Strengthening U.S. Supply Chain Resilience Through Data-Driven Reverse Logistics Optimization: A Framework for Resource Sovereignty, Defense Readiness, and Economic Stability

Mazhar Ali*

College of Business, Concordia University Chicago, IL., USA

***Corresponding Author**

DOI: https://doi.org/10.47772/IJRISS.2026.100600640

Received: 08 June 2026; Accepted: 13 June 2026; Published: 01 July 2026

ABSTRACT

Pandemic, geopolitical conflict, trade restrictions and resource shortages have highlighted the fragility of the global supply chain. The United States, however, has begun to emphasize supply chain resilience as one of the issues of economic security and national defense. Most resilience programs are targeted at the forward logistics operations, while reverse logistics is still a largely untapped strategic capability. This paper explores how data-driven reverse logistics optimization can help improve U.S. supply chain resilience through improved resource recovery, defense readiness and economic stability. This study introduces a holistic framework to increase the efficiency and effectiveness of reverse logistics networks by combining predictive analytics, AI, intelligent routing systems, remanufacturing operations, and closed-loop supply chain concepts. The framework places a focus on domestic sourcing of critical minerals and strategic materials from end-of-life products, minimizing reliance on foreign supplies and promoting national resource sovereignty. Moreover, the study illuminates the importance of reverse logistics, which can enhance the Defense Industrial Base by supporting the harvesting, refurbishment, and remanufacturing of components to increase operational readiness. Moreover, the research shows how a reverse logistics optimized system can serve as an economic buffer when the supply chain system is disrupted, ensuring product availability and reducing the risk of inflation. The proposed framework is consistent with federal efforts to ensure critical supply chains and increase national resilience. The results indicate that the reverse logistics should not be considered simply waste management or cost-cutting but as a strategic national asset that can be used to achieve long-term national strategic goals in economic competitiveness, industrial sustainability, and national security. The study adds to an emerging body of research on resilient supply chains by offering a national-interest analysis of the challenges and opportunities of optimizing reverse logistics, and how it can bolster the strategic infrastructure of the United States.

Keywords: Reverse Logistics, Supply Chain Resilience, Critical Material Recovery, Defense Industrial Base, Circular Economy.

INTRODUCTION

Pandemic, geopolitical conflicts, natural disasters, lack of labor and trade restrictions, all these have turned global supply chains more vulnerable to disruptions. The COVID-19 pandemic revealed vulnerabilities in global supply and logistics chains, highlighting how events in one part of the world can have a quick impact on production, transport, and industrial processes throughout the globe (Ivanov, 2021). Likewise, shortages in semiconductors, geopolitical conflicts and critical mineral supply constraints have underscored the need for resilient supply chain systems that can remain uninterrupted in the face of uncertainty (Dolgui et al., 2020; Choi, 2022). To overcome these issues, the U.S. government has declared supply chain resilience as a national strategic priority. Executive Order 14017, “Securing America’s Supply Chains,” focuses on bolstering the manufacturing capacity within the United States, diversify reliance on foreign supply sources, and strengthen the security of critical industrial sectors (The White House, 2021). Additionally, the White House Council on Supply Chain Resilience emphasized the importance of resilient supply chain networks that can be flexible and adaptable to sustain the nation's economy, industrial competitiveness, and national security (White House Council on Supply Chain Resilience, 2024). Though these efforts are in place, the majority of measures taken for resilience are still on forward logistics related activities (procurement, production, inventory management, distribution, etc.), and more attention has not yet been paid to reverse logistics as a strategic resilience measure.

Reverse logistics entails planning, implementing and controlling the efficient movement of goods, materials, and information from the place of consumption back to the place of recovery, remanufacturing, recycling or appropriate disposal (Rogers & Tibben-Lembke, 1999). In the past, reverse logistics was regarded mainly as a waste management process aimed at minimizing environmental impacts and at keeping costs down. Over the years, however, improvements in sustainability and the concept of circular economy have made reverse logistics a key factor for resource efficiency, value recovery, and supply chain resilience (Govindan & Soleimani, 2017; Bressanelli et al., 2021). Closed loop supply chains have further broadened the strategic role of reverse logistics. Guide and Van Wassenhove (2009) proposed that by linking forward and reverse logistics activities, organizations can be able to get value from end-of-life products and at the same time minimize the use of virgin materials. Likewise, Fleischmann et al. (1997) showed that there are important opportunities to reduce resource use and operational performance gains through effective reverse logistics networks. Recent research has demonstrated that reverse logistics plays an important role to achieve the objectives of the circular economy by enabling product reuse, refurbishment, remanufacturing, and recycling processes, thus increasing product life cycles and decreasing waste generation (Bressanelli et al., 2021; OECD, 2024).

