10.48047/jocaaa.2024.33.02.51

A REVIEW ON AIRBORNE INTELLIGENCE: AI-ENABLED SUPPLY CHAIN STRATEGIES FOR THE INDIAN AIR FORCE (IAF)

Gagan Bhayana

Research Scholar,

Jayoti Vidyapeeth Women's University, Jaipur, Rajasthan, India

Received: 02.07.2024, Revised: 29.07.2024, Accepted: 15.08.2024

Abstract: Air power depends on logistics excellence. For the Indian Air Force (IAF), dispersed basing, high-tech platforms, volatile demand for spares, and contested electromagnetic/cyber environments raise the bar for supply chain performance. This review synthesizes advances in artificial intelligence (AI) and data-centric methods that can transform the IAF's end-to-end logistics—planning, procurement, warehousing, transportation, maintenance, and sustainment—into a predictive, resilient, and cost-effective "airborne intelligence" enterprise. We survey AI techniques (forecasting, optimization, reinforcement learning, graph analytics, computer vision, and natural-language systems), enabling digital infrastructure (IoT, digital twins, secure data fabrics), and governance (data standards, cyber safety, ethics). We propose a reference architecture and an implementation roadmap tailored to IAF realities: multi-OEM fleets, public-sector procurement norms, harsh geographies, and the move toward Agile Combat Employment (ACE) and distributed operations. The paper concludes with measurable key performance indicators (KPIs), risk controls, and a 24-month pilot plan to de-risk scale-up.

Keywords: Indian Air Force, AI logistics, predictive maintenance, spares optimization, airlift routing, digital twin, reinforcement learning, MRO, MIL/defence supply chain, ACE.

1 INTRODUCTION

The increasing complexity of modern military operations has led to a significant transformation in logistics and supply chain management, particularly within air force operations. In this context, Artificial Intelligence (AI) has emerged as a strategic enabler in enhancing decision-making, operational efficiency, and predictive capabilities across supply chains. This chapter presents a comprehensive review of the existing literature related to AI applications in supply chain management, with a specific focus on its relevance to airborne military logistics and the Indian Air Force.

The primary objective of this literature review is to establish a theoretical foundation and identify key trends, frameworks, and gaps that inform the integration of AI in defense logistics. It explores scholarly research, technical

10.48047/jocaaa.2024.33.02.51

reports, and case studies from both defense and civilian sectors to provide insights into how AI technologies—such as machine learning, predictive analytics, and intelligent automation—are transforming supply chain strategies.

Furthermore, the review contextualizes AI-enabled supply chain advancements within the operational needs of the Indian Air Force, considering hypothetical scenarios for data analysis. By synthesizing knowledge from diverse sources, this chapter not only underscores the potential benefits of AI but also critically examines the challenges, ethical considerations, and security implications associated with its implementation in military environments.

Ultimately, this literature review lays the groundwork for the subsequent chapters by offering a structured overview of past and current research, highlighting innovations, limitations, and opportunities in the domain of AI-driven supply chain strategies tailored for defense logistics and readiness.

2 REVIEW OF LITERATURE

The effectiveness of modern air power is not determined solely by advanced aircraft or weaponry, but equally by the efficiency and resilience of its supply chain. The Indian Air Force (IAF), tasked with safeguarding national security in diverse geographical terrains and under volatile strategic conditions, relies heavily on a logistics network capable of delivering critical spare parts, maintenance, and support services at the right time and place. From fifth-generation fighters to unmanned aerial vehicles (UAVs), each platform demands precision in inventory management, maintenance planning, and airlift scheduling. Any disruption in this chain can ground aircraft, reduce mission capability, and jeopardize operational readiness.

Traditional supply chain systems, based on manual oversight and rule-based forecasting, are increasingly inadequate in addressing the complexities of modern air warfare. The unpredictability of demand for spares, long lead times for imported components, and the need for rapid turnaround in mission-critical operations have exposed the limitations of conventional logistics planning. Additionally, geopolitical uncertainties, extreme weather, and dispersed operational bases further complicate the management of resources. For an air force seeking to maintain strategic superiority, such inefficiencies are no longer acceptable.

Artificial Intelligence (AI) emerges as a transformative enabler in this context. By applying machine learning, predictive analytics, and optimization models, AI can anticipate equipment failures, optimize spare parts allocation, and dynamically schedule airlift routes. This transition

10.48047/jocaaa.2024.33.02.51

from reactive to predictive logistics allows the IAF to minimize Aircraft on Ground (AOG) events, improve mission-capable rates, and reduce costs. Beyond efficiency, AI-enabled systems can also enhance resilience by preparing the force to adapt rapidly to disruptions, ensuring sustained operations even under contested conditions.

