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Policy-Oriented Framework for Risk and Resilience Indicators in FMCG Supply Chains

Anna Zelenajova

Digital Safety & Security, Austrian Institute of Technology, Austria. E-mail: anna.zelenajova@ait.ac.at

Stefan Schauer

Digital Safety & Security, Austrian Institute of Technology, Austria. E-mail: stefan.schauer@ait.ac.at

Martin Latzenhofer

Digital Safety & Security, Austrian Institute of Technology, Austria. E-mail: martin.latzenhofer@ait.ac.at

Manuel Egger

Digital Safety & Security, Austrian Institute of Technology, Austria. E-mail: manuel.egger@ait.ac.at

Fast-moving consumer goods (FMCGs) comprise product categories with high turnover rates and essential daily use, including food staples, hygiene products, and household paper. Despite their central role in our social life, FMCG supply chains are less frequently addressed in national resilience frameworks than sectors traditionally classified as critical infrastructure, such as energy or water. Recent disruptions in global and national supply chains have demonstrated that vulnerabilities in FMCG provision can rapidly translate into significant societal impacts. This paper addresses the absence of a standardized, policy-oriented framework for assessing risks and resilience in FMCG supply chains. Existing approaches in supply chain risk management and agricultural risk analysis provide valuable analytical insights, yet they often remain fragmented, sector-specific, or insufficiently operationalized for public-sector application. The objective of this paper is to develop a structured set of risk and resilience indicators for FMCG supply chains, categorized into operational, social, and environmental dimensions, and defined through measurable units and thresholds. The framework is designed to support modelling and simulation-based analysis of disruptions and their effects on supply continuity, thereby providing a foundation for policy-relevant monitoring and decision support.

Keywords: fast-moving consumer goods (FMCG), crisis preparedness, policy-oriented framework, risk indicators, resilience indicators.

1. Introduction

Fast-moving consumer goods (FMCGs) food staples, hygiene products, and household paper – are characterized by high turnover rates, low margins, and essential daily consumption (Nielseniq 2022). Nevertheless, FMCG supply chains receive less policy attention than traditional critical infrastructure sectors such as energy, water, or telecommunications. Looking at recent EU regulation, the food and manufacturing sectors are only considered “important entities” in the NIS2 Directive (European Parliament and Council 2022) whereas at least food is considered “critical” under the CER Directive (European Parliament and Council 2022). This creates a blind spot in crisis preparedness: when FMCG supply chains fail, consequences manifest rapidly at household level, creating immediate societal pressure and potential cascading effects. Disruptions such as extreme weather and pandemic-induced shocks have demonstrated that FMCG vulnerabilities translate quickly into scarcity, panic buying, and decrease in the public´s confidence (Kakaei et al. 2022). The COVID-19 pandemic showed how rapidly disruptions reflect in the global supply chains, even in countries with robust supply infrastructure (Tai et al. 2021). Existing approaches to supply chain risk management provide valuable analytical insights but exhibit three key limitations for policy use:

(i) Existing risk and resilience frameworks lack FMCG-specific operationalization. Singh et al. (2019) identify commonly used resilience indicators but note limited product-level application and insufficient attention to supply chain performance measurement, while Xu et al. (2019) focus on sectors such as apparel and automotive, overlooking FMCG-specific characteristics.
(ii) The frameworks frequently rely on normalized scores or study-specific metrics without measurable units and decision-relevant thresholds that enable public-sector monitoring and intervention triggers (Emrouznejad et al. 2023).
(iii) Risk exposure and resilience capacity are often assessed in isolation, limiting the ability to design differentiated policy responses (Xu et al. 2019; Singh et al. 2019).

In this paper, we aim to create a risk and resilience monitoring concept that allows for an overview of the FMCG supply system at national and transnational levels. Our research is conducted within the national research project MERCURIUS, and combines static and dynamic analyses to identify potential vulnerabilities and improvement opportunities in the FMGC supply chains and the impact of their disruptions (Austrian Institute of Technology 2023). The FMCG risk and resilience framework described in this paper provides public authorities with:

- standardized indicators applicable across FMCG product categories while preserving product-specific interpretation,
- measurable units and thresholds that enable monitoring, comparison, and trigger-based intervention,
- analytical separation of risk exposure and resilience capacity to support differentiated policy responses,
- operational definitions suitable for national-level data collection and cross-sectoral benchmarking, and
- methodological foundation for modelling and simulation-based stress testing of disruption scenarios.

Overall, this framework is designed for policy application, focusing on a national perspective on the resilience of FMCG supply to the population, rather than company-level optimization.

