Open Science
BRAZIL

DOI: https://doi.org/10.37497/opsbrazil.43

PREPRINT

SUPPLY CHAIN RESILIENCE IN ENERGY OPERATIONS: INTEGRATING INTELLIGENT DATA, STRATEGIC INVENTORY, AND REGIONAL SUPPLY NETWORKS

Resiliência da Cadeia de Suprimentos nas Operações de Energia: Integração de Dados Inteligentes, Estoque Estratégico e Redes Regionais de Suprimentos

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ABSTRACT | Supply chain resilience has become a strategic requirement for organizations operating in increasingly complex and volatile environments. This challenge is particularly significant in the energy sector, where supply networks depend on geographically dispersed suppliers, specialized materials, complex logistics systems, regulatory requirements, and time-sensitive field operations. This article examines how intelligent data, strategic inventory management, regional supply networks, and operational excellence can be integrated to strengthen supply chain resilience in energy operations. The study adopts a qualitative, case-based analytical approach grounded in documented professional experience across global energy and industrial supply chains. The analysis examines supply chain transformation initiatives involving inventory strategy, vendor-managed inventory, localization, logistics network redesign, demand-to-delivery transformation, sourcing optimization, and digital supply chain capabilities. The evidence indicates that resilience should not be interpreted simply as maintaining additional inventory or duplicating suppliers. Rather, resilient supply networks emerge from the coordinated management of information, inventory, sourcing, logistics, regional capabilities, and organizational processes. The analysis further indicates that digital technologies, including artificial intelligence and the Internet of Things, can enhance supply chain visibility, forecasting, planning, and decision-making when supported by structured and reliable data. The findings suggest that organizations can simultaneously improve resilience and financial performance by redesigning inventory strategies, developing regional supply capabilities, optimizing logistics networks, and integrating data-driven decision-making into operational governance.

Keywords | Supply Chain Resilience; Energy Supply Chain; Inventory Management; Intelligent Data; Digital Supply Chain; Regionalization; Localization; Operational Excellence.

Submetido: 18-08-2026
Postado: 18-08-2026
e-ISSN: 2764-9822

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RESUMO | A resiliência da cadeia de suprimentos tornou-se um requisito estratégico para organizações que operam em ambientes cada vez mais complexos e voláteis. Esse desafio é particularmente relevante no setor de energia, no qual as redes de suprimentos dependem de fornecedores geograficamente dispersos, materiais especializados, sistemas logísticos complexos, requisitos regulatórios e operações de campo sensíveis ao tempo. Este artigo analisa como dados inteligentes, gestão estratégica de estoques, redes regionais de suprimentos e excelência operacional podem ser integrados para fortalecer a resiliência das cadeias de suprimentos em operações de energia. O estudo adota uma abordagem qualitativa e analítica, baseada em casos e fundamentada em experiência profissional documentada em cadeias de suprimentos globais. Os resultados indicam que a resiliência não deve ser interpretada simplesmente como manutenção de estoques adicionais ou duplicação de fornecedores, mas como resultado da gestão coordenada de informação, estoques, sourcing, logística, capacidades regionais e processos organizacionais. A análise também indica que tecnologias digitais, incluindo inteligência artificial e Internet das Coisas, podem ampliar a visibilidade, a previsão, o planejamento e a tomada de decisões quando apoiadas por dados estruturados e confiáveis.

Palavras-chave | Resiliência da cadeia de suprimentos; cadeia de suprimentos de energia; gestão de estoques; dados inteligentes; regionalização.

1. INTRODUCTION

Global supply chains have become increasingly exposed to disruptions resulting from geopolitical uncertainty, transportation constraints, supplier concentration, regulatory complexity, demand volatility, and rapidly changing operating environments. These challenges are particularly significant in the energy industry, where supply chain performance can directly influence field operations, equipment availability, service reliability, production continuity, and financial performance.