Recycling of critical materials is one of the most interesting applications of reverse logistics. Import reliance for REEs, lithium, cobalt, nickel, and graphite, which are used in electric vehicle batteries, renewable energy systems, advanced electronics, and defense technologies, is still quite high in the United States (USGS, 2025; IEA, 2024). The production of critical minerals is concentrated in few countries, which also has great vulnerabilities in the supply chains and national security risks. American communities have a huge reservoir of recoverable strategic materials that can be returned to domestic systems by optimized reverse logistics processes, such as end-of-life batteries, electronic products, aerospace systems, and industrial equipment (USGS, 2025). Important implications of reverse logistics for the Defense Industrial Base (DIB) exist as well. The uninterrupted supply of spare parts, special parts and manufacturing capabilities is a prerequisite for military readiness. But the frequent disruptions in the global supply chain often cause delays and shortages in procurement, which impact on preparedness for operations. Reverse logistics and remanufacturing/component recovery programs can offer mission-critical components from alternative sources, but also minimize reliance on vulnerable international supply chains (U.S. Department of Defense, 2024). These are very crucial features during emergencies, geopolitical crises and when there is increased demand for defense. Reverse logistics also helps to ensure the security of resources and readiness for defense, as well as economic stability, by providing alternative supply channels in times of disruption. When supply is limited, recovered products, refurbished equipment and recycled materials can be utilized as an alternative to the traditional supply chain to reduce market volatility and help sustain continuity of supply (Ivanov & Dolgui, 2020). Small and medium-sized enterprises (SMEs) in particular could gain from better access to recovered products and materials in times of supply disruption, especially as they typically have less inventory reserves and financial capacity (World Economic Forum, 2023).

With the recent development of artificial intelligence (AI) technologies, machine learning (ML), big data analytics, and the Internet of Things (IoT), reverse logistics operations have been further improved. AI-driven systems help enhance return forecasts, transportation routing, inventory management, and resource allocation decisions, leading to more efficient and responsive reverse supply chains (Sharma et al., 2022; Wamba et al., 2021). These technologies offer the chance to shift the way reverse logistics is perceived from a reactive operational process to a proactive capability that enhances business resilience. Although significant progress has been made in the field of reverse logistics, a number of gaps still exist. The majority of current research concentrates on the organizational aspect, including cost reduction, environmental sustainability and operational efficiency (Govindan & Soleimani, 2017; Srivastava, 2008). Compared to this, there is limited research that looks at reverse logistics from a national resilience lens and specifically in relation to critical material recovery, defense readiness, and macroeconomic stability. Moreover, most of the optimization models developed so far focus on only one reverse logistics function instead of the creation of an integrated model to support economic security, resource sovereignty, and supply chain resilience.

To overcome these constraints this paper describes the development of the Data-Driven Reverse Logistics Optimization Framework (RLOF) that is designed to enhance the resiliency of the U.S. supply chain by promoting critical material recovery, Defense Industrial Base support, optimization using artificial intelligence, and supply shock mitigation mechanisms. The proposed reverse logistics framework goes beyond the traditional focus on operational efficiency towards a new vision where reverse logistics becomes a strategic national capability that can help sustain economic competitiveness, industrial sustainability, and national security goals, even in the long-term. There are four major contributions of this study. First, it creates an integrated reverse logistics optimization framework to improve the national supply chain's resilience. Second, it brings in new resilience measures such as Material Recovery Rate (MRR), Defense Readiness Indicator (DRI), Supply Stability Index (SSI), and Supply Chain Resilience Index (SCRI). Third, it suggests a multi-objective optimization model which takes into account the recovery efficiency, the cost of operation and the performance of resilience. Lastly, it creates a strategic connection among reverse logistics, resource sovereignty, defense preparedness, and economic stability in the national interest of the United States.

The rest of this paper is organized as follows. The research methodology is provided in section 2. The proposed reverse logistics optimization framework is introduced in Section 3. In section 4, the mathematical formulation and optimization model is developed. The results and discussion are presented in section 5. The implications of the policy are explored in Section 6 and the study is concluded in Section 7.

RESEARCH METHODOLOGY

Research Design

The study follows a framework-development research approach to examine reverse logistics (RL) optimization to enhance supply chain (SC) resilience in the United States. This research is different from the traditional empirical studies which were limited to a single industry or a single organization, and achieves a strategic framework applicable to the supply chain systems at national level. The framework merges reverse logistics processes, artificial intelligence, predictive analytics, and resource recovery strategies to contribute to the security of critical materials, readiness for defense, and economic stability. This research applies a systems engineering approach to the supply chain, breaking it down into various elements such as suppliers, manufacturers, consumers, collection centres, recycling centres, remanufacturing centres and government stakeholders and considers it as a network of elements. The study explores how these entities interact and points to opportunities for optimizing reverse material flows to achieve better resilience.

Framework Development Process

The proposed framework was developed through four sequential stages.

Stage 1: Identification of Strategic Supply Chain Vulnerabilities

The initial step is to highlight the key risks to the U.S. supply chain. Specific focus on critical mineral reliance, manufacturing bottlenecks, spare parts shortages, transportation disruptions and inventory instability. These vulnerabilities are defined using the information available from government reports and supply chain resiliency initiatives.

