

Stock Control in Airline Logistics: AI-Driven Inventory Optimization for Spare Parts

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Abstract

This paper examines the transformative role of artificial intelligence in optimizing inventory management for airline logistics, specifically focusing on spare parts. The study aims to assess how AI-driven techniques improve operational efficiency, reduce costs, and enhance service reliability through advanced forecasting, automated replenishment, and real-time data analytics. A systematic literature review was conducted, incorporating empirical data, case studies, and mathematical modeling approaches to analyze the performance of methods such as Monte Carlo simulation, Bayesian forecasting, and neural networks. The results indicate significant improvements in inventory control, with cost reductions ranging from 2.4% to 60%, stock level decreases between 34% and 54%, and enhanced fill rates reaching up to 80.58%. These findings highlight the potential of AI to drive predictive maintenance, facilitate real-time inventory tracking, and improve supplier coordination, ultimately contributing to more strategic decision-making in airline logistics. The research provides a comprehensive framework for integrating AI-based solutions into existing systems, underscoring both the practical benefits and the challenges associated with transitioning from legacy infrastructures to modern, data-driven operations.

Keywords: Airline Logistics, Inventory Optimization, Artificial Intelligence, Spare Parts Management, Predictive Maintenance, IoT

1. Introduction

1.1. Background and Rationale

Effective stock control is a cornerstone of safe and efficient airline operations. In the airline industry, the management of spare parts is particularly critical not only for ensuring regulatory compliance and safety but also for achieving cost efficiency. The high-value nature of these components, combined with the necessity for rapid replacement in the event of component failure, underscores the importance of an optimized inventory system [1]. Advanced approaches, such as AI-driven inventory optimization, offer the potential to transform traditional stock control methods by leveraging real-time data and predictive analytics [2].

1.2. Problem Statement

Airline logistics face significant challenges in managing high-value inventories. Traditional inventory management systems often struggle to balance the competing risks of stock-outs which can compromise safety and operational continuity and overstocking, which increases holding costs. Furthermore, the reliance on legacy systems hampers the adoption of innovative solutions that could enhance responsiveness and precision in spare parts management. These issues necessitate a strategic shift towards integrated, AI-driven approaches that can more effectively manage inventory levels and support maintenance operations.

1.3. Research Objectives and Scope

The primary aim of this study is to assess the impact of AI-driven inventory optimization on airline logistics, with a particular focus on spare parts management. To achieve this, the research evaluates:

- The effectiveness of advanced analytical techniques and predictive algorithms in forecasting demand and automating replenishment processes.
- Key performance indicators (KPIs) that measure improvements in operational efficiency, cost reduction, and service levels.
- Methodologies that integrate AI with existing logistics frameworks to overcome the limitations of legacy systems [3].

1.4. Significance of the Study

This study contributes to both the academic discourse and practical decision-making in airline logistics. By demonstrating how AI-driven inventory optimization can enhance operational efficiency, reduce costs, and improve strategic planning, the research provides a roadmap for airlines seeking to modernize their inventory management systems. The findings are expected to guide chief logistics officers and industry practitioners in adopting data-driven strategies that ensure both safety and cost-effectiveness, thereby reinforcing the overall resilience of the supply chain.

The following sections provide an in-depth exploration of these topics, supported by empirical data and a comprehensive review of relevant literature [4].

2. Literature Review

2.1. Theoretical Background

Traditional inventory management in aviation has long relied on established techniques such as periodic reviews, ABC analysis, and basic forecasting methods to balance safety requirements and cost control [5]. These conventional practices focus on maintaining critical spare parts at levels that meet regulatory compliance and operational readiness, albeit often at the expense of flexibility and efficiency [1]. In parallel, the fundamentals of artificial intelligence (AI) and machine learning (ML) have gradually permeated the logistics domain. AI techniques offer enhanced capabilities in processing large datasets, identifying hidden demand patterns, and automating replenishment processes all critical in dynamic environments like airline operations.

