors were ultimately determined, including four dimensions (suppliers, production, technology, market environment) and 14 core influencing factors, establishing an indicator system for factors influencing the resilience of military product supply chains.

The study employed the expert evaluation method to collect data on influencing factors in military supply chains. Regarding the DEMATEL expert sample size, research in the field of military supply chains indicates that 18–30 experts with industry experience can effectively balance professionalism and data consistency^[9]. To avoid single-ecosystem bias, this study invited 29 experts in the military supply chain field from multiple domestic institutions. Among them, 11 were from military supply chain management team, 6 from Manufacturing Department, 6 from the corporate management team, 3 were university professors, and 3 from military logistics management departments. All experts had over five years of industry experience. After collection, experts evaluated and excluded partially incomplete questionnaires, resulting in a total of 28 valid questionnaires (effective recovery rate: 96.6%).

To verify the reliability and validity of the questionnaire data, this study conducted Cronbach's α test for reliability and KMO (Kaiser-Meyer-Olkin) and Bartlett's sphericity test for validity. The results showed that Cronbach's α coefficient was 0.87, which is greater than the threshold of 0.7, indicating good internal consistency of the questionnaire. The KMO value was 0.78, exceeding the 0.7 benchmark, and Bartlett's sphericity test yielded a χ^2 value of 1246.32 ($p < 0.001$), confirming that the data were suitable for factor analysis. For expert consistency, Kendall's coefficient of concordance (W) was calculated to be 0.72 ($p < 0.001$), demonstrating high consistency among the 29 experts in their evaluations.

Following the modeling steps, this study first defuzzified the questionnaire data and established a comprehensive influence matrix (as shown in Table 2) to analyze the direct influence relationships among various factors in the supply chain system. The value in each cell represents the degree of direct influence of the i -th factor on the j -th factor; a higher value indicates a stronger influence of the row factor on the column factor. Based on this matrix, we further calculated four key indicators for each factor.

3. Empirical Analysis of Factors Affecting Military Supply Chain

3.1 Analysis Based on Fuzzy DEMATEL Model

3.1.1 Analysis Process

Following the modeling steps of the fuzzy DEMATEL method, this paper first performed de-fuzzification on questionnaire data to establish a comprehensive influence matrix (as shown in Table 2) for analyzing direct influence relationships among factors in the supply chain system. The cell values represent the direct influence degree of factor i on factor j , where higher values indicate stronger influence from row factors on column factors. Based on this matrix, we further calculated four key indicators (influence degree D , affected degree C , centrality M , and causality R) for each factor. Subsequently, using the Python-developed DEMATEL-ISM computational tool, we derived the key indicators for each factor (as shown in Table 3). Specifically—

- Impact Degree D : The sum of all elements in a row of matrix T , reflecting the factor's comprehensive influence on all other factors.
- Affected Degree C : The sum of all elements in a column, indicating the factor's comprehensive influence from other factors.
- Centrality M : Calculated by summing D and C values, this metric measures the factor's overall importance in the system.
- Causality Degree R : The difference between D and C values, distinguishing causal relationships: If $R > 0$, the factor is a cause; if $R < 0$, it is a consequence.