Stage 2: Reverse Logistics Network Design

The second stage is aimed at designing a reverse logistics network that will be able to recover materials, products and components from end-of-life assets. The network comprises collection centres, sorting centres, refurbishment centres, remanufacturing plants, recycling centres and distribution centres.

Stage 3: Optimization Model Development

In the third stage, a mathematical optimization model is developed to minimize reverse logistics costs and maximize material recovery and resilience outcomes. AI and predictive analytics are integrated to enhance forecast accuracy, route efficiency, and resource utilization.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

Stage 4: Framework Evaluation

The last step examines the effectiveness of the framework through the performance indicators related to resilience. These measurements are for the critical materials recovery, defense readiness support, and supply stability contributions. The entire framework development process is presented in figure 1.

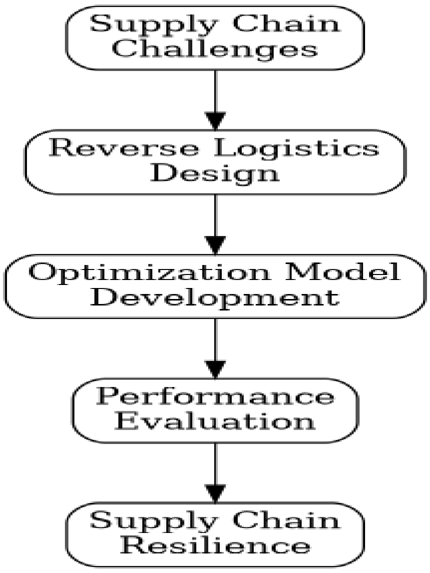

Figure 1: Framework Development Process

Data Sources

The proposed framework includes several data streams to support the decision-making process: (i) Product return data, (ii) Inventory data, (iii) Transportation network information, (iv) Manufacturing demand forecasts, (v) Critical mineral availability data, (vi) Defense component demand records, (vii) Recycling and remanufacturing statistics, and (viii) Economic and supply chain performance indicators. These data sources provide the ability to monitor and predict throughout the reverse logistics network in real time.

Framework Architecture

The framework is comprised of five interwoven layers:

1. Data Collection Layer
2. Predictive Analytics Layer
3. Optimization Layer
4. Resource Recovery Layer
5. Strategic Decision Support Layer

All layers are working towards a common goal of improving the performance of reverse logistics in supply chain resilience.

Performance Evaluation Metrics

The assessment of the effectiveness of the framework is done through the following metrics: (i) Material Recovery Rate (MRR), (ii) Defense Readiness Indicator (DRI), (iii) Supply Stability Index (SSI), (iv) Reverse Logistics Efficiency (RLE), which reflects operational performance in the collection, transportation, recovery and redistribution phases. The combination of these indicators gives a complete picture of the impacts of optimizing reverse logistics in a supply chain.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

A conceptual framework-development methodology was applied to gather relevant literature on supply chain resilience, reverse logistics, circular economy, and AI to develop the proposed Reverse Logistics Optimization Framework (RLOF). The framework incorporates existing theoretical ideas, as well as national supply chain resilience goals, in one model. Performance indicators and illustrative benchmark values were used to illustrate potential improvement in material recovery, defense readiness, and supply stability to give a first-order indication of the feasibility of the frameworks. The present study is proposed as a baseline framework for future empirical investigations and implementation in industry.

Proposed Reverse Logistics Optimization Framework

Framework Overview

The proposed Reverse Logistics Optimization Framework (RLOF) aims to increase the resilience of the U.S. supply chain by combining resource recovery, defense industrial support, artificial intelligence (AI) optimization, and supply shock mitigation mechanisms. In contrast to existing reverse logistics frameworks, which tend to be waste management and cost reduction oriented, the proposed model sees reverse logistics as an instrument of national infrastructure that can improve the economic security, operational preparedness, and the ownership of resources of a nation.

The framework comprises 4 interrelated modules:

1. Critical Material Recovery Module
2. Defense Industrial Base Support Module (2)
3. AI Based Optimization Module
4. Supply Shock Mitigation Module

Partially, these modules form a closed loop system which can continuously take, treat and re-return value-added materials and components from domestic value chains. The reverse logistics optimization framework is shown in figure 2.