2.2. Advancements in AI for Inventory Optimization

Recent studies illustrate substantial progress in applying AI-driven methods to optimize spare parts inventory. Advanced techniques such as Monte Carlo simulation, Bayesian forecasting, and neural networks are now frequently employed to improve forecasting accuracy and reduce inventory costs. For instance, Bayesian forecasting methods have achieved fill rates as high as 80.58%, while neural network models contribute to reducing forecast errors, thereby ensuring a more precise alignment between demand and supply [6][7]. Additionally, integrated analytics pipelines that combine machine learning models with traditional time-series methods have further strengthened predictive capabilities. These advancements not only yield cost efficiencies ranging from 2.4% to 60% but also enable significant reductions in stock positions often between 34% and 54% demonstrating the transformative potential of AI in inventory management [8][9].

2.3. Integration of IoT and Real-Time Data Analytics

The advent of Internet-of-Things (IoT) technologies has ushered in a new era of real-time inventory management. In airline logistics, IoT devices facilitate continuous tracking and synchronization of spare parts across disparate locations, thereby enhancing traceability and responsiveness. Systems that integrate IoT with AI-driven analytics can monitor inventory levels in real time, trigger automated replenishment, and provide immediate insights into stock discrepancies. This integration is pivotal for achieving higher operational efficiency and ensuring that critical parts are available when needed [10].

2.4. Gaps in Existing Research

Despite these promising advancements, several limitations persist in the current literature. Many studies focus narrowly on individual AI techniques or isolated performance metrics without offering a comprehensive framework that addresses both operational and technological challenges. Furthermore, discrepancies in data quality, implementation scale, and variability in outcome measurements make it difficult to generalize findings across different airline contexts. The need remains for an integrative model that simultaneously

considers cost efficiency, forecast accuracy, fill rate improvements, and system integration challenges [3].

2.5. Summary of Key Findings from Prior Studies

A synthesis of the reviewed literature reveals several consistent trends. First, AI-driven models have achieved notable cost reductions with some studies reporting savings of up to 60% and annual savings in the millions [11][12]. Second, the integration of advanced forecasting techniques has led to improvements in demand prediction accuracy by as much as 7%, alongside enhanced fill rates [6][13]. Third, significant operational benefits are evident in the form of reduced stock positions up to 34–54% and increased overall availability of spare parts [14]. Finally, the incorporation of IoT and real-time analytics into inventory management systems substantially bolsters traceability and synchronization, addressing critical limitations of legacy systems [10]. These findings collectively set the stage for further research aimed at developing a unified, AI-driven framework that holistically addresses the multifaceted challenges of airline spare parts inventory management.

3. Methodology

This study employs a systematic literature review to evaluate the impact of AI-driven inventory optimization in airline logistics. A selection of 25 studies was made based on explicit criteria such as industry focus, AI/ML implementation, and documented evidence of inventory management improvements. A large language model was used to extract key information from each study, focusing on research designs including mathematical modeling, case studies, and optimization research as well as analytical techniques such as Monte Carlo simulation, Bayesian forecasting, neural networks, and integrated analytics pipelines. Performance metrics, including forecast accuracy, fill rate, cost efficiency, and stock reduction, were then used to quantitatively compare AI-driven methods against traditional inventory practices. Findings revealed improvements in demand forecasting accuracy (up to 7%), fill rates (as high as 80.58%), cost reductions (ranging from 2.4% to 60%), and stock position decreases (34–54%). Multiple reviewers cross-validated the extracted data to ensure reliability, and ethical standards were maintained through proper attribution of all sources [1][3][4]. Although variability in reporting and the operational diversity among studies present certain limitations, the methodology provides a robust framework for assessing AI's transformative role in enhancing inventory control within airline logistics.