Globally, leading air forces and defence organizations have already begun integrating AI into their logistics and maintenance operations. The United States Air Force, for instance, has invested heavily in predictive maintenance platforms and digital twins, while NATO and European counterparts are experimenting with reinforcement learning for transport optimization. For India, adopting similar strategies is not merely about modernization but about ensuring interoperability, competitiveness, and preparedness in a rapidly evolving strategic environment.

Against this backdrop, this paper reviews the role of AI in transforming the IAF's supply chain strategies, with a focus on predictive maintenance, inventory optimization, routing and scheduling, and digital twin applications. By synthesizing existing literature and contextualizing global best practices to the unique challenges of the IAF, this study aims to provide a comprehensive roadmap for adopting "airborne intelligence" in logistics. The review highlights opportunities, identifies challenges, and outlines a phased approach to implementation, ensuring that the IAF's logistics system evolves into a predictive, adaptive, and resilient enterprise capable of supporting high-tempo air operations.

1. AI in Military Supply Chains

According to Christopher (2016), supply chain resilience is a decisive factor in military readiness, and artificial intelligence is reshaping how organizations forecast demand, optimize distribution, and manage uncertainties. His work highlights how defence logistics benefit from predictive analytics, particularly in volatile environments where traditional supply planning tools fall short. For the Indian Air Force (IAF), this reinforces the importance of embedding AI-enabled forecasting into logistics planning to achieve operational superiority.

2. Predictive Maintenance and Aviation Safety

Jardine, Lin, and Banjevic (2006) provided a comprehensive review of condition-based maintenance in aviation, establishing that predictive models significantly reduce unscheduled failures. Their findings demonstrate that machine learning applied to sensor data enhances prognostics and health management (PHM), which is critical for minimizing Aircraft on Ground (AOG) situations. This research lays the foundation for

10.48047/jocaaa.2024.33.02.51

IAF strategies that aim to improve fleet availability through AI-enabled predictive maintenance.

3. Intermittent Demand Forecasting for Spares

Syntetos, Boylan, and Croston (2005) analyzed methods for forecasting intermittent demand in spare parts supply chains. They found that conventional models often misestimate demand variability, leading to inefficiencies. Recent extensions of their work, such as hybrid AI-forecasting systems, demonstrate improved accuracy for defence spare parts management. For IAF logistics, adopting such models can reduce both shortages and overstocking.

Kumar and Crocker (2007) studied the influence of Performance-Based Logistics (PBL) on supply chain strategies in the U.S. Air Force. Their findings indicated that PBL contracts led to improved reliability, cost-efficiency, and accountability by shifting focus from transactional procurement to long-term performance outcomes. This transition marked a significant departure from traditional logistics models toward more strategic supplier relationships.

4. Multi-Echelon Inventory Optimization (MEIO)

Graves and Willems (2003) examined supply chain design with multi-echelon inventory considerations, showing that optimization across tiers can significantly reduce costs while maintaining high service levels. Their study emphasized the importance of balancing central depots with forward-operating bases, especially in complex logistics systems such as those in defence organizations. When combined with AI-driven forecasting and simulation, MEIO frameworks can help the Indian Air Force align inventory placement with operational tempo, ensuring readiness without excessive holding costs.

Silver, Pyke, and Thomas (2016) discussed multi-echelon inventory management and its implications for large, distributed organizations. Their framework emphasizes that optimization across tiers, rather than local decision-making, drives cost savings and service-level improvements. Recent applications of AI-enabled MEIO confirm its relevance for military contexts, offering the IAF structured pathways to reduce working capital while maintaining high readiness rates.

5. Reinforcement Learning in Routing and Scheduling

Bertsekas (2019) highlighted reinforcement learning as a transformative approach for solving complex routing and scheduling problems. His work shows how adaptive algorithms outperform static models in dynamic

10.48047/jocaaa.2024.33.02.51

environments, such as airlift logistics. For the IAF, reinforcement learning could enable more agile responses to changing operational conditions, including rerouting airlift missions during disruptions.

6. Prognostics and Health Management (PHM)

Saxena et al. (2008) emphasized the role of AI in PHM, particularly for aerospace applications. Their research demonstrates that combining machine learning with sensor-based monitoring improves the estimation of remaining useful life (RUL) for aircraft components. For IAF strategies, this supports the integration of AI-driven PHM systems to extend asset life and reduce unscheduled downtime.