The Section 2 discusses conceptual foundations, followed by an introduction of the applied methodology. Section 4 describes the framework design, i.e., indicators and its characteristics. The paper ends with a conclusion, the limitations and the outlook on further research.

2. Conceptual Foundations

Supply chain risk and supply chain resilience represent distinct yet complementary analytical dimensions that must be measured individually but considered in combination with each other for effective policy intervention. The former covers the exposure to disruptive events and the vulnerability of system components to those events and the latter deals with the organizational capabilities to anticipate, adapt, respond, recover, and learn from disruptive events (Schauer et al. 2022; Karl et al. 2018). From an organizational but also from a national perspective, both aspects are equally relevant to guarantee a high level of preparedness against various crises.

Risk indicators capture external threats and internal vulnerabilities that can disrupt supply chain functionality. Xu et al. (2019) operationalized the categorization of supply chain risks into operational, social, and environmental dimensions through integrated sustainability assessment. In the context of FMCG supply chains, these categories can manifest themselves through product-specific mechanisms, e.g., milk supply chains face environmental risks through feed scarcity and animal disease, while supply chains for soaps and other hygiene products are dependent on global chemical sources, and toilet paper supply chains demonstrate logistics sensitivity through their high volume and low monetary value.

Policy-oriented frameworks must maintain both the risk and resilience dimensions to enable the differentiated assessment and the corresponding policy response. Corporate frameworks optimize company-level performance through procurement decisions and operational efficiency (Xu et al. 2019), while policy frameworks must support public-sector functions, such as national-level monitoring across companies and products, threshold-based early warning for intervention triggers, cross-sector comparability for resource allocation, and integration with critical infrastructure protection strategies (Emrouznejad et al. 2023).

FMCGs differ from traditional critical infrastructure in several ways. Logistics systems with a high throughput make disruptions immediately visible (Nielseniq 2022). Agricultural perishables such as milk are characterized by fast product deterioration, biological production dependencies (animal health, feed supply), continuous process requirements (milking, cooling, pasteurization), and regional sourcing patterns. Resilience strategies for such products emphasize rapid response and redundant cooling capacity over inventory buffering. Recent empirical evidence from FMCG distribution networks during COVID-19 demonstrates the operational consequences of these perishability constraints (Asgharizadeh et al. 2023).

Furthermore, processed industrial goods like soap require global sourcing (e.g., by using palm oil or coconut oil from tropical regions), energy-intensive manufacturing, chemical process expertise requirements, and substantial inventory buffering potential. Resilience strategies for these products can benefit from geographic diversification and strategic stockpiling. Bulk paper product supply chains such as toilet paper are characterized by high-volume logistics demands, forestry resource dependencies and predictable demand patterns. For these products, resilience strategies focus on transport flexibility and production capacity.

The framework developed in this paper takes these product-specific differences into consideration.

3. Methodology

The framework we propose follows a qualitative-conceptual research design and was developed within the MERCURIUS project. The methodological goal is not to estimate event probabilities or produce company-level optimization models. Rather, the objective is to create an indicator system enabling national-level monitoring, cross-product comparison, and a basis for the modelling of FMCG supply chains.

The design approach integrates three complementary knowledge sources, i.e., systematic literature review, project-based empirical evidence, and structured expert consultation. The desk research set the basis for the methodology and covered academic literature related to supply chain risk management, resilience and risk assessment, critical infrastructure management, and FMCG provisioning. The outcome was the identification of a first set of risk and resilience indicators (52 risk and 43 resilience indicators). Following the categorization developed by (Xu et al. 2019), these indicators were grouped into environmental, social and operational factors. This clustering enabled a reduction to 20 risk and 15 resilience indicators, which were subsequently subjected to a consultation process with supply chain experts, industry and public sector representatives, ensuring that the framework was grounded in practical expertise and sector-specific knowledge. Through this iterative process, the final set of indicators, the thresholds and product-specific multiplicators were formed.

This included the mapping of key supply chain structures and processes, and analysis of potential threats and risks affecting selected Austrian FMCG supply chains. Within the MERCURIUS project, the focus was laid on three product categories, i.e., milk and related products (due to their special requirements on cooling), soap and hygiene products (due to their international supply chains) and toilet paper (due to its high volume and low value and the specificities on logistics going along with that).

4. Framework Design

Existing approaches to supply chain risk management exhibit three key limitations for policy use: sector-agnostic frameworks with limited FMCG transferability, lack of measurable units and decision-relevant thresholds as well as isolated assessment of either risk or resilience without integration (Singh et al. 2019; Emrouznejad et al. 2023; Xu et al. 2019). This framework addresses the limitations by providing risk-resilience separation and specific FMCG indicator interpretations together with defining measurable units and thresholds suitable for national-level monitoring and cross-product comparison.

