AI-DRIVEN GREEN LOGISTICS IN THE MILITARY SECTOR

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Abstract

Recent developments in sustainability policy and digital transformation have reshaped the operational environment of military logistics. European defense organizations increasingly rely on artificial intelligence to modernize logistics systems and reduce environmental impact while preserving operational effectiveness. This paper explores the contribution of AI-based logistics solutions to green military supply chains, focusing on efficiency gains, emission reduction, and improved decision-making processes. The findings indicate that the strategic deployment of artificial intelligence enhances logistical resilience and supports alignment with European sustainability objectives.

Beyond operational optimization, the study highlights the broader strategic implications of integrating artificial intelligence within defense logistics systems. AI-driven predictive analytics, intelligent energy management, and data-supported governance mechanisms contribute not only to environmental performance improvement, but also to cost rationalization and enhanced institutional transparency. The research further examines the interaction between sustainability objectives and defense resilience, arguing that green logistics, supported by artificial intelligence, represents a structural component of contemporary European defense modernization. By embedding environmental considerations into core logistics processes, military institutions strengthen long-term strategic autonomy and adaptability in an increasingly volatile geopolitical environment.

Keywords: *military logistics, artificial intelligence, sustainability, green logistics, ESG.*

Clasificare JEL : *Q56, O33, H56, M14.*

1. Introduction and context of the study

The incorporation of sustainability principles into military logistics reflects a broader shift in European defense policy toward responsible resource management and environmental protection. Military supply chains are increasingly required to adapt to sustainability objectives without compromising operational readiness (NATO, 2023).

Artificial intelligence provides advanced analytical capabilities that support logistics planning, predictive maintenance, and transport optimization (OECD, 2022). This study analyzes the strategic relevance of AI-driven green logistics solutions for enhancing sustainability and efficiency in the military sector.

In recent years, the operational complexity of military logistics has increased significantly due to geopolitical instability, supply chain disruptions, and growing environmental accountability standards. European defense structures are now required to reconcile rapid deployment capabilities with sustainability-oriented performance indicators. This dual requirement creates structural tension between traditional efficiency metrics and environmental responsibility objectives. As a result, digital transformation has become not merely an innovation strategy, but a necessity for institutional adaptation.

The European strategic environment increasingly integrates sustainability considerations into defense planning documents (European Commission, 2024), procurement policies, and infrastructure investments. Military logistics systems are no longer evaluated exclusively through operational effectiveness, but also through their environmental footprint and long-term resource sustainability. Within this evolving framework, artificial intelligence emerges as a bridging mechanism capable of translating sustainability targets into operationally measurable outcomes.

Moreover, the integration of AI technologies into military logistics reflects a broader paradigm shift toward data-driven governance models. Decision-making processes are progressively supported by predictive analytics, real-time monitoring systems, and algorithmic optimization tools. These technological advancements allow defense institutions to anticipate logistical needs, minimize inefficiencies, and reduce resource-intensive corrective interventions.

Therefore, the study of AI-driven green logistics is not limited to technological innovation, but extends to institutional modernization and strategic alignment with European sustainability policies.

The transformation of military logistics must also be understood within the broader framework of European strategic autonomy. In recent years, supply chain disruptions, energy volatility, and geopolitical tensions have exposed structural vulnerabilities in defense logistics systems. These vulnerabilities have reinforced the necessity of developing logistics models that are not only operationally efficient but also structurally resilient and environmentally sustainable.

Sustainability in defense logistics should therefore not be interpreted solely as ecological responsibility, but as a component of long-term strategic security. Excessive fuel dependency, inefficient transport networks, and unsustainable resource consumption patterns can generate operational fragility in crisis scenarios. By integrating artificial intelligence into logistics planning, military institutions enhance their capacity to reduce dependency risks while simultaneously improving environmental performance.

Furthermore, digital transformation facilitates the transition from linear supply chains to adaptive logistics ecosystems. Traditional models based on static forecasting and fixed distribution structures are increasingly replaced by dynamic, data-driven coordination mechanisms. Artificial intelligence enables real-time monitoring of stock levels, transport flows, and equipment status, creating an interconnected logistics environment capable of self-adjustment.