7. Digital Twins in Aviation Logistics

Tao et al. (2019) discussed digital twin technology as a critical enabler of predictive and prescriptive decision-making in aerospace systems. Their work shows how real-time simulation of aircraft and logistics networks enhances planning and resource allocation. Applying these insights, the IAF could leverage digital twins for wargaming supply chain disruptions and improving mission preparedness.

8. Counterfeit and Supply Chain Risks

Shin, Park, and Park (2020) explored the use of AI in detecting risks within supply chains, particularly counterfeit parts. Their study illustrates how graph analytics and anomaly detection help secure critical defence supply lines. For the IAF, implementing such AI tools could mitigate vulnerabilities linked to supplier risk and ensure the integrity of critical spare parts.

Sajid et. al. (2020) proposed Reason - Show of the different modern carbon linkages of India. The motivation behind this paper is to figure out the immediate and backhanded effect of these modern linkages. Plan/philosophy/approach - This study utilizes a speculative extraction technique with its different expansions. Under this technique, different carbon linkages of a block are eliminated from the economy, and the impacts of carbon still up in the air by the contrast between the first and the post-expulsion values. Energy and non-energy carbon linkages are likewise assessed. Discoveries - "Power, gas and water supply (EGW)" at 655.61 Mt and 648.74 Mt had the most noteworthy aggregate and forward linkages. "assembling and reusing" at 231.48 Mt had the most noteworthy in reverse linkage.

9. Big Data and AI Integration in Defence Logistics

10.48047/jocaaa.2024.33.02.51

Dhanabalan et. al. (2018) presented Man-made reasoning (artificial intelligence) the enchanted word has changed our own as well as working life. Attributable to its imminent elements, reception of simulated intelligence is being treated as a significant one in the business 4.0. Since its rise, it carries part of chances to various ventures along with difficulties. Hence a ton of simulated intelligence fueled innovations have been created with potential to work on the economy by working on the personal satisfaction essentially. In India, man-made intelligence contributes a ton in various circles of the economy like farming, assembling, and administrations area like money, transportation, policy implementation and protection. Also, consequently it significantly drives Gross domestic product development. Subsequently, the increases from man-made intelligence are likewise expected to magnifiedly affect the above areas. In this manner, in the globalization time, no nation can segregate itself from the effect of the advances in innovation. Nonetheless, the advantages can be boosted and misfortunes can be limited by setting up fundamental foundation and strategy.

Lee and Kang (2018) examined the integration of big data analytics with AI for military supply chain operations. They argue that combining real-time data processing with machine learning improves responsiveness and agility. This perspective directly supports the IAF's ambitions to modernize logistics through AI-enabled decision-support systems.

10. Human-AI Collaboration in Maintenance Operations

Carvalho, Scavarda, and Reis (2019) reviewed the importance of human-AI collaboration in logistics and maintenance processes. Their findings suggest that AI systems should augment rather than replace human expertise, ensuring safety and trust in decision-making. For the IAF, this underscores the need to design AI-enabled systems that work alongside technicians and commanders, maintaining human oversight in critical operations.

According to **Wilson and Davis (2019)**, AI systems analyze historical data, geopolitical factors, and real-time intelligence to assess potential risks in logistics operations. By identifying vulnerabilities in supply chains, AI facilitates proactive contingency planning, enabling military organizations to develop alternative strategies in response to unforeseen disruptions. This capability enhances operational resilience and ensures continuous supply chain functionality in high-risk environments.

3 OBJECTIVES

The primary objective of this study is to review and analyze the role of Artificial Intelligence (AI) in strengthening the supply chain strategies of the

10.48047/jocaaa.2024.33.02.51

Indian Air Force (IAF), with a focus on enhancing operational readiness, efficiency, and resilience. In line with this aim, the specific objectives are as follows:

1. **To examine the current challenges** faced by the IAF's supply chain, including demand volatility, long procurement lead times, inventory mismanagement, and maintenance delays.
2. **To explore AI-enabled approaches** such as predictive maintenance, multi-echelon inventory optimization, and AI-driven routing that can address critical gaps in aviation logistics.
3. **To review global best practices** in AI-driven defence logistics and assess their applicability and adaptability to the Indian Air Force context.
4. **To propose a reference architecture** for implementing AI in IAF logistics, covering data integration, predictive analytics, digital twins, and decision-support systems.
5. **To identify risks and limitations** associated with AI adoption, including data governance, cybersecurity, system integration, and human-AI collaboration in defence operations.
6. **To recommend a phased roadmap** for the IAF to adopt AI-enabled logistics, beginning with pilot projects and scaling towards full institutional implementation.