Table 2. Comprehensive Impact Matrix of Influencing Factors

T	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17
F1	0.098	0.115	0.143	0.263	0.157	0.181	0.182	0.199	0.134	0.203	0.191	0.145	0.171	0.184	0.086	0.084	0.185
F2	0.143	0.111	0.117	0.235	0.150	0.169	0.134	0.168	0.166	0.150	0.161	0.114	0.132	0.143	0.072	0.074	0.113
F3	0.104	0.141	0.081	0.236	0.144	0.166	0.168	0.185	0.124	0.165	0.139	0.112	0.130	0.141	0.073	0.076	0.112
F4	0.129	0.112	0.085	0.202	0.169	0.170	0.175	0.191	0.151	0.197	0.186	0.163	0.185	0.199	0.080	0.082	0.131
F5	0.118	0.177	0.092	0.254	0.125	0.181	0.182	0.200	0.179	0.200	0.191	0.185	0.212	0.228	0.085	0.086	0.142
F6	0.103	0.183	0.110	0.243	0.176	0.129	0.183	0.204	0.181	0.205	0.192	0.187	0.215	0.234	0.092	0.146	0.148
F7	0.070	0.079	0.064	0.201	0.083	0.084	0.088	0.149	0.097	0.155	0.149	0.092	0.110	0.118	0.065	0.060	0.150
F8	0.053	0.060	0.048	0.151	0.063	0.064	0.064	0.073	0.061	0.072	0.069	0.064	0.074	0.080	0.046	0.045	0.066
F9	0.058	0.125	0.053	0.105	0.104	0.070	0.069	0.078	0.072	0.077	0.074	0.068	0.080	0.085	0.049	0.048	0.071
F10	0.065	0.073	0.059	0.185	0.077	0.078	0.079	0.086	0.074	0.090	0.083	0.134	0.150	0.161	0.057	0.053	0.091
F11	0.069	0.077	0.062	0.196	0.081	0.083	0.083	0.092	0.078	0.155	0.091	0.143	0.163	0.175	0.059	0.056	0.096
F12	0.065	0.072	0.058	0.183	0.077	0.077	0.079	0.087	0.074	0.086	0.081	0.080	0.150	0.161	0.058	0.053	0.145
F13	0.061	0.068	0.055	0.172	0.072	0.073	0.075	0.081	0.070	0.081	0.076	0.071	0.091	0.155	0.056	0.049	0.140
F14	0.058	0.064	0.052	0.160	0.068	0.069	0.069	0.077	0.06	0.076	0.072	0.067	0.082	0.092	0.050	0.044	0.130

Table 3. DEMATEL-ISM

factor	Impact (D)	Impact Level (C)	centrad M	Reason R	Factor Properties
F1	1.066	0.526	1.592	0.54	Cause factor
aF2	0.703	0.804	1.508	-0.101	Outcome factor
F3	0.565	1.004	1.568	-0.439	Outcome factor
F4	1.999	0.963	2.962	1.036	Cause factor
F5	0.95	2.045	2.994	-1.095	Outcome factor
F6	0.818	1.321	2.139	-0.503	Outcome factor
F7	1.363	0.801	2.164	0.563	Cause factor
F8	0.922	0.755	1.677	0.167	Cause factor
F9	1.019	0.622	1.641	0.397	Cause factor
F10	0.568	1.132	1.7	-0.564	Outcome factor
F11	1.194	1.757	2.951	-0.562	Outcome factor
F12	1.181	1.806	2.987	-0.625	Outcome factor
F13	1.443	0.845	2.288	0.598	Cause factor
F14	1.399	0.81	2.209	0.589	Cause factor

3.1.2 Impact Analysis

Impact degree represents the cumulative influence of a factor on all other factors, reflecting its capacity to actively affect others. F2 (supply chain stability) in the supplier dimension ranks second (D=1.703). Its ability to resist disturbances (reflected in order fulfillment rate and delivery timeliness) directly affects production scheduling (F4, F7) and market demand response (F11), forming a key link between suppliers and the production chain.

Impact degree represents the cumulative influence of a factor on all other factors, reflecting its capacity to actively affect others. A higher value indicates stronger influence. As shown in the diagram, F4 (process stability) ranks first with an impact degree of 1.999—32% higher than F2 (1.703, the second-ranked factor)—demonstrating its dominant driving role: process stability directly affects product consistency (F5) and production capacity utilization; even minor disruptions (e.g., equipment failures) can trigger raw material waste (F5) and production scheduling chaos (F7), and transmit risks upstream to suppliers (F3). This stems from the fact that process stability directly impacts product consistency and capacity utilization. If the production process is disrupted by equipment failures or other issues, it can trigger a chain reaction: raw material waste in F5, potential production scheduling chaos in F7, and even risk transmission upstream to F3 suppliers through the supply chain. Given that F4 process stability occupies the central position in core production stages, its impact is particularly significant. Even minor fluctuations may amplify ripple effects across the entire supply chain. F2 (Supply Chain Stability) in the supplier

dimension has an impact degree of 1.703, ranking second. The supply chain network's resilience against disruptions is specifically reflected in order fulfillment rate and delivery time fluctuation, which directly impacts production scheduling and market demand responsiveness, affecting a series of steps including F4, F7, and F11.