Traditional supply chain strategies have frequently emphasized cost reduction, inventory minimization, global sourcing, and supplier consolidation. These approaches can generate substantial efficiency gains under stable conditions. However, excessive optimization around cost can simultaneously increase exposure to disruptions by reducing buffers, increasing dependence on geographically distant suppliers, and extending recovery times.

Supply chain resilience has consequently become an important strategic capability. Christopher and Peck (2004) describe resilient supply chains as systems capable of responding effectively to unexpected events, while Sheffi and Rice (2005) emphasize the importance of organizational capabilities that allow companies to absorb disruptions and recover operational performance.

Resilience, however, should not be interpreted as the opposite of efficiency. The strategic challenge is to identify where additional flexibility, redundancy, regional capability, or inventory creates sufficient operational value to justify its cost.

This issue is particularly relevant to energy operations. Critical materials may have relatively low demand frequency but substantial operational importance. A component that costs comparatively little may nevertheless generate significant economic consequences if its absence delays a wellsite operation, maintenance activity, or production process.

At the same time, digital transformation is changing the way supply chains can respond to uncertainty. Artificial intelligence, Internet of Things technologies, advanced analytics, and digital supply chain platforms can improve visibility, forecasting, planning, and decision-making. Industry discussions involving Aniebo Etudor have similarly emphasized the importance of structured data and digital technologies in improving supply chain visibility and predictability.

However, technological sophistication alone does not create resilience. Digital systems depend on reliable data, standardized processes, appropriate governance, and organizational capabilities capable of converting information into decisions.

This article therefore examines the relationship between four strategic dimensions of supply chain resilience:

- strategic inventory management;
- logistics and network design;
- regionalization and localization;
- intelligent data and digital transformation.

The central research question is:

> **How can organizations integrate intelligent data, strategic inventory management, regional supply networks, and operational excellence to strengthen supply chain resilience in energy operations?**

2. LITERATURE REVIEW

2.1 Supply Chain Resilience

Supply chain resilience has developed into a significant field of research as organizations have become increasingly exposed to complex and interconnected risks.

Christopher and Peck (2004) argue that resilience requires organizations to understand their supply networks, establish collaborative relationships, develop flexibility, and prepare for unexpected events.

Sheffi and Rice (2005) similarly emphasize that resilient enterprises require mechanisms capable of absorbing disruptions and restoring performance.

Craighead et al. (2007) demonstrate that the severity of supply chain disruptions is influenced by both supply chain design characteristics and the mitigation capabilities available to organizations.

These perspectives suggest that resilience is not simply a response mechanism activated after disruption occurs. It is a capability that should be embedded in supply network design.

2.2 Inventory Management and Resilience

Inventory represents one of the most important areas in which financial efficiency and operational resilience intersect.

Traditional inventory optimization focuses on demand variability, replenishment lead times, carrying costs, and service levels. In critical industrial environments, however, inventory decisions must also consider material criticality, supplier concentration, replacement difficulty, transportation exposure, and the potential cost of operational downtime.

This creates an important distinction between **excess inventory** and **strategic inventory**.

Excess inventory represents capital that does not provide proportional operational value. Strategic inventory, in contrast, provides a deliberate buffer against supply uncertainty and operational risk.

The objective of a resilient inventory strategy is therefore not simply to increase or decrease stock levels, but to determine where inventory generates the greatest operational value.

2.3 Digital Supply Chains and Intelligent Data

Digital technologies are increasingly transforming supply chain management.

Artificial intelligence, IoT, advanced analytics, digital twins, and integrated enterprise systems can increase visibility across complex supply networks and support more informed operational decisions.

Ivanov and Dolgui (2020) demonstrate how digital supply chain twins can support the management of disruption risks and resilience by creating more comprehensive representations of interconnected supply networks.

However, digital transformation also creates a fundamental organizational requirement: data must be structured, reliable, accessible, and governed.