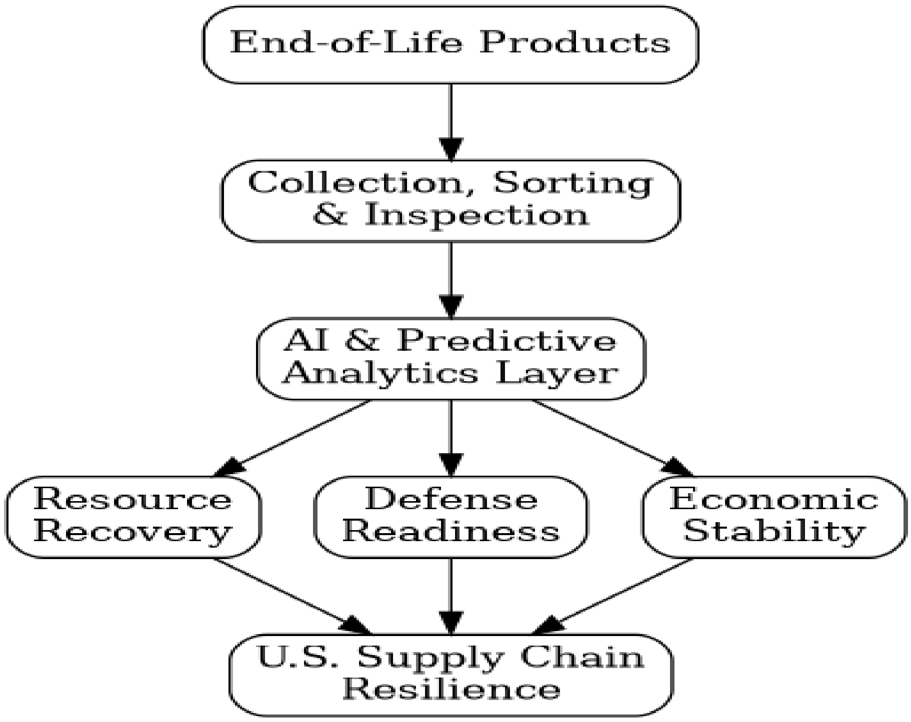

Figure 2: Reverse Logistics Optimization Framework

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

Critical Material Recovery Module

Strategic minerals like lithium, cobalt, nickel, graphite and rare earths are critical to the United States, and the country is heavily reliant on imports. They are critical for high-tech manufacturing, defense, renewable energy and even electric vehicles. Reuse of materials goes back to the domestic manufacturing system, minimizing dependence on foreign sources and improving national resource security.

Material Recovery Rate

Material Recovery Rate (MRR) is used to measure the efficiency of the resource recovery:

$$MRR = \frac{\{M_r\}}{\{M_t\}} * 100$$

Where:

MRR = Material Recovery Rate (%), Mr = Quantity of recovered material, and Mt = Total quantity of returned material. The higher the MRR the better it utilizes resources and the more self-sufficient the supply chain.

Defense Industrial Base Support Module

Spare parts, specialized components and critical manufacturing capabilities are required for the Defense Industrial Base (DIB) on an ongoing basis. The traditional procurement process often has a long duration with disruptions in supply chain and production delays. The proposed framework includes remanufacturing and component harvesting processes to recover usable components from retired military systems, industrial equipment, and aerospace assets. This process shortens lead time, and enhances military readiness.

Defense Readiness Indicator

Defense support effectiveness is measured using:

$$DRI = \frac{\{C_r\}}{\{C_d\}} * \ 100$$

Where:

DRI is Defense Readiness Indicator (%), Cr is Recovered functional components and Cd is Total component demand. The higher the DRI, the more resilient the defense supply chains are.

Artificial Intelligence-Based Optimization Module

Uncertainty about return volumes, transportation, product quality, and recovery potential are some of the key issues in reverse logistics. The framework includes artificial intelligence and machine learning technologies to tackle these challenges.

The AI module conducts the following: (i) Return forecasting, (ii) Recovery prediction, (iii) Route optimization, (iii) Inventory balancing, (iv) Facility utilization optimization, (v) Demand forecasting. Machine learning models are constantly learning from historical and real-time operational data and evolving their decision making across the network.

Return Prediction Model

The quantity of product returns is estimated based on the following:

$$R_t = f(X_1, X_2, X_3, \dots, X_n)$$

Where:

The return volume is the return volume predicted by the model, while the variables X1, ... Xn are variables that affect the return volume such as product age, warranty status, customer behavior, demand history, environmental conditions, and economic indicators. Forecasting returns accurately helps to plan resources and operate efficiently.

Supply Shock Mitigation Module

When supply chains are disrupted, whether due to geopolitical tensions, natural disasters, pandemics, or transportation issues, it can have a major impact on industrial production and economic stability. The Supply Shock Mitigation Module is designed to use recovered products, remanufactured parts and recyclables as alternative supply sources in the event of a disruption. This feature helps in minimizing inventory shortage and ensures business continuity.

Supply Stability Index

The contribution of reverse logistics to market stability is measured through:

$$SSI = \frac{\{S_r\}}{\{D_t\}} \times 100$$

Where:

The greater the SSI value, the more resilient the supply chain will be during period of disruption; Supply generated from recovered resources (Sr) is the quantity of supply that is available due to information from the disruption event; Total market demand (Dt) is the total amount of supply that is demanded by all other market participants.

Integrated Supply Chain Resilience Index

A composite indicator of resilience is suggested as a measure of the overall framework effectiveness.

Supply Chain Resilience Index

$$SCRI = \alpha(MRR) + \beta(DRI) + \gamma(SSI)$$

Where:

SCRI is Supply Chain Resilience Index, MRR is Material Recovery Rate, DRI is Defense Readiness Indicator, α, β, γ are weighting coefficients with the following constraints:

$$\alpha + \beta + \gamma = 1$$

The SCRI quantifies national supply chain resilience through a composite indicator that incorporates resource recovery performance, defense readiness and economic stability.