It comprises nine indicators, organized into risk indicators (numbered 1-5) and resilience indicators (numbered 6-9) (cf. Fig. 1). Following Xu et al. (2019), the risk and resilience indicators capture operational (*Indicator 1, 3, 4, 6-9*), social *(Indicator 5*) and environmental (*Indicator 2*) factors. Risk indicators are designed to capture both the potential for external disruption and.

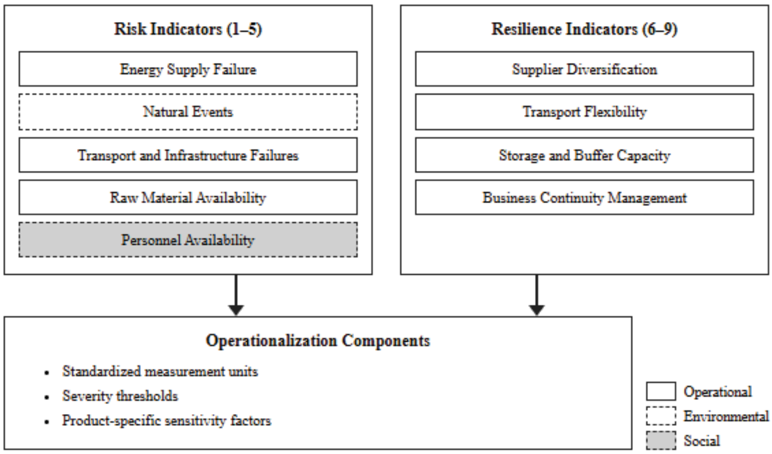

Fig. 1: The structure of the risk and resilience frameworks, including the operationalization components.

inherent supply chain vulnerabilities. The framework comprises the following indicators:

Indicator 1: Energy Supply Failure measures disruptions to electricity, gas, or heating supply that cause a complete halt of the production or related quality deterioration

With regards to the three product groups from the project, we identified several product-specific dependencies, e.g., milk production faces immediate spoilage risks requiring continuous cooling and pasteurization, soap manufacturing involves energy-intensive heating and mixing processes, or toilet paper production depends on continuous drying and pressing operations.

Indicator 2: Natural Events captures vulnerabilities to extreme weather phenomena and natural disasters (e.g., droughts, heatwaves or wildfires). The indicator encompasses both acute shock events and gradual climatic stressors. In the context of the selected products, droughts reduce milk production through feed scarcity and water constraints, floods disrupt transport infrastructure which is critical for high-volume toilet paper distribution, extreme weather events impact raw material sourcing for soap ingredients from tropical regions.

Indicator 3: Transport and Infrastructure Failures measures physical disruptions in transport networks and logistics infrastructure, including road closures, rail blockages, port shutdowns, and damaged critical infrastructure. For example, milk requires time-critical transportation where hours matter due to perishability, soap depends on international shipping routes for chemicals required in the production and toilet paper faces high-volume logistics sensitivity where large-scale disruptions rapidly impact the availability. This indicator also represents the counterpart to the *Indicator 7: Transport Flexibility.*

Indicator 4: Raw Material Availability includes disruptions from contamination, pest infestation, and animal diseases that threaten quality or availability of inputs. With respect to milk, risks encompass feed scarcity, water availability, animal disease, and biological disruptions with immediate production consequences. In soap production, pest infestations in palm oil or coconut plantations reduce harvest volumes and quality, while contamination in chemical additives can trigger batch failures. For toilet paper, pest damage in forestry and cellulose supply chains impairs raw material quality and delivery stability. This indicator also represents the counterpart to the *Indicator 8: Storage and Buffer Capacity.*

Indicator 5: Personnel Availability measures workforce disruptions through illness, strikes, skill shortages, or inadequate staffing flexibility. Milk processing requires high availability in staffing for animal care and refrigeration, creating high vulnerability to workforce absences. Soap manufacturing needs qualified operators for chemical processes and toilet paper production depends on maintenance personnel for high-capacity machinery, where skill shortages trigger downtime.

Resilience indicators measure capabilities to maintain functionality during disruptions. These indicators capture both absorption capacity (e.g., maintaining operations during disruptions) and adaptive capacity (e.g., reconfiguring operations in response to changed conditions), distinguishing resilient systems from merely robust ones (Karl et al. 2018).