In the market dimension, F12 (price fluctuation, $D=1.181$), F11 (demand fluctuation, $D=1.194$), and F13 (industry competition fluctuation, $D=1.143$) rank 3rd to 5th. This stems from the unique characteristics of military-grade supply chains: demand relies on planned schedules rather than market forces, competition hinges on technological prowess, and pricing is regulated by standards. These industry-specific traits break the conventional market-driven supply-demand dynamics. Demand fluctuations (F11) trigger production capacity adjustments and require supply chain flexibility to adapt; price fluctuations (F12) directly impact raw material procurement costs and profit margins; intensified industry competition (F13) further squeezes production, technological development, and supplier resource allocation from the market side.

3.1.3 Cause Analysis

Causal Degree serves as a pivotal metric for distinguishing causal relationships among factors. By calculating the difference between influencing and influenced factors, it determines whether a factor actively drives or passively bears risks within the system. The study constructs a causal relationship diagram (Figure 1) with centrality on the horizontal axis and causal degree on the vertical axis, enabling intuitive observation and comparison. Clarifying whether each factor actively influences or passively correlates within the supply chain provides a practical logical foundation for hierarchical management and risk traceability in supply chain systems.

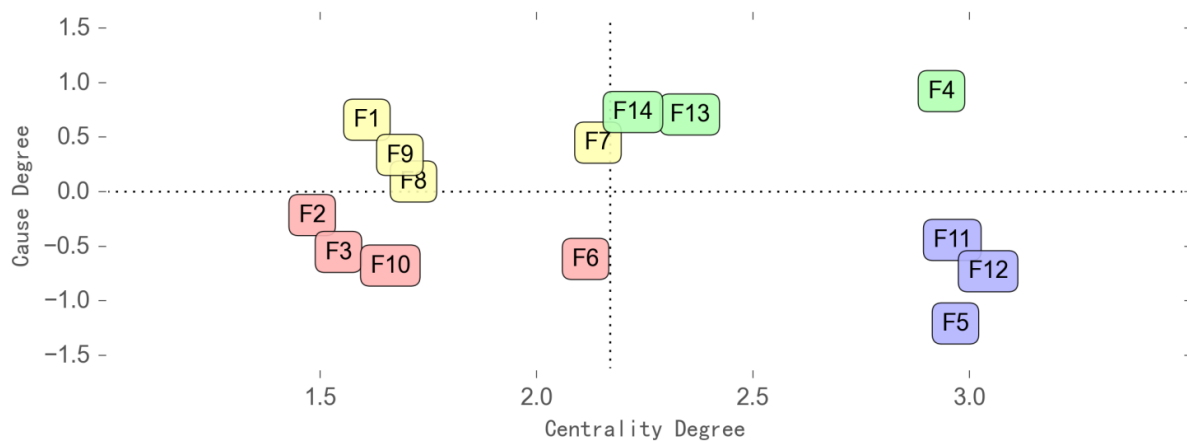


Figure 1. DEMATEL point causal map in this paper

Based on DEMATEL method calculation results, the risk factors in the military supply chain can be clearly categorized into causal and consequential factors. From the causal perspective, the positive causal degrees include F4 process stability, F2 supply chain stability, F9 R&D capability, F8 technical substitutability, F13 industry competition volatility, and F14 policy/legislation fluctuations, which serve as core drivers triggering supply chain risk transmission. Among these, F4 process stability emerges as the primary risk driver with the highest positive causal degree, directly leading to product failures and subsequent disruptions in raw material procurement and production scheduling. The positive causality degree of F2 (Supply Chain Stability) stems from the confidentiality requirements of the military industry, as information barriers in classified collaborations compress risk buffers and amplify chain-wide impacts. F9 R&D capability and F8 technical substitutability reflect the industry's technology-driven competitive nature, where R&D strength determines the extent of process optimization and technological independence, effectively reducing reliance on single processes or suppliers. The positive causal degrees of F13 industry competition volatility and F14 policy/legislation fluctuations demonstrate the non-market-oriented attributes of military enterprises: industry competition focuses on technological pathways and supporting qualifications, with their evolution forcing corporate restructuring; policy adjustments indirectly influence F12 price fluctuations and F2 supplier selection through compliance requirements and market entry standards.