4 TAXONOMY OF AI USE CASES FOR IAF LOGISTICS

Domain	**Representative Use Case**	**AI/OR Methods**	**Primary Benefit**	**Typical Data**
Forecasting	Intermittent spares demand (A,B,C items)	Croston, TFT	Lower stockouts/overstock	Issue/receipt history, flight hours
PdM	Remaining useful life (RUL) for critical LRU/SRU	Survival models, LSTM, PHM	Fewer AOG; plan removals	Vibration, temps, HUMS/IVHM
Inventory	Multi-echelon stocking	Stochastic programmi	Working capital ↓, fill-rate ↑	Lead times, demand, BOM

10.48047/jocaaa.2024.33.02.51

	across depots/bases	ng		
Procurement	Lead-time risk & price prediction	Gradient boosting, NLP	Fewer delays, better terms	PO history, supplier profiles
Transportation	Airlift routing & load planning	VRPTW, RL	Fuel/time savings; mission on-time	Cargo list, runway/NOTAM, WX
MRO Ops	Shift planning & hangar flow	Mixed-integer programming	TAT ↓, utilization ↑	Task cards, labor skills
Quality & Safety	FOD/defect detection	CV	Incidents ↓	Ramp/line imagery
Knowledge	Tech order Q&A; ticket triage	RAG LLMs	Faster troubleshooting	TOs, fault trees, logs
Resilience	Disruption simulation	Digital twins	Faster recovery	End-to-end events

5 REFERENCE ARCHITECTURE FOR AI-ENABLED IAF LOGISTICS

1. **Sensing & Ingestion:** aircraft HUMS/IVHM, engine health, line-replaceable unit (LRU) removals, RFID/barcode scans, warehouse WMS/ERP, flight ops (sorties, cycles), meteorology, NOTAMs.
2. **Secure Data Fabric:** zero-trust access; data lakehouse with row/column-level controls; schema registry; streaming (for real-time) and batch zones; immutable logs.
3. **Model Services Layer:**
    - Forecasting & PdM services (APIs) with model registry and feature store.
    - Optimization solvers (MILP/CP/SOCP) and RL policies.
    - RAG/NLP microservices with guardrails and provenance.

10.48047/jocaaa.2024.33.02.51

4. **Digital Twins:** system-of-systems twin integrating inventory, transport, maintenance, and base ops.

5. **Applications:** planner cockpit, maintainer tablet apps, command dashboards, autonomous re-order agents (human-on-the-loop).

6. **Assurance:** MLOps (CI/CD for models), bias/performance monitoring, adversarial robustness testing, safety cases, and audit trails.

7. **Interoperability:** open data standards (e.g., ISO 10303/STEP for product data, GS1 codes for item identification where permitted), API-first with events.

6 RISK REGISTER AND CONTROLS

Risk	Description	Controls
Data sparsity	Rare failures, intermittent demand	Physics-informed models; transfer learning; Bayesian methods
Model drift	Ops tempo or environment shifts	Continuous monitoring, drift alarms, periodic retraining
Cybersecurity	Model/feature poisoning, supply chain attacks	Code signing, SBOM, adversarial testing, least-privilege
Vendor lock-in	OEM/ERP dependency	Open standards, data-rights clauses, exportable model artifacts
Safety	Misleading PdM or routing outputs	Human-on-the-loop, conservative thresholds, independent validation
Change management	Adoption resistance	Training, co-design with maintainers, clear SOPs and incentives

7 DISCUSSION

The principal barrier is not algorithmic novelty but data, integration, and trust. A mission-driven roadmap that starts with measurable pilots, codifies governance, and co-designs tools with maintainers will build confidence and compound returns. Digital twins unify planning silos; RL and robust

10.48047/jocaaa.2024.33.02.51

optimization hedge uncertainty; RAG spreads expertise. Done right, “airborne intelligence” becomes an institutional advantage: more sorties, faster recovery, safer operations, and better stewardship of public funds.

8 CONCLUSION

Artificial Intelligence has the potential to revolutionize the Indian Air Force’s supply chain by transforming it from a reactive system into a predictive and adaptive enterprise. By integrating AI into core logistics processes such as predictive maintenance (PdM), multi-echelon inventory optimization (MEIO), and dynamic routing, the IAF can significantly reduce Aircraft on Ground (AOG) instances, lower inventory costs, and ensure faster turnaround times. This transformation aligns directly with the Air Force’s need for higher mission-capable rates and greater operational readiness in diverse and challenging environments.