This systemic transformation reflects a paradigm shift from logistics as a support function to logistics as a strategic capability. In this context, AI-driven green logistics becomes a structural element of modern defense governance.

This paper brings several original contributions to the existing literature on military logistics and sustainability.

First, it proposes an integrated analytical framework that connects artificial intelligence, sustainability objectives, and defense resilience, highlighting their interdependence within contemporary European defense systems.

Second, the study extends the concept of green logistics from the civilian domain to the military sector, emphasizing the specific operational constraints and strategic implications associated with defense logistics.

Third, the research provides a structured analysis of the main operational applications of artificial intelligence in military logistics, focusing on their impact on efficiency, environmental performance, and decision-making processes.

Finally, the paper contributes to the understanding of how sustainability objectives can be operationalized within defense institutions through data-driven logistics systems, positioning artificial intelligence as a key enabler of strategic transformation.

1.1 Research methodology

The present study is based on a qualitative and exploratory research design, focusing on the conceptual and strategic analysis of artificial intelligence applications in military logistics.

The methodological approach combines a structured review of academic literature with the analysis of institutional and policy documents relevant to sustainability and defense logistics, including sources from the European Commission, NATO, OECD, and the European Defence Agency.

In addition, the research employs a comparative analytical perspective, examining the interaction between artificial intelligence, sustainability objectives, and defense resilience within European strategic frameworks. This approach allows the identification of key operational mechanisms through which AI contributes to environmental optimization and logistical efficiency.

The study does not rely on primary empirical data, but integrates secondary data sources and institutional reports in order to construct a coherent analytical framework. The objective is to highlight the strategic implications of AI-driven green logistics and to provide a structured interpretation of its role in modern defense systems.

This methodological framework supports an in-depth understanding of the transformation of military logistics from a traditional support function to a data-driven strategic capability.

2. Artificial intelligence as a driver of green military logistics

Green logistics initiatives in the military sector involve the systematic reduction of environmental impact through improved supply chain design and execution. Artificial intelligence enables these initiatives by processing operational data and generating optimized logistics scenarios.

The integration of artificial intelligence into military supply chains transforms the traditional reactive logistics model into a predictive and adaptive system. By processing large volumes of operational data, AI systems identify inefficiencies that would otherwise remain undetected within conventional planning frameworks. This analytical capability enhances coordination between logistics units, reduces redundancies, and supports dynamic allocation of resources in real time.

AI-driven optimization also contributes to the redesign of supply chain architecture. Instead of relying solely on fixed distribution routes and static inventory levels, intelligent systems continuously recalibrate logistics parameters according to operational tempo, mission requirements, and environmental constraints. This flexibility allows military organizations to maintain readiness while simultaneously reducing unnecessary transport cycles and excess stock accumulation.

Furthermore, artificial intelligence enhances interoperability within multinational defense frameworks. Standardized data processing mechanisms facilitate coordination between allied forces, improving logistical synchronization and reducing duplication of resources. In this sense, AI contributes not only to environmental sustainability but also to collective strategic efficiency.

Artificial intelligence contributes to environmental optimization not only by reducing inefficiencies, but also by generating predictive insights that shape strategic planning. Through machine learning models trained on historical operational data, AI systems identify recurring consumption patterns and propose optimized allocation strategies. These predictive mechanisms reduce the probability of surplus inventory accumulation and unnecessary transport operations, thereby limiting emissions and material waste.

Moreover, AI facilitates the integration of renewable energy sources into military infrastructure. Intelligent energy management systems can balance consumption loads, anticipate peak demand periods, and coordinate storage solutions for renewable inputs. This integration supports decarbonization objectives while preserving operational continuity.

The cumulative impact of these innovations results in a redefinition of military logistics performance indicators. Efficiency is no longer measured exclusively in terms of delivery speed and mission support capacity, but also in terms of environmental footprint and resource sustainability. Artificial intelligence provides the analytical foundation necessary to quantify and manage these multidimensional performance metrics.

2.1. Operational applications of artificial intelligence

AI technologies are applied to demand forecasting, route optimization, inventory management, and predictive maintenance of military assets. These applications contribute to reduced fuel consumption, lower emissions, and improved equipment availability.