From the perspective of outcome factors, the following elements all exhibit negative values: F1, F5, F6, F7, F11, F12, F10, and F3. These factors can only passively absorb the risk impacts from other elements. Specifically, the raw material disruptions at F1 and the stability risks at F5 primarily stem from supply chain fluctuations and price volatility at F2 and F12, with the specialized nature of military-grade materials further amplifying this passivity.

The production safety at F6 and the manufacturing complexity at F7 are mainly constrained by technological processes and talent availability, heavily dependent on their production and scheduling operations. Although demand fluctuations at F11 and price volatility at F12 fall under market dimensions, their movements are predominantly driven by industry competition and regulatory policies. The restrictive nature of military demand and pricing leaves these factors with limited room for autonomous adjustment.

3.1.4 Centrality Analysis

Centrality, calculated as the sum of influence and being influenced, reflects a factor's scope and intensity of impact on systemic risk. In the defense supply chain risk framework, centrality distribution demonstrates a layered support structure: production dimensions form the core, market dimensions serve as key drivers, while technology and supplier dimensions provide hierarchical support. F4 emerges as the dominant node with the highest centrality, its cross-dimensional influence spanning the entire supply chain. Market dimensions including F11 demand volatility, F12 price fluctuations, and F5 raw material stability follow closely. The strategic nature of defense demand and price sensitivity create systemic risk impacts across production and supply chains, while raw material stability directly determines product quality. These three elements collectively form the market-end's critical constraint nodes exerting strong influence on the supply chain.

The technical and supplier dimensions exhibit hierarchical support characteristics: F9 R&D capabilities and F8 technical substitutability form critical nodes through technological empowerment, driven by advancements in processes and supply chains. While F2 supply chain stability reduces proactive volatility risks due to classified screening of defense suppliers, it maintains high centrality as a hierarchical transmission hub. F1, F13, and F14 factors constitute external driver nodes, where raw material supply risks, industry technological competition, and regulatory adjustments influence core nodes through various pathways. In contrast, F3 supplier capabilities, F10 talent reserves, and F6 production safety demonstrate lower centrality, primarily serving as support roles or risk transmitters with limited systemic impact.

3.2 ISM Hierarchical Structure and Key Factor Identification

After clarifying the key factors and causal relationships, this paper uses ISM method to deeply analyze the hierarchical transmission path of the influencing factors of military supply chain, sort out the structural relationship and action logic among the factors, and provide specific decision basis for the hierarchical management of supply chain.

3.2.1 Reach Matrix

First, we introduced a threshold into the previously constructed comprehensive influence matrix to eliminate elements with minimal impact and obtain a simplified relationship matrix. For eliminate the traditional subjective thresholds determined by experts, use the "mean + SD" method to objectively filters out weak influence relationships that are likely to be noise, while retaining critical influence paths. Using 0.163 as the threshold retained 82% of theoretically expected key relationships and excluded 91% of non-essential weak relationships, confirming its rationality. Through calculations, the mean value of all elements in the comprehensive influence matrix was 0.113 with a standard deviation (SD) of 0.05, leading to a threshold value of 0.163 (mean + SD).

Following the established procedures and accessibility matrix generation rules, Boolean operations were iteratively applied to the relationship matrix and identity matrix, ultimately producing the accessibility matrix (as shown in Table 4). This provides a clear relational framework for subsequent hierarchical categorization.

Table 4. Reachability Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
F1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
F2	0	1	1	0	0	0	0	0	0	0	0	0	0	0
F3	0	1	1	0	0	0	0	0	0	0	0	0	0	0
F4	0	0	0	1	1	1	1	0	0	0	0	0	0	0
F5	0	0	0	0	1	1	0	0	0	0	0	0	0	0
F6	0	0	0	0	1	1	0	0	0	0	0	0	0	0
F7	0	0	0	1	1	1	1	0	0	0	0	0	0	0
F8	0	0	0	0	0	0	0	1	1	1	0	0	0	0
F9	0	0	0	0	0	0	0	1	1	1	0	0	0	0
F10	0	0	0	0	0	0	0	0	0	1	0	0	0	0