Indicator 6: Supplier Diversification assesses the amount and geographic distribution of independent suppliers for critical inputs. The indicator measures both the number of independent suppliers per raw material and their geographic distribution across regions and countries, recognizing that true diversification requires independence in sourcing decisions and dispersion of supply locations to avoid common-cause failures. In milk production, a large number of farmers often ensure a good distribution but only few processing facilities might affect resilience whereas the soap supply chain is heavily relying on suppliers from tropical regions, e.g. south-east Asia or South America. The toilet paper production is also rather centralized with regards to manufacturers.

Indicator 7: Transport Flexibility measures availability of alternative transport modes redundant routes, and backup logistics service providers. The indicator captures the system's capacity to reroute shipments when primary transport channels fail, recognizing that modal diversity and route redundancy provide critical buffering against infrastructure disruptions. Having specific requirements on cooling, modes of transport for milk cannot be changed easily, whereas it is easier for soap or toilet paper. However, soap and toilet paper have specific requirements regarding their origin and volume. This indicator also represents the counterpart to the *Indicator 3: Transport and Infrastructure Failures.*

Indicator 8: Storage and Buffer Capacity quantifies the presence of decentralized storage locations and inventory reach in days. The indicator measures how long production can continue without new deliveries and assesses whether inventory is concentrated at single locations or distributed across multiple sites to reduce single-point-of-failure risk. This indicator also represents the counterpart to the *Indicator 4: Raw Material Availability.*

Indicator 9: Business Continuity Management assesses organizational capabilities for crisis detection, response, and recovery, encompassing crisis communication structures, incident response processes in information technology, as well as monitoring and early warning systems. The indicator captures recovery time requirements: the duration needed to restore full operational functionality after a disruption, recognizing that different production processes face different restart complexities and temporal urgencies.

Each of the above indicators is operationalized through three complementary features:

(i) **Standardized Measurement Units:** Each indicator employs clearly defined units such as duration (days), proportional loss (percent), or count (e.g. number of suppliers), selected based on potential data availability.

(ii) **Severity Thresholds:** Indicator values map onto a standardized severity spectrum ranging from minimal to catastrophic impact. Thresholds represent decision-relevant breakpoints rather than probabilistic risk estimates, refined iteratively through expert validation and cross-checking with mapped supply chain structures and use-case scenarios. They balance national-level comparability with operational meaning.

(iii) **Product-Specific Sensitivity Weighting:** While indicators and severity levels remain standardized across FMCGs, sensitivity factors (e.g., from 0.1 to 1.0) translate standardized assessments into product-specific impact evaluations, accounting for the different potential impacts, base perishability, inventory feasibility, and process continuity requirements.

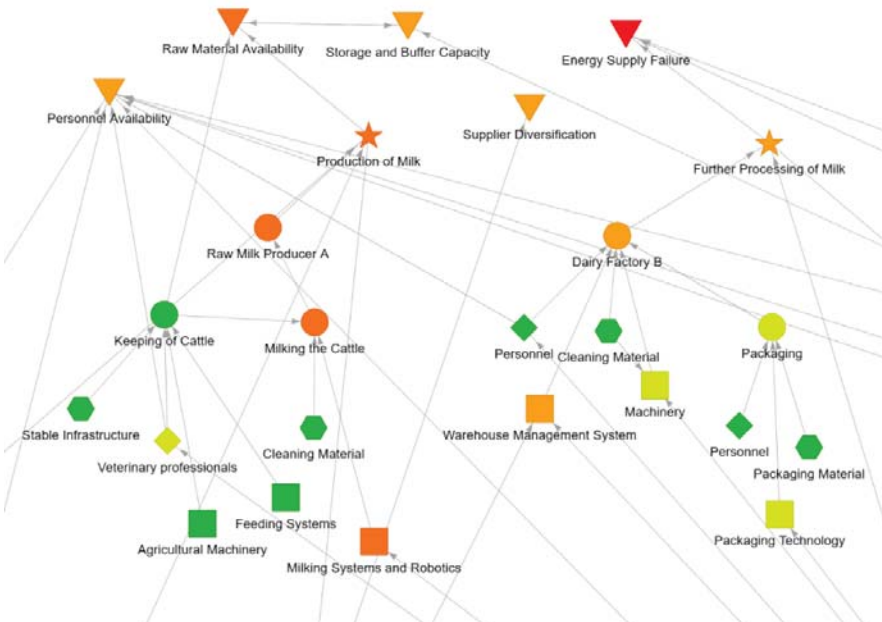

Fig. 2: Indicator states and interdependencies in milk supply chain under blackout conditions

To illustrate the applicability of the proposed indicator framework, we show how they can be integrated into a critical supply chain, i.e., the milk production in Austria, since this is one of the core supply chains analyzed in the MERCURIUS project. As an exemplary disruption scenario, we analysed the impacts of an electricity blackout. Because not all nine indicators are relevant in every crisis scenario, the framework allows for a selective application depending on the disruption type. In the blackout case, the most critical indicators were identified as Energy Supply Failure (Indicator 1), Raw Material Availability (Indicator 4), Personnel Availability (Indicator 5), and Storage and Buffer Capacity (Indicator 8). These are depicted as downward-facing triangles.

