

A Risk Assessment and Classification Framework for the Military Clothing Supply Chain

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Military Clothing Supply Chains (MCSC) operate under compliance-driven constraints, limited substitutability, and low tolerance for disruption. Although Supply Chain Risk Management (SCRM) is well established, research on clothing supply chains is dominated by fashion-apparel contexts, where short life cycles, seasonality, and consumer demand volatility shape the prevailing assumptions about risk. These assumptions are not directly transferable to military clothing systems, where material-flow decisions must simultaneously satisfy qualification requirements, documentation, traceability, and continuity objectives. Consequently, an empirically grounded approach to risk assessment and classification tailored to material flow management in the MCSC remains underdeveloped. This paper proposes a risk assessment and classification framework for material flow management in a MCSC. The study applies a mixed-methods design conducted with an expert group representing different stages of material flows. The research procedure comprises five stages. A process-oriented expert study identified 40 undesirable events affecting material flows in the MCSC. All events were classified into ten operational domains and labelled using a four-dimensional impact typology covering material (M), informational (I), financial (F), and quality-related (J) consequences. Experts then estimated probability (P) and impact (I) on a five-point scale to calculate the risk indicator R for each event. For detailed reporting, the analysis focuses on 19 events whose risk indicator corresponds to medium or high risk levels. In addition, a risk matrix is provided to visualise the assignment of the identified events to the respective risk classes and to support prioritisation of mitigation actions. The proposed framework supports risk prioritisation and targeted mitigation planning for material flows in compliance-driven MCSC. It also provides a replicable basis for further validation and refinement of risk classification in defence-oriented apparel networks.

Keywords: SCRM, Decision-Making Under Uncertainty, Risk Classification

1. Introduction

Military clothing supply chains represent a specific class of defence-oriented supply systems in which operational continuity, compliance, and traceability are not “nice to have” but hard constraints. Unlike many commercial apparel networks, these supply chains are subject to stricter acceptance requirements and limited substitution options, while operating in environments characterised by volatile demand signals, constrained supplier bases, and frequent disruptions. In such conditions, the management of material flows—planning, coordinating, and executing the movement and availability of fabrics, components, and semi-finished items—

becomes a critical reliability driver for the entire supply chain.

Despite the maturity of the broader literature on supply-chain risk management, there is still limited empirical work focused on risk assessment and classification for material flow management in the Military Clothing Supply Chain. Existing contributions often address procurement risks, supplier evaluation, or logistics performance metrics, but they rarely deliver an empirically grounded classification framework that supports prioritisation and mitigation in defence-oriented apparel supply systems. This gap is important: without a structured classification anchored in the realities

of material-flow decisions, risk management tends to become a “list of issues” rather than an actionable instrument for reliability improvement.

This paper addresses this gap by proposing a risk assessment and classification framework for material flow management in the Military Clothing Supply Chain. The study follows a mixed-methods design: semi-structured interviews with managers involved in procurement and logistics are used to identify and define risk factors, and an expert-based quantitative assessment is applied to estimate risk indicators (probability and impact), enabling comparability and prioritisation. The resulting framework is designed to support both research and practice by providing a structured typology of risks and a repeatable procedure for assessing them in compliance-driven, disruption-sensitive supply chain environments.

The paper's structure, in addition to the Introduction, includes a presentation of the theoretical background for the study (Section 2). Next, Section 3 describes the research procedure and outlines the methodology applied in the analyses. The results are reported in Section 4, while their interpretation and further analysis are provided in Section 5 (Discussion). The paper is concluded in Section 6.

2. Theoretical Background

Supply Chain Risk Management (SCRM) is the process of identifying, assessing, and mitigating risks across the supply chain to ensure continuity and long-term profitability. This involves collaboration and coordination among supply chain partners and the application of various risk management tools (Faisal, 2015; Shahbaz et al., 2017). The primary goal of SCRM is to reduce the likelihood of uncertain situations and manage them efficiently and effectively when they arise (Bandyal et al., 2012).

SCRM concept focuses on the identification, assessment, mitigation, and monitoring of risks in supply chains through (a) the internal implementation of tools, techniques, and strategies and (b) external coordination and collaboration among supply chain members. The overarching purpose is to reduce vulnerability to disruptions and ensure business continuity while maintaining profitability, thereby supporting competitive advantage (Fan & Stevenson, 2018). A crucial

premise for advancing SCRM is that organisations need to recognise that their exposure and vulnerability to risk are, to a large extent, shaped by other actors in the supply chain (Blos et al., 2012).