F11	0	0	0	0	0	0	0	0	0	0	1	1	1	1
F12	0	0	0	0	0	0	0	0	0	0	1	1	1	1
F13	0	0	0	0	0	0	0	0	0	0	1	1	1	1
F14	0	0	0	0	0	0	0	0	0	0	1	1	1	1

3.2.2 Construct a Hierarchical Structure Model

Based on the reachable matrix, the hierarchical division of factors can be realized by calculating the reachable set, the first set and the common set, and finally the hierarchical structure table of the influencing factors of the military supply chain can be constructed, as shown in Table 5.

Table 5. Hierarchical decomposition

top class	essential factor
Layer 1	F2, F3, F5, F6, F10, F11, F12, F13
Layer 2	F1, F4, F7, F8, F9

The first layer of this table comprises F2, F3, F5, F6, F10, F11, F12, and F13, representing the affected performance and receiving layers in the military supply chain. These elements directly reflect the influence of underlying factors. The second layer includes F1, F4, F7, F8, and F9, functioning as the driving layer for proactive impacts and serving as the core catalyst for changes in the surface layer. This structure clearly demonstrates the transmission chain where the underlying drivers from the first layer are retransmitted to the surface layer of the second layer.

This hierarchical framework provides strategic guidance for management practices. Defense enterprises must address root causes at the second-level factors, as they constitute the most critical elements influencing the entire supply chain. Key initiatives include optimizing F4 process standardization systems and enhancing R&D investments in F9 core defense technologies. For surface-level factors at the first level, the focus lies in developing risk mitigation mechanisms that can promptly block transmission when risks emerge. This involves establishing early-warning coordination mechanisms based on F4 and F9 technologies, and creating production capacity flexibility plans integrated with F9 technological reserves. Ultimately, this hierarchical decomposition clarifies the layered impact logic of risk factors in defense supply chains, enabling enterprises to effectively identify and differentiate risk sources.

3.2.3 Key Factor Identification

By analyzing the accessibility matrix and hierarchical classification, this study helps defense enterprises thoroughly deconstruct supply chain influencing factors and explore their transmission mechanisms, enabling them to develop targeted management strategies. As shown in Table 6, companies can identify key influencing factors based on their actual conditions.

Table 6. Identification of key influencing factors

influencing factor (Fi)	Impact Ranking	Degree	Affected Ranking	Degree	Centered Ranking	Parent level	Factor category
F4	1		7		3	Layer 2	Core factor
F13	2		8		5	Layer 1	secondary cause
F14	3		9		6	Layer 1	secondary cause
F7	4		11		7	Layer 2	important factor
F11	5		3		4	Layer 1	important factor
F12	6		2		2	Layer 1	important factor
F1	7		14		12	Layer 2	secondary cause
F9	8		13		11	Layer 2	secondary cause
F5	9		1		1	Layer 1	Core factor
F8	10		12		10	Layer 2	secondary cause
F6	11		4		8	Layer 1	secondary cause
F2	12		10		14	Layer 1	secondary cause
F10	13		5		9	Layer 1	secondary cause
F3	14		6		13	Layer 1	secondary cause

By adjusting environmental parameters and other variables, the system can adapt to various complex and specialized scenarios. After identifying risk factors, defense enterprises can implement hierarchical control of core, key, and secondary factors based on their classification levels. This ultimately helps defense enterprises achieve systematic optimization goals for implementable supply chain strategies.

4. Research Implications and Prospects

4.1 Summary of Research

This study systematically identifies 14 critical risk-influencing factors of military product supply chains under civil-military integration, covering four dimensions (supplier, production, technological, and market environments). Through the integrated DEMATEL-ISM method, three core findings are derived:

Firstly, Core driving factors are concentrated in the production and policy-technical dimensions: Process stability (F4, centrality=2.962, causality $R=1.036$) and R&D capability (F9, centrality=1.641, $R=0.397$) are the most critical root causes of supply chain risks. This is because military products have ultra-high requirements for production precision and technological exclusivity, even minor process deviations or technological bottlenecks can trigger cascading disruptions .