4. Findings and Results

The analysis reveals that AI-driven inventory optimization significantly enhances stock control in airline logistics. The research design incorporated mathematical modeling, case studies, and optimization research, drawing data from the Semantic Scholar corpus and

filtering for studies with a clear industry focus, AI/ML implementation, and empirical evidence. Data extraction focused on techniques such as Monte Carlo simulation, Bayesian methods, neural networks, and integrated analytics pipelines, and on key inventory parameters including Target Stock Levels (TSL), Re-Order Points (ROP), Safety Stock (SS), fill rate, and cost minimization. Quantitative outcomes indicate cost savings ranging from 2.4% to 60%, stock reductions between 34% and 54%, and fill rate improvements reaching up to 80.58%. Comparative analysis across different airline logistics contexts including commercial, military, and Maintenance, Repair, and Overhaul (MRO) operations demonstrates that the effectiveness of AI methods varies with operational scale and context. Visual representations, including centrally aligned tables and figures, sequentially detail these trends and facilitate the interpretation of key data. Overall, the results underscore the transformative potential of AI in reducing inventory costs, enhancing forecast accuracy, and improving overall operational efficiency in airline logistics.

5. Discussion

5.1. Interpretation of Results

The analysis confirms that AI-driven inventory optimization improves operational efficiency and cost management by enhancing demand forecasting, automating replenishment processes, and reducing excess inventory. Advanced methods such as Monte Carlo simulation, Bayesian forecasting, and neural networks yield significant cost savings (ranging from 2.4% to 60%) and reduce stock levels by 34% to 54%. However, the variability in benefits across different implementation contexts (commercial, military, and MRO) indicates that the performance of AI solutions is strongly influenced by factors such as existing infrastructure, scale of operations, and the specific logistical challenges each context presents.

5.2. Implications for Airline Logistics

The improvements driven by AI extend beyond inventory control to impact several critical areas within airline logistics. Enhanced predictive maintenance, for example, enables airlines to preemptively address equipment failures, thereby reducing unplanned downtime and maintenance costs. Real-time inventory tracking, facilitated by the integration of IoT technologies, improves the synchronization of spare parts across multiple locations, ensuring timely replenishment and more effective supplier coordination. These advancements have strategic significance, as they contribute to overall cost reduction, improved service levels, and increased operational reliability, which are crucial for maintaining competitive advantage in the dynamic aviation market.

5.3. Challenges and Limitations

Despite the promising benefits, several challenges persist. Data quality and integration issues remain significant obstacles, as inconsistent data formats and reliance on legacy systems hinder the seamless implementation of advanced AI technologies. Organizational resistance

to change further complicates the adoption process, as stakeholders may be reluctant to transition from traditional methods to novel, data-driven approaches. Additionally, compatibility issues between new AI systems and existing infrastructures limit the extent to which these innovations can be fully exploited.

5.4. Future Trends and Research Directions

Looking forward, further research should focus on the integration of IoT technologies with AI-driven inventory systems to enhance real-time tracking and sustainability in airline logistics. There is also considerable potential for developing advanced forecasting techniques and KPI-driven strategies that can better capture the complexities of airline operations. Future studies should pursue additional empirical validation through case studies and pilot projects, which would help refine these AI methodologies and demonstrate their scalability across different operational contexts. Addressing these areas will be critical to fully realizing the transformative potential of AI in enhancing both the efficiency and sustainability of airline logistics.

6. Conclusion

6.1. Summary of Key Insights

This study demonstrates that AI-driven inventory optimization can fundamentally transform airline stock control. Advanced techniques such as Monte Carlo simulation, Bayesian forecasting, and neural networks not only enhance demand forecasting but also significantly reduce inventory costs and excess stock. Quantitative findings reveal cost savings ranging from 2.4% to 60% and stock reductions between 34% and 54%, underscoring AI's potential to streamline operations and improve service levels.

6.2. Contributions to the Field

By integrating a systematic review of empirical studies, this research advances both academic and practical understanding of inventory management in the aviation industry. It bridges the gap between traditional inventory practices and modern AI-driven approaches, providing a comprehensive framework that highlights key performance indicators (KPIs), predictive maintenance, and real-time data analytics. This contribution is instrumental for practitioners and researchers seeking to optimize supply chain resilience in an increasingly competitive market.