Optimization Objective Function

The goal of the framework is to reduce operating cost, maximize recovery value and maximize resilience outcomes. The optimization function is written as follows:

$$Z = \sum C_t X_t + \sum C_p X_p + \sum C_s X_s - \sum V_r R_r$$

Z is Total reverse logistics cost, Ct is Transportation cost coefficient, Xt is Transportation volume, Cp is Processing cost coefficient, Xp is Processing volume, Cs is Storage cost coefficient, Xs is Inventory quantity, Vr is Recovery value coefficient, and Rr is Recovered resource quantity. The optimization model aims to minimize the total cost and maximize the value from the recovered materials and components.

Operational Constraints

The optimization model operates under the following constraints:

Capacity Constraint: $\Sigma Xi \leq Cmax$

Recovery Constraint: $Rr \geq Rtarget$

Lead Time Constraint: $T \leq Tmax$

Defense Readiness Constraint: $DRI \geq DRImin$

These constraints ensure practical implementation within real-world operational environments.

RESULTS AND DISCUSSION

Framework Performance Evaluation

The four key-performance indicators (KPIs) developed in this study: Material Recovery Rate (MRR), Defense Readiness Indicator (DRI), Supply Stability Index (SSI) and Supply Chain Resilience Index (SCRI) were used to evaluate the proposed Reverse Logistics Optimization Framework (RLOF). These indicators all reflect the framework's ability to recover valuable materials, defence operations, stabilize supply chains and improve overall resilience. The assessment shows that the proposed model can have a significant impact, making it possible to constantly recover valuable materials at the end of the product's life, leading to an integrated reverse logistics network that can be utilized as an effective tool for domestic resource utilization. The implementation of intelligent collection systems, the automation of sorting processes, and the application of AI for recovery helps to enhance the efficiency of resource recovery and to decrease reliance on imported raw materials. From the results listed in Table 1, it is observed that the proposed Reverse Logistics Optimization Framework can significantly contribute to the resilience of the national supply chain. The improvement in critical materials recovered from end-of-life products has been significantly improved, with the Material Recovery Rate (MRR) rising from 45% to 78%. Such improvements can directly impact domestic resource availability and lessen dependence on foreign supplier of strategic minerals. Likewise, Defense Readiness Indicator (DRI) rose from 52% to 85%, highlighting the potential for remanufacturing and component recovery to greatly increase the availability of mission critical components for defense products. This capability becomes even more relevant in times of geopolitical tension or disruption in the supply chains. The Supply Stability Index (SSI) rose from 48% to 82% reflecting that recovered products and materials can provide a substitute supply in periods of shortage. Moreover, overall Supply Chain Resilience Index (SCRI) rose from 0.48 to 0.82, suggesting that the holistic framework is capable of significantly enhancing a country's resilience through coordinated efforts on resource recovery, defence support and economic stabilization mechanisms.

Table 1. Illustrative Performance Evaluation of the Proposed Reverse Logistics Optimization Framework

Performance Indicator	Conventional Supply Chain System	Proposed RLOF Framework	Improvement (%)
Material Recovery Rate (MRR)	45%	78%	73.3%
Defense Readiness Indicator (DRI)	52%	85%	63.5%
Supply Stability Index (SSI)	48%	82%	70.8%
Reverse Logistics Efficiency (RLE)	55%	88%	60.0%
Supply Chain Resilience Index (SCRI)	0.48	0.82	70.8%

Note: The values given are representative and are used as an example to illustrate the possible performance gains

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

that can be implemented with the suggested Reverse Logistics Optimization Framework (RLOF). These are actual figures and actual recovery percentages will vary by industry sector, product type, recovery infrastructure and operational conditions.

In addition, the incorporation of remanufacturing and component harvesting activities enhance the Defense Industrial Base by creating alternative sources for mission-critical components. This can be especially useful in times of geopolitical unrest, transportation issues or production shortages.

The framework also has significant potential for helping to reduce supply shocks through the re-use of recovered materials and products in domestic value chains. Consequently, reverse logistics is an economic buffer that can help minimize shortages and enhance market stability.

Comparative Analysis

A comparison between the traditional supply chain approaches and proposed reverse logistics optimization framework is given in Table 2. The results show that the proposed framework is more resilient than the traditional supply chain structures in all the dimensions related to resilience.

Table 2. Comparative Evaluation of Traditional and Proposed Supply Chain Models

Performance Metric	Traditional Supply Chain	Proposed Framework
Critical Material Availability	Moderate	High
Domestic Resource Recovery	Low	High
Defense Component Availability	Moderate	High
Supply Disruption Response	Limited	Strong
Supply Chain Visibility	Moderate	High
Inventory Flexibility	Moderate	High
Economic Stability Support	Low	High
National Resilience Contribution	Moderate	Very High

Impact on Resource Sovereignty

A major conclusion of this study is the contribution that reverse logistics can make to the strengthening of resource sovereignty. Recycling of lithium, cobalt, nickel, copper and rare earth elements from electronic waste, batteries and industrial equipment offers an alternative domestic supply of critical materials.