The importance of structured data has also been emphasized in industry discussions. In a 2024 Procurement & Supply Chain LIVE session, Aniebo Etudor highlighted the role of digital technologies in increasing supply chain visibility and enabling organizations to use structured data for everyday decision-making and forecasting.

Thus, the transition toward artificial intelligence should be understood as part of a broader process of organizational data maturity.

2.4 Regionalization and Localization

Global sourcing has historically provided organizations with access to lower-cost production and specialized suppliers. However, geographic concentration can increase exposure to transportation disruptions, trade restrictions, geopolitical events, and extended replenishment cycles.

Colicchia et al. (2010) emphasize the importance of considering resilience when designing globally sourced supply networks.

Regionalization can provide an alternative or complementary mechanism. Regional suppliers, manufacturing capabilities, logistics hubs, and service ecosystems may reduce lead times and create additional sources of supply.

The strategic objective is therefore not necessarily to replace global sourcing with local sourcing. Instead, resilient supply networks can combine global economies of scale with strategically positioned regional capabilities.

3. METHODOLOGY

This study adopts a qualitative case-based analytical approach.

The analysis is based on documented professional experience in global supply chain management across energy, industrial, and consumer-goods organizations. The evidence includes supply chain transformation initiatives involving inventory strategy, sourcing, logistics, vendor-managed inventory, localization, demand-to-delivery processes, working capital, and operational excellence.

The study does not attempt to establish statistical causality. Instead, it examines documented operational outcomes and interprets them through established theoretical concepts in supply chain resilience and network design.

The analysis is organized around four dimensions:

- **Dimension 1 — Strategic Inventory Management:** Inventory optimization, inventory turns, working capital, vendor-managed inventory, consignment, and redeployment.
- **Dimension 2 — Logistics Network Resilience:** Transportation mode optimization, network redesign, geographic diversification, and service reliability.
- **Dimension 3 — Localization and Sourcing:** Best-value-country sourcing, localization, supplier ecosystems, and sourcing diversification.
- **Dimension 4 — Digitalization and Operational Excellence:** Advanced analytics, structured data, digital technologies, standardized performance metrics, Lean Six Sigma, and cross-functional governance.

The professional evidence was selected because these dimensions are directly related to the ability of organizations to absorb disruptions while maintaining operational and financial performance.

4. FINDINGS AND ANALYSIS

4.1 Strategic Inventory as a Resilience Mechanism

The analysis demonstrates that inventory optimization and resilience should not be treated as inherently conflicting objectives.

Within the global Drilling & Completion Fluids operation, a five-year inventory strategy was established to increase inventory turns from 4.1 to 5.5 in FY2026, with a long-term target above 7.0. Structural initiatives associated with the strategy were projected to unlock approximately US$35–45 million in free cash flow.

The strategic significance of this approach lies in differentiating inventory according to operational value.

Rather than applying indiscriminate inventory reduction, the strategy seeks to identify inventory that protects critical operations while reducing excess, duplication, and structurally inefficient stock.

This approach illustrates a central principle of resilience: organizations do not necessarily become more resilient by holding more inventory. They become more resilient when the **right inventory is positioned in the right location at the right time**.

4.2 Vendor-Managed Inventory

Vendor-managed inventory provides an additional mechanism for balancing resilience and working capital.

Within the analyzed regional operation, VMI programs released approximately US$30 million annually while maintaining service levels above 95%.

The result demonstrates that resilience can be achieved through network-level coordination rather than solely through internal ownership of inventory.

Under appropriately designed VMI arrangements, suppliers assume greater responsibility for replenishment and inventory availability while the focal organization can reduce working capital exposure.

This approach illustrates the broader principle that supply chain resilience can emerge from collaboration and governance across organizational boundaries.

4.3 Logistics Network Redesign

A significant logistics transformation involved the development of a coastal shipping network connecting 15 Sub-Saharan African seaports.