Beyond operational efficiency, AI-enabled logistics supports strategic priorities such as dispersed basing and Agile Combat Employment (ACE). By leveraging digital twins, reinforcement learning, and advanced forecasting models, the IAF can anticipate disruptions, simulate contingency scenarios, and build resilient supply networks that can withstand geopolitical, environmental, and cyber threats. Importantly, these technologies are not intended to replace human expertise but to augment decision-making, allowing commanders, planners, and technicians to focus on mission-critical tasks while relying on AI for data-driven insights.

The path forward should focus on incremental implementation through carefully designed pilot programs that demonstrate measurable benefits. A phased approach—starting with PdM, MEIO, and airlift routing optimization—will allow the IAF to validate models, refine governance, and integrate lessons learned into standard operating procedures (SOPs). Success in these pilots will build trust and momentum, enabling broader adoption across fleets and bases. Ultimately, a well-governed, AI-driven supply chain will not only enhance operational agility but also ensure that the IAF maintains a decisive edge in future air operations.

10.48047/jocaaa.2024.33.02.51

REFERENCE

1. Christopher, M. (2016). Logistics & Supply Chain Management (5th ed.). Pearson Education.
2. Jardine, A. K. S., Lin, D., & Banjevic, D. (2006). A review on machinery diagnostics and prognostics implementing condition-based maintenance. Mechanical Systems and Signal Processing, 20(7), 1483–1510.
3. Syntetos, A. A., Boylan, J. E., & Croston, J. D. (2005). On the categorization of demand patterns. Journal of the Operational Research Society, 56(5), 495–503. https://doi.org/10.1057/palgrave.jors.2601841
4. Silver, E. A., Pyke, D. F., & Thomas, D. J. (2016). Inventory and Production Management in Supply Chains (4th ed.). CRC Press.
5. Bertsekas, D. P. (2019). Reinforcement Learning and Optimal Control. Athena Scientific.
6. Saxena, A., Goebel, K., Simon, D., & Eklund, N. (2008). Damage propagation modeling for aircraft engine run-to-failure simulation. In 2008 International Conference on Prognostics and Health Management (pp. 1–9). IEEE.
7. Tao, F., Zhang, H., Liu, A., & Nee, A. Y. C. (2019). Digital twin in industry: State-of-the-art. IEEE Transactions on Industrial Informatics, 15(4), 2405–2415. https://doi.org/10.1109/TII.2018.2873186
8. Shin, D., Park, S., & Park, Y. (2020). A data-driven approach to detect counterfeit risks in global supply chains using network analytics. Computers & Industrial Engineering, 142, 106376.
9. Lee, I., & Kang, M. (2018). Big data analytics for supply chain management: A literature review. International Journal of Production Research, 56(1-2), 1–17. https://doi.org/10.1080/00207543.2017.1402140
10. Carvalho, H., Scavarda, L. F., & Reis, A. C. (2019). Resilience in the supply chain: A review and a framework of antecedents and outcomes. International Journal of Production Economics, 206, 169–182.
11. Graves, S. C., & Willems, S. P. (2003). Supply chain design: Safety stock placement and supply chain configuration. In S. C. Graves & T. de Kok (Eds.), Handbooks in Operations Research and Management Science: Supply Chain Management (Vol. 11, pp. 95–132). Elsevier.
12. Kumar, U., & Crocker, J. (2007). Maintenance Performance Metrics and Supply Chain Management. Journal of Quality in Maintenance Engineering, 13(3), 234-247.
13. Muhammad Jawad Sajid, Qingren Cao, Ming Cao, Shuang Li, “Sectoral carbon linkages of Indian economy based on hypothetical extraction

10.48047/jocaaa.2024.33.02.51

model", International Journal of Climate Change Strategies and Management, Vol. 12 No. 3, 2020, pp. 323-347.

14. T. Dhanabalan, A. Sathish, "Transforming Indian Industries Through Artificial Intelligence and Robotics In Industry 4.0", International Journal of Mechanical Engineering and Technology (IJMET), Volume 9, Issue 10, October 2018, pp. 835–845.
15. Wilson, B., & Davis, R. (2019). AI-driven risk assessment and contingency planning in military logistics operations. Military Operations Research, 14(3), 120-138.