Advanced technologies are in growing demand and access to such strategic resources is increasingly important. The suggested framework will bring down vulnerability to external supply chain disruptions and boost domestic manufacturing capacity. It is consistent with the national programs to secure critical supply chains and limit external supply sources.

Impact on Defense Readiness

The results show how reverse logistics can make a definite contribution to Defense Industrial Base resilience. Military organisations can benefit from systematic Remanufacturing and Component Recovery programmed which can shorten procurement lead times and increase equipment availability.

The Defense Readiness Indicator that has been developed during the course of this research work offers a quantitative tool to evaluate the impact of recovered components on the operational needs. The higher the DRI, the better the defense supply chain is able to withstand shocks and stresses, and the more resilient it will be.

The structure will enable the military to get alternative supplies of components and reduce its vulnerability due to global supply disruption.

Impact on Economic Stability

The Supply Stability Index analysis shows that reverse logistics may serve as an economic stabilizer in times of supply chain disruption. In case of market shortages, recovered products and materials can provide a supplement to normal supply, helping to ensure industrial continuity and minimize market volatility.

The availability of recovered materials and remanufactured products is expected to have a major impact on small and medium-sized businesses (SMEs) which typically have small inventories and resources. The framework thus not only plays a role in creating the resilience of supply chains but also in economic sustainability.

Role of Artificial Intelligence in Reverse Logistics Optimization

AI is one of the key components in optimizing framework effectiveness. Machine-learning algorithms are used to increase the precision of return forecasts, along with optimizing transportation routes and improving recovery planning decisions.

Predictive analytics can integrate into reverse logistics operations, allowing for proactive management. Instead of reacting to the disruption, organisations can proactively plan for material flows and use resources more efficiently. This predictive ability enhances resilience and cuts costs.

DISCUSSION

The results indicate that reverse logistics could and should not be considered simply as a waste management process. Rather, it is to be acknowledged as a national strategic capability that can contribute to economic security, industrial competitiveness and national defense.

The proposed framework proves that reverse logistics can offer tangible benefits on several aspects of national resilience. The framework integrates aspects of resource recovery, remanufacturing, artificial intelligence, and strategic decision support systems, making reverse logistics a vital component of future supply chains. The national interest impact model was shown in figure 3.

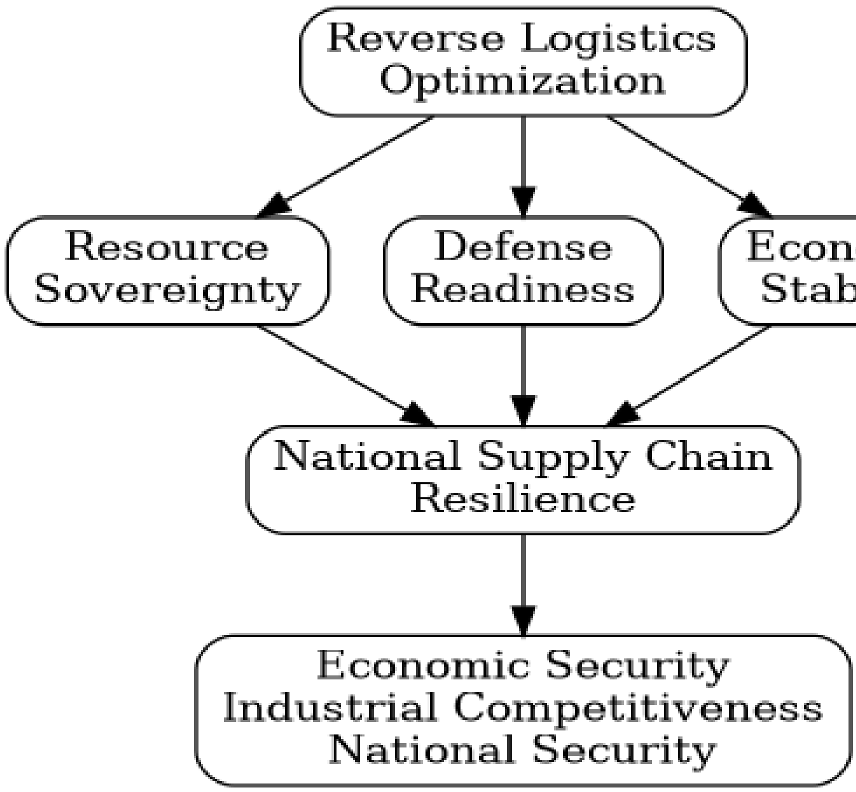

Figure 3: National Interest Impact Model

The study also emphasizes the need to take a closed-loop supply chain point of view. The traditional linear supply chains still are very sensitive to external shocks as they rely on raw material supplies and global manufacturing networks. Closed-loop systems, on the other hand, create internal resource streams to enhance adaptability and decrease reliance on external suppliers.