The initiative shifted a significant portion of freight from air transportation to maritime transportation, generating approximately 50% freight-cost reduction while achieving approximately 90% on-time delivery.

The case demonstrates that logistics network design can simultaneously influence cost, service, and resilience.

A network that incorporates multiple transportation options and strategically positioned gateways can provide greater flexibility than a system heavily dependent on premium transportation.

The result also demonstrates that resilience does not necessarily require higher logistics expenditure. In some circumstances, resilience and efficiency can be achieved through structural network redesign.

4.4 Localization and Supplier Strategy

Localization provides another important dimension of supply chain resilience.

Within the analyzed operations, localization initiatives generated approximately US$10 million in cash-flow improvement and approximately US$50 million in cost-out at program level over a three-year period.

Localization can reduce geographic exposure while improving supplier responsiveness and potentially shortening replenishment cycles.

However, localization should not be interpreted as an absolute replacement for global sourcing. Instead, organizations should determine which categories and components justify regional sourcing based on criticality, lead time, supply risk, cost, technical requirements, and alternative availability.

This creates a differentiated sourcing architecture in which global suppliers provide scale while regional capabilities provide flexibility and resilience.

4.5 Demand-to-Delivery Transformation

Supply chain resilience also depends on organizational integration.

A Demand-to-Delivery transformation aligned more than 200 professionals across workstreams and introduced performance metrics designed to improve end-to-end execution.

The transformation resulted in a reported 25% improvement in service delivery.

The finding illustrates that supply chain resilience is not solely a procurement or logistics problem.

Demand planning, sourcing, manufacturing, materials management, logistics, commercial functions, and field operations must operate as interconnected components of the same system.

Cross-functional governance therefore becomes an important resilience capability.

4.6 Long-Range Planning and Lead-Time Reduction

Long-range planning provides another mechanism through which organizations can improve resilience.

Within the analyzed regional operation, the establishment of a long-range planning cycle reduced lead times by approximately 20% and generated approximately US$14 million in operating cash-flow improvement.

The result suggests that resilience can be strengthened by increasing planning horizons and reducing uncertainty before operational requirements become urgent.

Longer planning horizons allow organizations to identify supply constraints earlier, coordinate production and procurement decisions, and reduce dependence on emergency logistics.

4.7 Sourcing Optimization and Cost Competitiveness

Strategic sourcing also contributes to resilience when it reduces excessive dependence on individual sources and improves the competitiveness of the supply base.

Within the global Drilling & Completion Fluids operation, sourcing and best-value-country strategies generated approximately US$25 million in product cost savings, associated with approximately one percentage point of EBITDA margin expansion.

The strategic implication is that sourcing resilience and cost competitiveness do not necessarily represent opposing objectives.

A diversified and appropriately structured sourcing network can improve negotiating leverage, create alternatives, and reduce exposure while simultaneously improving total delivered cost.

4.8 Digital Supply Chain and Intelligent Data

The analysis demonstrates the increasing role of data and digital technologies in supply chain management.

In public industry discussions, Aniebo Etudor has emphasized that digital technologies can improve supply chain visibility by converting large volumes of information into structured data that can support everyday decisions. He has also highlighted applications of AI and IoT in forecasting and planning.

These observations are consistent with the literature on digital supply chain resilience.

The strategic value of artificial intelligence does not simply arise from automation. It arises from the ability to identify patterns, improve forecasts, evaluate scenarios, and support faster decision-making.

However, these benefits depend on data quality and organizational readiness.

An organization that automates poorly structured processes may simply accelerate existing problems. Digital transformation therefore requires process discipline, data governance, change management, and workforce capability.

5. DISCUSSION

The findings indicate that supply chain resilience in energy operations is inherently multidimensional.

Inventory provides protection against uncertainty, but excessive inventory creates financial inefficiency.

Global sourcing provides scale and cost advantages, but geographic concentration can increase exposure to disruption.

Regionalization can increase responsiveness, but local supply may not always provide the same economies of scale as global sourcing.