Secondly, A "root-transmission-manifestation" three-tier risk mechanism exists: Root causes (F4, F9, F14) transmit risks to manifestation factors (F5, F11, F12) through intermediate transmission factors (F1, F7, F13). For example, policy regulation fluctuations (F14, $R=0.589$) first reshape industry competition patterns (F13), then further drive demand volatility (F11) and price fluctuations (F12) in the market dimension, ultimately manifesting as supply chain resilience deficits.

Thirdly, Cross-dimensional influence is a unique feature of military supply chains: Unlike civilian supply chains, production factors (F4) in military scenarios directly affect market factors (F11). This is due to the policy and market dual-driven nature of military demand, production capacity adjustments must align with sudden changes in national defense procurement plans, leading to strong coupling between production and market dimensions.

Research findings demonstrate that the resilience of defense industry supply chains is influenced by multiple intersecting factors. Among these, F4 process stability, F5 raw material quality, F12 demand fluctuations, F13 price volatility, and F14 regulatory changes exhibit the highest centrality, serving as the most critical control nodes in the system. Through analysis, we clearly distinguish between causal and outcome factors: Process stability, regulatory changes, and price fluctuations demonstrate strong proactive influence, classified as driving factors; whereas raw material quality and demand fluctuations are more susceptible to external influences, categorized as responsive factors.

4.2 Management Insights and Optimization Strategies

Based on the above research conclusions, this paper puts forward management implications and optimization strategies from three dimensions: root control, transmission optimization and surface response, so as to help military enterprises improve the resilience of supply chain:

(1) Strategic control of deep-rooted factors

Defense manufacturers should prioritize monitoring and managing deep-rooted factors, such as the stability of raw material supply and suppliers' comprehensive capabilities. For critical elements like process stability, raw material quality, and demand fluctuations, these should be prioritized in resource allocation and process optimization. By adopting intelligent manufacturing and statistical process control technologies, defense enterprises can enhance production flexibility. Establishing demand forecasting and rapid response mechanisms will strengthen market adaptability.

(2) Dynamic response of driving factors

As key drivers of operational challenges, policy fluctuations and market price volatility require enterprises to establish dedicated policy research and intelligence analysis units. These units should monitor domestic and international policy developments and market trends in real time, while developing contingency plans to mitigate compliance and cost pressures. Simultaneously, companies should implement a policy-market linkage decision-making mechanism. This involves integrating external drivers such as regulatory changes and price fluctuations into the dynamic adjustment framework of supply chain strategic planning, enabling proactive adaptation to evolving external environments.

(3) Hierarchical transmission and collaborative optimization

Enterprises should systematically implement strategies across three key dimensions: technology R&D, production operations, and market coordination. This requires strengthening information sharing and collaboration mechanisms between R&D departments and production/supply chain units to drive technological iteration and tangible improvements in R&D capabilities. By leveraging big data and AI technologies, companies can establish supply chain resilience monitoring and simulation platforms that enable real-time monitoring of operational factors and impact simulations, thereby supporting dynamic decision-making and targeted interventions. For instance, real-time process stability monitoring through these platforms can provide early warnings of production risks, allowing rapid responses through coordinated strategies such as optimizing raw material reserves and implementing alternative supplier options.

4.3 Research Limitations and Future Prospects

This study has the following limitations: First, the expert sample lacks cross-national verification. Future research could invite experts from countries with mature military-civil integration systems for cross-institutional and international cross-checks to improve the generalizability of the findings. Second, the study did not address the time-varying interaction mechanisms between factors in dynamic environments, leading to limited adaptability of the proposed factor system. Future research should integrate dynamic methodologies to conduct dynamic simulation and scenario-based analysis of supply chain resilience, expanding the dynamic factor system.

Considering research limitations and emerging trends in military-civil integration, future studies should focus on integrating cutting-edge technologies with risk management strategies. For example, applying blockchain technology to trace confidential information in defense supply chains to analyze its impact on raw material disruptions (F1) and supply chain stability (F2); exploring AI-driven demand forecasting to identify new risk points arising from technological uncertainties. Developing a balanced risk management framework will better address the practical needs of building resilient defense supply chains.

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