6.3. Recommendations for Practice

Airlines should adopt a strategic approach to integrating AI-based inventory systems. This includes:

- Implementing real-time tracking and predictive maintenance through IoT-enabled technologies.
- Developing KPI-driven frameworks to monitor inventory performance and streamline supplier coordination.

- Upgrading legacy systems incrementally to ensure compatibility with modern data analytics tools. These steps will help airlines achieve greater operational efficiency, reduce costs, and enhance overall service reliability.

6.4. Suggestions for Future Research

Further investigation is warranted to address remaining challenges and capitalize on emerging opportunities. Future research should focus on:

- Exploring advanced forecasting techniques and refining KPI-driven strategies.
- Investigating integration challenges between new AI systems and existing legacy infrastructures.
- Assessing the sustainability impacts of AI-driven inventory optimization on airline logistics. Empirical validation through additional case studies and pilot projects will be essential to refine these methodologies and ensure their scalability across diverse operational contexts.

This study thus lays a robust foundation for transforming airline logistics, providing both a practical roadmap for implementation and a clear direction for future academic inquiry.

7. Acknowledgments

We extend our gratitude to all the researchers, industry experts, and academic institutions whose contributions and published works have provided a rich foundation for this study. The research results presented in this article indicate that AI-driven inventory optimization substantially improves airline stock control, achieving notable cost savings, enhanced demand forecasting accuracy, and significant reductions in excess inventory. These findings underscore the strategic benefits of integrating AI with real-time data analytics and IoT-enabled tracking, thereby fostering improved predictive maintenance and more effective supplier coordination. We recommend that airlines consider adopting comprehensive, KPI-driven inventory systems and progressively update legacy infrastructures to realize these benefits. Future research should focus on refining advanced forecasting methods, addressing integration challenges, and exploring the sustainability impacts of AI applications in airline logistics. Our study thus provides both a practical roadmap for industry practitioners and a clear direction for ongoing academic inquiry.

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Appendix

Appendix A: Comprehensive KPI Inventory for Stock Control Director, Airline Logistics

Aligned with “Stock Control in Airline Logistics: AI-Driven Inventory Optimization for Spare Parts” and the Universal KPI Development Framework

To operationalize the AI-driven inventory optimization model presented in our research, this appendix delivers the Top 100 role-specific KPIs for the Stock Control in Airline Logistics Director. Each metric is anchored to

strategic objectives cost efficiency (CASK), asset utilization, service level and leverages industry vernacular (ASK, AOG, ERP/MRO data feeds) and digital enablers (AI forecasting, IoT).

How to Use This Inventory

1. Populate Dashboards
 - Embed each KPI's Definition, Formula (numerator/denominator), Data Source (ERP/MRO, IoT feeds, AODB), and Cadence (Daily/Weekly/Monthly/Quarterly).
2. Define RACI
 - Assign "Responsible," "Accountable," "Consulted," and "Informed" across Stock Control, Maintenance Planning, Supply Chain, Finance, OCC, and Digital Transformation.
3. Benchmark Performance
 - Compare against IATA/ICAO standards, peer-group best practices, and internal AI-twin pilots to set "leading practice" thresholds.
4. Integrate Across Functions
 - Chain metrics end-to-end e.g., Forecast Accuracy → Replenishment OTD → AOG Response Time → On-Time Departure → CASK—to ensure inventory levers drive network reliability and cost outcomes.
5. Embed Advanced Enablers
 - Incorporate AI-driven demand forecasting, digital-twin scenario simulation, blockchain parts provenance, and green-inventory measures (CO₂/ASK, SAF sourcing) into decision-support platforms.

Together, these 100 KPIs equip the Stock Control Director with the tactical levers and strategic guardrails necessary to translate our AI-optimization recommendations into measurable, sustainable improvements in spare-parts availability, cost control, and digital maturity.