A literature review by Ho et al. (2015) indicates that SCRM research commonly distinguishes two broad categories of risk. The first category comprises internal risks, referring to disruptions originating within the focal organisation. These include adverse events related to capacity availability, internal operations, information systems, internal control mechanisms, demand, production, and distribution. The second category includes external risks arising from the organisation's environment, including environmental events (such as natural disasters), political conditions, market dynamics and competition, terrorist attacks, and exchange-rate fluctuations.

Some authors additionally identify a third category—network-related risk—which reflects the organisation's embeddedness in a specific supply chain structure and the interdependencies among its members (Christopher and Peck, 2004). From the perspective of a single organisation, network-related risk is external; however, from the perspective of the supply chain as a whole, it can be treated as internal, as it arises from the network's relational and structural characteristics.

When these perspectives are applied to clothing and apparel supply chains, the available evidence is extensive, yet it is also notably skewed: in the context of risk management, the literature predominantly addresses fashion apparel supply chains and consumer-oriented markets. As a result, many established findings reflect assumptions typical for fashion settings—short product life cycles, strong seasonality, and pronounced demand volatility—rather than the full spectrum of clothing supply chains, including defence-oriented ones. In fashion-focused networks, these characteristics complicate planning and synchronisation across multi-tier and often offshore structures (McMaster et al., 2020; Parker-Strak et al., 2022; Weingarten and Spinler, 2021). They also intensify the bullwhip effect, leading to overproduction, excessive inventories, and, simultaneously, stockouts—particularly when long, inflexible lead times require early purchasing decisions under limited market visibility (Nenni et al., 2013).

Moreover, prior research indicates a structural asymmetry in risk allocation between retailers and manufacturers. Retailers frequently bear a disproportionate share of the consequences associated with forecast errors and markdown pressure, which creates coordination tensions and increases the need for joint governance mechanisms in risk management (Alom et al., 2024). From a material-flow perspective, recurrent risk mechanisms cluster around: (a) upstream material availability and supplier reliability (e.g., delays, shortages, quality variability), (b) production execution and capacity synchronisation, (c) logistics handoffs and transport disruptions, and (d) information and planning integrity, including master-data errors (e.g., bill of materials), delayed status updates, and frequent replanning cycles. These mechanisms directly affect operational continuity and delivery performance and may cascade across processes when inter-organisational coordination is insufficient (Alom et al., 2024).

Fashion-oriented clothing supply chains differ substantially from military clothing supply chains, as confirmed by the authors' earlier research (Tubis and Świerczek, 2026). In particular, the Military Clothing Supply Chain is typically characterised by: (a) stringent specification, compliance, and acceptance requirements linked to functional performance, durability, and user safety; (b) enhanced traceability and documentation obligations across multiple tiers, often coupled with auditability and formal approval procedures; (c) limited substitutability of materials, components, and suppliers due to qualified-source constraints and tightly defined technical parameters; (d) a low tolerance for nonconformities and delivery deviations, since disruptions may affect not only cost and service levels but also operational readiness; and (e) decision-making under higher uncertainty, where material-flow planning and coordination must reconcile availability, qualification constraints, inspection/verification procedures, and time pressure. Consequently, risk mechanisms observed and modelled in fashion apparel settings cannot be transferred directly without adaptation, and generic SCRM taxonomies may not sufficiently capture the configuration of risks emerging from material-flow management in this domain. This provides a clear rationale for the study presented in this paper, which develops a risk

assessment and classification framework tailored to material flow management in the Military Clothing Supply Chain.

3. Research procedure and methodology

The study was conducted in collaboration with a group of experts with knowledge covering different stages of material flows in the Military Clothing Supply Chain. This ensured a comprehensive analytical perspective that captured multiple aspects of how the examined supply chain operates. The research procedure comprised five stages, including risk identification, classification, analysis, and evaluation. These stages, together with their outputs, are presented in Figure 1.

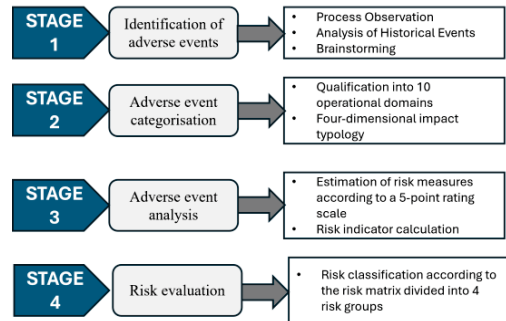


Fig. 1. Stages of the research procedure.