The structure, dependencies and indicator interactions of the milk supply chain were gathered in several expert workshops and modelled using AIT's cascading effects and risk analysis tool CASSANDRA, which captures interdependencies among the supply chain's core components and simulates the propagation of cascading effects throughout the supply chain (Austrian Institute of Technology 2024). The simulation results show how disruptions affecting one component influence other components and, accordingly, several of the connected indicators.

Within the tool, each indicator is represented as a node and is assigned one of five severity

States of impact, i.e., Minimal, Minor, Moderate, Severe, and Catastrophic, corresponding to the thresholds defined in the framework and assigned colors ranging from red to green. Threshold values are specified in the respective measurement units and incorporate product-specific sensitivity weighting. Consequently, the milk supply chain is modelled more sensitive to energy supply disruptions than other FMCG categories such as soap or toilet paper.

Dependencies between components of the supply chain and specific indicators can be explicitly defined within the model, thus accounting for the various possible relations and influences among them. Based on these relationships, the cascading effects simulation changes the severity states of the indicators, visualizing how much a scenario affects the risk and the resilience of the supply chain.

Figure 2 shows the system during the blackout scenario, highlighting how energy supply failure rapidly propagates into reduced processing capacity and constrained raw material availability. In addition, the simulation demonstrates the balancing relationship between Raw Material Availability (Indicator 4) and Storage and Buffer Capacity (Indicator 8), as inventory buffering can partially compensate for short-term supply interruptions. This is visualized using the arrow connecting these two indicators.

5. Conclusion and Future Research

FMCG supply chains play a critical, albeit under-recognized role in national resilience frameworks. While disruptions generate immediate household-level impacts and societal pressure, existing approaches to supply chain risk management lack the policy-oriented operationalization necessary for effective public-sector intervention. This paper addresses this gap by developing a structured indicator framework specifically designed for FMCG supply chain risk and resilience assessment. Our framework makes three key contributions.

(i) It maintains risk and resilience as analytically separate dimensions rather than combined scores. This separation enables policymakers to distinguish between scenarios requiring monitoring (high risk, high resilience) versus urgent capacity-building investment (high risk, low resilience).

(ii) It employs standardized measurement units and thresholds, providing public authorities with actionable intervention triggers and enabling cross-product comparison.

(iii) It supports dynamic modelling of disruption scenarios through measurable indicators with explicit severity thresholds, allowing policymakers to simulate FMCG supply chains under various crisis conditions.

The indicator-based approach offers several advantages for policy application. Standardized measurement units and explicit severity thresholds enable monitoring, cross-product comparison, and transparent communication among government agencies, industry stakeholders, and the public. The analytical separation of risk and resilience supports differentiated policy responses, targeting capacity-building where resilience is low versus enhancing monitoring where risk is high. Product-specific sensitivity weighting allows for comparability across FMCG categories. As a result, this framework can be used for simulation models and in early warning systems.

However, one limitation of this approach is that an indicator-based assessment simplifies the complex supply chain dynamics, but potentially creates false precision through numerical scoring. The framework treats indicators as discrete dimensions, not explicitly capturing cascading effects and probabilistic interdependencies. Guertler and Spinler (2015) demonstrate that understanding interrelationships is important to increase the effectiveness of risk monitoring and that network-oriented approaches can reveal how the occurrence of one risk increases the probability and/or impact of another risk.

Furthermore, data collection requirements may prove demanding for public authorities, particularly for smaller companies or supply chain segments with little documentation. Threshold values, while derived through expert consultations, require empirical validation through historical disruption analysis.

As future research, this framework could be extended by a cross-impact analysis, systematically mapping interdependencies between the nine indicators for each product archetype. This would enable development of composite risk scores that account for cascading effects, providing policymakers with more accurate system-wide vulnerability assessments. Additionally, empirical calibration of thresholds through historical data would strengthen the framework's predictive capacity. While expert-derived thresholds provide operational plausibility, statistical validation through analysis of past supply chain disruptions would enhance confidence in severity classifications and enable refinement of intervention triggers.

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