Digital technologies can improve visibility and forecasting, but their effectiveness depends on the quality and structure of organizational data.

Consequently, resilience should not be understood as the maximization of any single capability.

Instead, it should be understood as the **optimization of the entire supply network under uncertainty**.

The evidence suggests that resilient supply chains integrate several mechanisms:

- strategically positioned inventory;
- alternative sourcing options;
- regional capabilities;
- flexible logistics networks;
- long-range planning;
- cross-functional governance;
- reliable operational data;
- advanced analytics;
- collaborative supplier relationships.

These mechanisms reinforce one another.

Better data improves forecasting.

Better forecasting improves inventory positioning.

Improved inventory positioning reduces working capital requirements while protecting critical operations.

Regional sourcing reduces geographic exposure.

Flexible logistics networks reduce dependence on a single transportation mode.

Cross-functional governance connects these capabilities.

This integrated architecture represents a more mature approach to supply chain resilience.

6. MANAGERIAL IMPLICATIONS

The findings provide several practical implications for supply chain leaders in energy and other asset-intensive industries.

6.1 Reclassify Inventory According to Risk

Inventory should be evaluated according to operational criticality, lead time, supplier concentration, substitution possibilities, and the potential consequences of stockouts.

6.2 Treat Working Capital as a Resilience Variable

Working capital optimization should not focus exclusively on reducing inventory. The objective should be to release unnecessary capital while preserving the inventory required to protect operational continuity.

6.3 Build Flexible Logistics Networks

Transportation strategies should incorporate appropriate combinations of maritime, road, air, and regional logistics capabilities according to criticality and urgency.

6.4 Develop Strategic Regional Capabilities

Localization should be applied selectively to categories where regional capabilities can provide meaningful improvements in lead time, responsiveness, supply security, or cost.

6.5 Integrate Digital Technologies with Process Discipline

Artificial intelligence, IoT, and advanced analytics should be implemented alongside data governance, standardized processes, and change-management capabilities.

6.6 Measure Resilience Through Multiple Performance Indicators

Organizations should monitor not only cost but also inventory turns, working capital, lead time, service reliability, recovery capability, supplier concentration, and operational continuity.

7. CONCLUSION

Supply chain resilience has become a strategic capability for energy organizations operating in increasingly uncertain and interconnected environments.

The analysis presented in this article demonstrates that resilience can be strengthened through the coordinated management of inventory, sourcing, logistics, regionalization, planning, data, and organizational processes.

The documented professional cases analyzed in this study demonstrate that resilience does not necessarily require greater inventory or higher operating costs. Strategic inventory redesign generated projected free-cash-flow opportunities while increasing inventory turns. Vendor-managed inventory released working capital while maintaining high service

levels. Logistics network redesign reduced transportation costs while maintaining delivery performance. Localization initiatives improved cash flow and cost competitiveness while strengthening regional supply capabilities.

These findings suggest that the traditional distinction between efficiency and resilience should be reconsidered.

The strongest supply chains are not necessarily those with the lowest inventory, the largest supplier base, or the most advanced technology. They are those capable of **allocating resources intelligently according to operational risk and strategic value**.

Digital transformation reinforces this capability when reliable data is converted into actionable intelligence. Artificial intelligence and IoT can improve visibility, forecasting, and decision-making, but their effectiveness depends on the quality of the organizational foundations on which they operate.

The central conclusion is therefore that supply chain resilience should be designed as an integrated organizational capability.

For energy companies, this means connecting strategic inventory management, sourcing, regionalization, logistics, digital technologies, and operational excellence within a common framework focused on continuity, responsiveness, financial performance, and long-term competitiveness.

Future empirical research should test this framework through longitudinal studies involving energy companies and other asset-intensive industries. Particular attention should be given to the relationships among data maturity, inventory positioning, supplier diversification, localization, recovery time, service reliability, working capital, and financial performance.

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