The first stage of the study involved identifying undesirable events characteristic of supply-chain operations. The study engaged a group of experts (8 people) with long-term professional experience (more than 6 years) in handling material flows in Military Clothing Supply Chains. The identification was process-oriented, with the primary emphasis placed on recognising disruption mechanisms that are specific to military clothing supply networks. The identification process comprised: (a) process observation and elicitation of expert knowledge regarding how activities are executed; (b) an empirical review of events disrupting the proper course of operations and their consequences; and (c) expert workshops using brainstorming to refine disruption statements and calibrate the interpretation of the rating scales.

The second stage aimed to categorise the identified undesirable events according to the proposed classification framework. The

framework was operationalised as ten operational domains reflecting where disruptions originate and how they propagate within material-flow processes. These domains are presented in Figure 2. In addition, for each domain, the typical dominant disruption mechanisms (i.e., causal “why” drivers) were described, which supported the structuring of results and facilitated subsequent analysis.

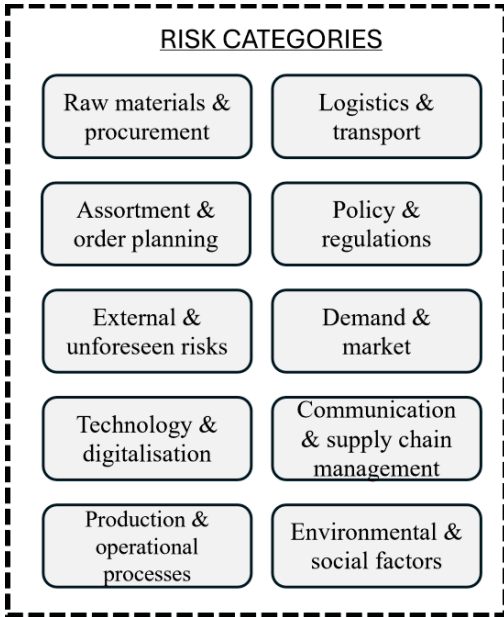


Fig. 2. Domains that form the risk classification framework.

In addition to being assigned to a domain, each undesirable event was labelled using a four-dimensional impact typology covering **material (M)**, **informational (I)**, **financial (F)**, and **quality-related (J)** consequences. It should be noted that an undesirable event may affect more than one flow (material, informational, financial) and may also escalate, resulting in quality losses. Therefore, individual events may be associated with more than one impact label.

The undesirable events identified in Stage 3 were subsequently analysed, and experts estimated values for both risk measures: probability (P) and impact (I) of occurrence. Both measures were assessed using the five-point rating scale presented in Table 1.

Table 1. Probability and impact scale used for risk assessment.

Level	Probability / Likelihood (P) – descriptor	Impact / Consequence (I) – descriptor
1	Very unlikely – exceptional, rare	Negligible – local effect, absorbed by routine buffers
2	Unlikely – possible, sporadic	Minor – limited disruption, minor replanning/effort
3	Possible – occurs occasionally	Moderate – noticeable disruption, replanning/expediting needed
4	Likely – occurs repeatedly	Major – significant delivery/cost impact; QA/Compliance exposure
5	Very likely – frequent/almost certain	Critical – severe interruption; major nonconformity/compliance breach

Experts provided independent ratings, which were aggregated using the median to obtain robust central estimates and reduce sensitivity to outliers and individual calibration differences. As the experts’ assessments showed a high level of agreement, the evaluation was supported by basic consistency checks and a short reconciliation step focused on clarifying definitions (without forcing full consensus), thereby preserving the transparency of expert judgement and the practical usefulness of the decision-making process. Based on the estimated probability and impact values, risk indicators were calculated for each event using Equation (1).

$$R = P \times I \tag{1}$$

In Stage 4, the risk evaluation was carried out based on the estimated probability and impact parameters. The evaluation relies on a risk matrix divided into four areas:

- **Zone A (green)**—acceptable risk;
- **Zone B (yellow)**—low, non-acceptable risk;
- **Zone C (orange)**—medium, non-acceptable risk; and
- **Zone D (red)**—high, non-acceptable risk

Table 2. Top-ranked material-flow disruptions and relative risk indicator *R*.