Beyond the applications already mentioned, artificial intelligence significantly improves lifecycle management of military equipment. By continuously analyzing performance data, AI systems optimize maintenance schedules and reduce premature replacement of components. This approach extends asset durability and lowers material consumption, contributing to circular economy principles within defense logistics.

Additionally, AI enhances transport fleet management by integrating fuel efficiency analytics with operational risk assessment. Algorithms are capable of determining optimal load configurations and deployment timing, thereby minimizing energy consumption without compromising mission effectiveness (International Energy Agency, 2023). The reduction of fuel dependency has both environmental and strategic implications, particularly in contexts where energy supply lines may be vulnerable to disruption.

Artificial intelligence also supports scenario simulation and contingency planning. Through advanced modeling techniques, logistics planners can evaluate multiple operational alternatives and assess their environmental impact before implementation. This proactive capability reduces reactive, resource-intensive interventions and supports more sustainable deployment strategies.

Consequently, operational AI applications create a cumulative effect in which efficiency improvements directly translate into measurable environmental benefits.

In addition to operational forecasting and route optimization, artificial intelligence enhances cross-domain logistics coordination. By integrating data from land, air, and maritime platforms, AI systems enable synchronized resource allocation across operational theaters. This integrated visibility reduces duplication of transport efforts and prevents inefficient parallel supply chains.

AI-driven decision-support systems also contribute to human capital optimization. Logistics commanders are supported by analytical dashboards that synthesize complex datasets into actionable insights. This reduces cognitive overload and enhances the quality of strategic decisions, particularly in high-pressure operational environments.

Another critical dimension relates to lifecycle sustainability assessment. Artificial intelligence can evaluate the environmental impact of equipment usage over time, supporting procurement strategies that prioritize durability, energy efficiency, and lower emissions. By influencing acquisition decisions, AI indirectly shapes the environmental profile of future military capabilities.

These operational applications illustrate that artificial intelligence does not merely automate existing logistics processes, but fundamentally restructures the way sustainability and efficiency are conceptualized within defense institutions.

3. Sustainability and governance implications

AI-supported logistics systems generate both environmental and organizational benefits. Emission reductions and improved resource efficiency support sustainability goals, while enhanced transparency and traceability strengthen governance and accountability.

The governance dimension of AI-driven logistics extends beyond environmental monitoring. By ensuring traceability across procurement chains and distribution networks, artificial intelligence strengthens institutional accountability and reduces the risk of resource misallocation. Transparent logistics data allows decision-makers to evaluate performance indicators objectively and to align operational practices with sustainability benchmarks.

Moreover, AI facilitates integration between environmental performance metrics and broader ESG reporting frameworks (World Bank, 2023; Deloitte, 2024). Defense institutions operating within European jurisdictions increasingly face expectations to demonstrate responsible resource management and climate-conscious operational conduct. AI-generated analytics provide credible data streams that can support internal evaluation mechanisms and external reporting requirements.

From a strategic governance perspective, AI also enhances risk management capabilities. Predictive systems identify vulnerabilities within supply chains, allowing for timely corrective action. This anticipatory governance model reinforces resilience and contributes to long-term institutional stability.

As sustainability becomes embedded within defense governance structures, artificial intelligence functions as both an operational tool and a transparency mechanism.

Beyond transparency and accountability, AI-driven governance contributes to strategic cost rationalization. By correlating environmental indicators with operational expenditures, defense institutions can quantify the economic benefits of sustainability-oriented measures. Reduced fuel dependency, optimized transport routes, and predictive maintenance models generate measurable financial savings over time. This financial dimension reinforces the argument that environmental responsibility and economic efficiency are mutually reinforcing rather than contradictory objectives.

In addition, AI-supported data ecosystems enhance interoperability between allied defense structures. Standardized analytics facilitate coordinated sustainability benchmarks across multinational missions, contributing to collective efficiency within European defense cooperation frameworks. Consequently, governance implications extend from institutional accountability to transnational strategic coherence and shared sustainability standards.