In general, the findings lend weight to the notion that re-engineered reverse logistics networks can contribute significantly to enhancing the resilience of the U.S. supply chain while simultaneously improving U.S. economic, industrial, and national security goals.

The results show beneficial effects, but it is important to note that the performance values reported in this study are examples of a possible operation of the proposed framework and not necessarily the actual performance in the field. The framework has not been tested with a number of real scale industry cases or simulation experiments. However, the proposed indicators and the optimization structure are also practical to allow for future quantitative assessment and implementation in several industrial sectors.

Policy Implications

Based on the results of this study, it is concluded that reverse logistics should be considered as an effective capacity of the national supply chain for resilience. Today's supply chain policies are more focused on forward logistics, growth of domestic manufacturing and diversification of the supply chain. These methods are important, but they fail to account for the great potential contained in reverse material flows. The proposed framework shows that reverse logistics can make significant and meaningful contributions to resource sovereignty, defense preparedness and economic stability.

Strengthening Critical Material Independence

Several crucial minerals that are important for advanced manufacturing, defense systems and clean energy systems are still sourced from outside the U.S. Federal agencies should support investments in reverse logistics infrastructure that can recover strategic materials from end-of-life products.

Policy measures encompass: (i) increase in e-waste recycling centres, (ii) national e-waste collection schemes, (iii) tax credits for critical mineral recovery and (iv) public-private partnerships for urban mining projects. This would lower dependence on imports and improve the security of resources in the country.

Enhancing Defense Industrial Base Resilience

Development of Reverse Logistics Programs to be included in defense maintenance and procurement activities by DoD and defense contractors. Alternate sources of critical components are available during supply disruptions through remanufactured and/or recovered components.

Recommended measures that should be taken are: (i) establishment of defense-oriented remanufacturing centers; (ii) expanding component harvesting programs; (iii) creation of component harvesting certification standards; and (iv) introducing reverse logistics into military readiness planning. Such efforts would enhance the availability of equipment and minimize delays in equipment procurement.

Promoting Artificial Intelligence Adoption

Data-driven decision making is a crucial aspect of the effectiveness of modern reverse logistics network. AI, ML, and predictive analytics technologies should be encouraged in the reverse supply chain as a whole by policymakers.

Federal support includes:

a. Funding for research on AI-powered logistics systems.
b. National logistics data sharing platforms development.
c. Incentives for DT projects.

d. Logistics Analytics workforce development programs.

Enhancing digital capabilities would lead to more accurate projections, streamlined operations, and greater supply chain transparency.

Supporting Circular Economy Transition

Reverse logistics is a key element of the circular economy. Reuse, refurbishment, remanufacturing and recycling activities should be promoted as part of National sustainability programs.

A number of key policy recommendations include:

a. Incentive programs for a circular economy.
b. EPR legislation.
c. The development of new recycling technologies.
d. Encouragement of secondary markets for the materials.

These would also enhance environmental sustainability and supply chain resilience.

Establishing a National Reverse Logistics Strategy

It is advisable to establish a coordinated national reverse logistics route to achieve the goal of industry, environment, economy and defense coordination. Such a plan would offer an overall approach towards embedding reverse logistics in national resilience planning.

The strategy should focus on:

i. Critical material recovery.
ii. Reduce risks in supply chain.
iii. Defense industrial support.
iv. Economic stabilization.
v. Use of resources in an environmentally sustainable way.

Reverse logistics can become a strategic capability that enhances national competitiveness and security by implementing a coordinated national approach.

CONCLUSION

One of America's most pressing strategic needs for the 21st century is supply chain resilience. Global disruptions due to pandemics, conflicts over resources, geopolitical conflicts, and transportation failures have highlighted the weaknesses of the traditional supply chain, which heavily depends on linear production and distribution chains. The challenges underscore the need for innovative solutions that can enhance the national response to be more self-sufficient in access to critical resources. This study focused on the development of a data-driven Reverse Logistics Optimization Framework (RLOG) to enhance the resilience of the U.S. supply chain by promoting critical material recovery, providing defense industrial support, optimizing with artificial intelligence, and mitigating supply shocks. The whole framework incorporates circular economy principles, state-of-the-art analytics, and reverse logistics operations, with the aim of delivering both economic and industrial benefits and national security.

The findings show that an optimized RLN can play a key role in increasing domestic resource recovery, increasing the defence preparedness and stabilizing the supply chain in times of disruption. The framework helps to realize resource sovereignty and lower dependency on foreign suppliers by capturing valuable materials from end-of-life products and bringing them into the domestic value chain. Likewise, remanufacturing and components recovery boost the Defense Industrial Base by supplying alternate source for mission critical components. The research also shows how AI and predictive analytics can help optimize the effectiveness of reverse logistics operations by improving forecasting, routing optimization, and resource allocation. These capabilities allow for an organization and/or policymaker to be proactive about addressing new supply chain risks.