Rank	Category (domain)	Adverse event	P	I	R
1	Raw materials & procurement	Dependence on a single supplier or region	4	5	20
2	Policy & regulations	Influence of global politics	4	5	20
3	Communication & supply chain management	Lack of supply chain transparency	4	5	20
4	Communication & supply chain management	Forecasting errors	4	5	20
5	Communication & supply chain management	Barriers to collaboration between departments and suppliers	5	4	20
6	Production & operational processes	Overproduction / shortages	4	5	20
7	Logistics & transport	Transport route changes	4	4	16
8	Technology & digitalisation	Lack of process automation	4	4	16
9	Technology & digitalisation	Lack of IT systems integration	4	4	16
10	Assortment & order planning	Incorrect size/colours curve (bias)	4	4	16
11	Assortment & order planning	MOQ constraints (minimum order quantity)	4	4	16
12	Production & operational processes	Production quality problems	3	5	15
13	Logistics & transport	Changes in trade regulations	5	3	15
14	Environmental & social factors	New environmental and ESG regulations	5	3	15
15	Raw materials & procurement	Limited availability of materials (raw materials/components shortages)	3	4	12
16	External & unforeseen risks	Natural disasters (floods/typhoons/fires disrupting supply and transport)	3	4	12
17	Assortment & order planning	Under/overestimation of the first order quantity (initial buy bias)	3	4	12
18	Assortment & order planning	Incorrect timing of placing the order (lead time risk)	3	4	12
19	Communication & supply chain management	Communication problems (language/cultural/time-zone barriers)	4	3	12

Based on the evaluation of the identified undesirable events, the company makes decisions on the prioritisation of risk-mitigation actions, taking into account available resources and the results of the applied categorisation. The allocation of risks to the respective matrix zones provides a basis for operational planning in the supply chain as well as for improving its systemic and procedural components.

4. Results

The findings from the identification of undesirable events were consolidated into an anonymised register. The register comprises 40 disruptions affecting material flows in the analysed Military Clothing Supply Chain. For each event, both risk parameters—probability and impact—were estimated, and the risk indicator **R** was subsequently calculated. Due to space limitations, Table 2 reports only the 19 events with the highest risk indicator values.

The undesirable events quantified in Table 2 were grouped according to the categories presented in Figure 2. This categorisation confirms that the identified risks span heterogeneous areas and operate at different managerial levels. Events with the highest values of the risk indicator ($R = 20$) relate both to strategic issues (e.g., the impact of global political dynamics, limited supply chain transparency) and to disruptions that directly affect the execution of material flows (e.g., overproduction or shortages). The proposed classification supports managerial practice by facilitating the differentiation of risk sources and enabling more targeted mitigation actions.

To support comparability and practical use, risks were structured using three complementary views:

- **Process-domain (where):** risks were assigned to one of the ten process-based categories shown in Table 2 (e.g., raw materials & procurement, production & operational processes, logistics & transport, demand & market, technology & digitalization).
- **Cause-mechanism (why):** for each of the ten categories, typical dominant causes were described to explain why disruptions occur within that process area.

- **Consequence-type (what):** risks were tagged using M/I/F/J, linking them to material (M), information (I), financial (F), and quality-related (J) effects.

This typology separates where the risk manifests, why it arises, and what it primarily affects, supporting clear ownership assignment and targeted mitigation.

Based on the estimated risk parameters, the risks were evaluated in accordance with the guidelines of Stage 4 of the research procedure described above.

For reporting, risks were grouped into the following bands: 1–4 (acceptable), 5–11 (low), 12–19 (medium), and 20–25 (high).

Across the 40 disruptions, the distribution across bands indicates a concentration in the middle-to-upper range: 6 high, 13 medium, 16 low, and 5 acceptable. Figure 3 visualises the undesirable events assigned to the respective risk acceptance levels. This representation enables risk prioritisation and supports more effective risk management.

The highest-priority group ($R=20$) contains six mechanisms spanning both upstream structure and governance/coordination: single supplier/region dependency (raw materials & procurement), global political influence (policy & regulations), lack of supply chain transparency, forecasting errors, cross-functional / supplier collaboration barriers (communication & SCM), and overproduction/shortages (demand & market).