The interaction between artificial intelligence, sustainability objectives, and defense resilience can be conceptualized as a triangular strategic framework. Artificial intelligence operates as the enabling technological layer, sustainability provides the normative and regulatory orientation, while resilience represents the strategic outcome of their integration.

AI enhances resilience by anticipating logistical disruptions and optimizing resource allocation in volatile environments. Sustainability reduces structural vulnerabilities associated with excessive energy dependence and inefficient consumption patterns. When combined, these elements generate a logistics architecture capable of maintaining operational continuity under conditions of uncertainty.

3.1 Conceptual model for AI-driven green logistics implementation

Based on the analytical framework developed in this study, the implementation of AI-driven green logistics in military systems can be structured as a multi-stage process integrating technological, operational, and governance dimensions.

The first stage involves data integration and digital infrastructure development, where logistics systems are connected through interoperable platforms capable of real-time data collection and processing. This stage enables visibility across supply chains and forms the foundation for AI-based optimization.

The second stage focuses on operational optimization through artificial intelligence applications, including predictive maintenance, route optimization, and dynamic inventory management. These mechanisms contribute directly to reducing resource consumption, minimizing emissions, and improving logistical efficiency.

The third stage consists of sustainability integration, where environmental performance indicators are embedded into logistics decision-making processes. AI systems support the monitoring of energy consumption, emissions, and resource allocation, enabling alignment with ESG and European sustainability objectives.

The final stage involves governance and strategic adaptation. At this level, AI-driven insights are integrated into decision-making frameworks, enhancing transparency, accountability, and resilience. This stage ensures that green logistics is not treated as an isolated initiative, but as a structural component of defense strategy.

This conceptual model illustrates how artificial intelligence can operationalize sustainability objectives within military logistics, transforming traditional supply chains into adaptive, efficient, and environmentally responsible systems.

The practical applicability of this model can be observed through existing military logistics systems and platforms currently used within NATO and European defense structures. Systems such as LOGFAS (Logistics Functional Area Services), ADAMS (Allied Deployment and Movement System), and EVE (Effective Vehicle Efficiency) support key components of logistics planning, transport coordination, and resource optimization.

These platforms already enable data integration, operational planning, and decision support, corresponding to the initial stages of the proposed model. The integration of artificial intelligence capabilities into such systems would further enhance predictive analytics, real-time optimization, and sustainability monitoring, facilitating the transition toward fully adaptive and environmentally responsible logistics systems.

4. Conclusions

In addition to improving operational efficiency, AI-driven green logistics contributes to the strategic modernization of defense institutions. The alignment between digital transformation and sustainability objectives strengthens institutional credibility and enhances compatibility with European policy frameworks. By integrating predictive analytics, energy optimization systems, and data-driven governance mechanisms, military organizations create logistics models that are simultaneously resilient, adaptive, and environmentally responsible.

The long-term impact of artificial intelligence in military logistics will depend on continuous investment in digital infrastructure, cybersecurity safeguards, and specialized human capital. Sustainable transformation is therefore not limited to technological acquisition, but requires organizational learning and institutional commitment.

The long-term evolution of AI-driven green logistics will likely redefine the relationship between technological innovation and environmental responsibility in the military domain. As data processing capabilities expand and algorithmic models become increasingly sophisticated, defense logistics systems will operate with greater precision, adaptability, and sustainability awareness.

However, technological adoption must be accompanied by organizational adaptation. Institutional culture, regulatory alignment, and professional training will determine the effectiveness of AI integration. Sustainable logistics transformation therefore requires a holistic approach combining digital infrastructure investment with governance reform and strategic vision.

AI-driven green logistics also generates significant economic implications for defense systems by improving resource allocation and reducing operational inefficiencies. Predictive maintenance, optimized transport, and real-time inventory management contribute to cost reduction and more efficient use of financial resources.

At the strategic level, these efficiency gains support the reallocation of resources toward modernization, cybersecurity, and sustainable infrastructure.

The economic dimension of AI-driven green logistics reinforces its environmental and governance benefits, positioning artificial intelligence as a multidimensional driver of institutional transformation within European defense systems.

In this context, AI-driven green logistics should be understood not as an optional modernization tool, but as a strategic necessity for future defense systems.

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