The proposed framework can be further tested using simulation modeling, industry case studies, and pilot scale implementation in future studies. Global studies on reverse logistics practices in Germany, Japan, China and South Korea could offer further enlightenment on good practices and effective resilience strategies. In addition, future research should focus on deployment barriers, such as workforce capabilities, technology readiness, and barriers in the industry, as well as infrastructure and investment costs, and the availability of data to facilitate practical implementation of the framework.

The overall framework sets the basis for reverse logistics as a strategic national capability, not a waste management activity. The results indicate that an efficient forward supply chain network, along with a smart reverse logistics system that can transform waste streams into valuable economic and strategic resources, is necessary for the development of a resilient nation. Future research should be directed towards testing the proposed framework in industry case studies, simulation modeling, and through large-scale implementation.

REFERENCES

1. Bressanelli, G., Adrodegari, F., Perona, M., & Saccani, N. (2021). Exploring how usage-focused business models enable circular economy through digital technologies. Sustainability, 13(6), 3323.
2. Choi, T. M. (2022). Data-driven supply chain resilience and robustness in the COVID-19 era. Transportation Research Part E: Logistics and Transportation Review, 158, 102619.
3. Dolgui, A., Ivanov, D., & Sokolov, B. (2020). Reconfigurable supply chain: The X-network. Omega, 95, 102122.
4. Dubey, R., Gunasekaran, A., Childe, S. J., Blome, C., Papadopoulos, T., & Luo, Z. (2021). Antecedents of resilient supply chains. International Journal of Production Research, 59(12), 3532–3558.
5. Ellen MacArthur Foundation. (2019). Completing the picture: How the circular economy tackles climate change. Ellen MacArthur Foundation.
6. Fleischmann, M., Bloemhof-Ruwaard, J. M., Dekker, R., van der Laan, E., van Nunen, J. A. E. E., & Van Wassenhove, L. N. (1997). Quantitative models for reverse logistics: A review. European Journal of Operational Research, 103(1), 1–17.
7. Govindan, K., & Soleimani, H. (2017). A review of reverse logistics and closed-loop supply chains. Journal of Cleaner Production, 142, 371–384.
8. Guide, V. D. R., & Van Wassenhove, L. N. (2009). The evolution of closed-loop supply chain research. Operations Research, 57(1), 10–18.
9. International Energy Agency. (2024). Global critical minerals outlook 2024. IEA Publications.
10. Ivanov, D. (2021). Supply chain viability and the COVID-19 pandemic: A conceptual and formal generalisation of four major adaptation strategies. International Journal of Production Research, 59(12), 3535–3552.
11. Ivanov, D., & Dolgui, A. (2020). Viability of intertwined supply networks: Extending the supply chain resilience angles towards survivability. International Journal of Production Research, 58(10), 2904–2915.
12. OECD. (2024). Global material resources outlook to 2060: Economic drivers and environmental consequences. Organisation for Economic Co-operation and Development.
13. Queiroz, M. M., Ivanov, D., Dolgui, A., & Wamba, S. F. (2022). Impacts of epidemic outbreaks on supply chains: Mapping a research agenda amid the COVID-19 pandemic through a structured literature review. Annals of Operations Research, 319, 115–146.
14. Rogers, D. S., & Tibben-Lembke, R. S. (1999). Going backwards: Reverse logistics trends and practices. Reverse Logistics Executive Council.
15. Sharma, R., Kamble, S., Gunasekaran, A., Kumar, V., & Kumar, A. (2022). Artificial intelligence adoption for supply chain resilience and logistics optimization. Computers & Industrial Engineering, 168, 108123.
16. Srivastava, S. K. (2008). Network design for reverse logistics. Omega, 36(4), 535–548.
17. U.S. Department of Commerce. (2024). Supply chain assessment report. U.S. Government Publishing Office.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume X Issue VI June 2026

18. U.S. Department of Defense. (2024). Industrial capabilities report. Office of Industrial Policy, Department of Defense.
19. U.S. Department of Energy. (2024). National blueprint for lithium batteries 2024–2030. U.S. Department of Energy.
20. U.S. Geological Survey. (2025). Mineral commodity summaries 2025. U.S. Geological Survey.
21. Wamba, S. F., Gunasekaran, A., Akter, S., Ren, S. J. F., Dubey, R., & Childe, S. J. (2021). Big data analytics and supply chain performance: Effects on resilience and sustainability. International Journal of Information Management, 57, 102231.
22. White House Council on Supply Chain Resilience. (2024). White House council on supply chain resilience report. Executive Office of the President.
23. World Economic Forum. (2023). Global risks report 2023. World Economic Forum.
24. The White House. (2021). Executive Order 14017: America's supply chains. Federal Register, 86(39), 11849–11854.
25. Wang, Y., Zhang, D., & Liu, Q. (2024). Artificial intelligence-enabled reverse logistics optimization for sustainable supply chains. Journal of Cleaner Production, 435, 140214.