The medium band ($R=12-19$) is dominated by execution enablers and structural constraints that amplify disruption propagation, including transport route changes ($R=16$), lack of process automation ($R=16$), lack of IT systems integration ($R=16$), incorrect size curve ($R=16$) and MOQ constraints ($R=16$), as well as production quality problems ($R=15$) and trade and ESG regulation changes ($R=15$). At the lower end of this band ($R=12$), additional disruption drivers include limited availability of materials ($R=12$), natural disasters disrupting supply and transport ($R=12$), under/overestimation of the first order quantity ($R=12$), incorrect timing of placing the order due to lead-time risk ($R=12$), and communication problems linked to language, cultural and time-zone barriers ($R=12$).

Table 3. Ten-category risk typology: dominant causes and dominant effects (M/I/F/J) within each process-based category

Category	Typical dominant causes within the category (why)	Dominant effects (M/I/F/J)
Raw materials & procurement	weak supplier qualification, limited supplier base, certificate gaps, late changes, low visibility	M, F, J
Production & operational processes	time pressure, process deviations, execution errors, rework, weak follow-up on quality issues	M, F, J
Logistics & transport	disruptions, planning errors, capacity constraints, storage issues, documentation holds	M, F, J, I
Policy & regulations	geopolitical shifts, trade restrictions, ESG and regulatory updates, stricter documentation	M, F, J, I
Communication & supply chain management	unclear ownership, weak escalation, fragmented channels, poor version control, delayed information	I, M, F, J
Demand & market	volatile demand, biased forecasts, shifting assumptions, weak demand signalling	F, M, I

Environmental & social factors	compliance gaps, stakeholder pressure, sustainability constraints	J, F, M
Technology & digitalisation	low integration, data fragmentation, master-data issues, downtime, slow data entry	I, M, F
External & unforeseen risks	external shocks, supplier instability, force majeure, weak monitoring	F, M, J
Assortment & order planning	poor assortment data, lead-time errors, late changes, wrong order sizing and timing	I, M, F, J

A portfolio-level insight is that communication & supply-chain management contains multiple top-ranked mechanisms, suggesting that visibility, coordination, and cross-party governance are core drivers of resilience in material-flow execution rather than merely supporting processes.

P \ I	I=1	I=2	I=3	I=4	I=5
P=5	0	0	2	1	0
P=4	0	4	1	5	5
P=3	0	4	5	4	1
P=2	0	1	1	1	0
P=1	0	2	0	2	1

Where: green — acceptable risk; yellow — low, non-acceptable risk; orange — medium, non-acceptable risk; and red — high, non-acceptable risk.

Fig. 3. Portfolio distribution in the 5x5 risk matrix (P x I): number of disruptions per cell. Counts are based on N = 40 identified disruptions.

At the risk evaluation stage, the calculated risk indicators were treated symmetrically when establishing priorities. However, when defining

risk mitigation strategies, the relative magnitude of probability and impact was additionally considered in order to select the most appropriate response strategy.

4. Discussion and Conclusion

Military clothing supply chains exhibit a distinct logic of planning and executing material flows compared with the practices typically observed in fashion apparel networks. Consequently, both the nature of undesirable events and the corresponding risk-management approach require a context-specific perspective. The literature review conducted for this study indicates a critical research gap in supply chain risk management for the Military Clothing Supply Chain. One plausible reason is that these material-flow processes do not fully align with mechanisms described for conventional apparel supply chains, nor do they fit the dominant patterns reported for “typical” defence supply chains. This hybrid, compliance-driven setting calls for dedicated empirical research to develop a risk assessment methodology that reflects its operational characteristics.

The risk assessment results reported in this paper should be interpreted as preliminary findings obtained within the framework of an Industrial PhD programme. They do not exhaust the broader problem of defining a comprehensive taxonomy of undesirable events and assigning robust risk priorities across all categories. Nevertheless, they demonstrate that selected risk categories differ in their relative importance when compared with traditional apparel supply chains. In particular, the findings highlight the elevated relevance of issues such as supplier certification, forecast reliability, and delivered material quality. While these factors also occur in conventional clothing supply chains, they typically do not receive the same level of prioritisation as in the Military Clothing Supply Chain.

The outcomes of this study can support risk-management practice among military clothing manufacturers and their upstream and downstream partners across the supply chain. They may also provide a useful reference for researchers investigating supply chain risk management and the specific dynamics of military clothing supply systems. For the authors, the presented results constitute a starting point for further research planned within the doctoral dissertation.

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