Strategic Dimensions & KPI Groups

1. Inventory Management & Accuracy
2. Demand Forecasting & Planning
3. Stock Level Optimization & Service
4. Cost & Financial Efficiency
5. Supplier & Vendor Performance
6. Logistics & Distribution Efficiency
7. Warehouse Operations & Throughput
8. Compliance, Safety & Regulatory Adherence
9. Spare Parts Availability & AOG Responsiveness
10. Performance Monitoring, Reporting & Digital Enablement
11. Risk Management & Contingency Planning
12. Sustainability & Environmental Impact

Inventory Management

(Strategic Dimension: Asset Optimization, Cost Efficiency)

- Inventory Turnover Ratio (ITR)
- Days Inventory Outstanding (DIO)
- Stock Accuracy Rate (SAR)
- Stockout Rate (SOR)
- Overstock Rate (OCR)
- Average Inventory Level (AIL)
- Inventory Carrying Cost (ICC)

- Inventory Shrinkage Rate (ISR)
- Slow-moving Inventory Percentage (SIP)
- Deadstock Inventory Value (DIV)

Demand Forecasting and Planning

(Strategic Dimension: Demand Accuracy, Planning Effectiveness)

- Forecast Accuracy (FA)
- Forecast Bias (FB)
- Demand Variability (DV)
- Lead Time Variability (LTV)
- Stock Replenishment Accuracy (SRA)
- Safety Stock Level Accuracy (SSLA)
- Forecast Horizon Effectiveness (FHE)
- Reorder Point Optimization (ROP)
- Forecast Error Rate (FER)
- Demand Planning Cycle Time (DPCT)

Stock Level Optimization

(Strategic Dimension: Inventory Optimization, Service Level)

- Economic Order Quantity (EOQ)
- Optimal Reorder Quantity (ORQ)
- Service Level Optimization (SLO)
- Minimum Stock Level Compliance (MSLC)
- Maximum Stock Level Compliance (MaxSLC)
- Buffer Stock Level Utilization (BULU)
- Just-in-Time Compliance (JITC)
- Critical Part Stock Level (CPSL)
- Parts Availability Rate (PAR)
- Stock Rotation Efficiency (SRE)

Cost Management

(Strategic Dimension: Cost Efficiency, Financial Performance)

- Inventory Holding Cost (IHC)
- Stock Obsolescence Cost (SOC)
- Procurement Cost per Order (PCO)
- Cost of Stockouts (COS)
- Stock Disposal Cost (SDC)
- Inventory Write-off Rate (IWR)
- Freight Cost per Shipment (FCPS)
- Cost Savings from Bulk Orders (CSBO)
- Total Cost of Ownership per Part (TCO)
- Annual Inventory Budget Utilization (AIBU)

Supplier and Vendor Management

(Strategic Dimension: Supplier Performance, Partnership Reliability)

- Supplier Lead Time Accuracy (SLTA)
- On-time Delivery Rate (OTDR)
- Vendor Performance Scorecard (VPS)
- Supplier Fill Rate (SFR)

- Vendor Contract Compliance (VCC)
- Supplier Quality Index (SQI)
- Supplier Risk Rating (SRR)
- Supplier Defect Rate (SDR)

Logistics and Distribution

(Strategic Dimension: Distribution Efficiency, Delivery Reliability)

- Order Fulfillment Lead Time (OFLT)
- Average Delivery Time (ADT)
- Shipment Accuracy Rate (ShAR)
- Backorder Rate (BOR)
- Percentage of Orders Delivered on Time (PODT)
- Order Picking Accuracy (OPA)
- Delivery Cost per Unit (DCU)
- Stock Transfer Lead Time (STLT)

Warehouse Operations

(Strategic Dimension: Operational Efficiency, Resource Utilization)

- Warehouse Utilization Rate (WUR)
- Space Optimization Efficiency (SOE)
- Picking Efficiency (Lines per Hour) (PEH)
- Put-away Accuracy (PAA)
- Cycle Count Accuracy (CCA)
- Warehouse Labor Productivity (WLP)
- Order Processing Time (OPT)
- Receiving Dock Utilization (RDU)

Compliance and Regulatory Adherence

(Strategic Dimension: Regulatory Compliance, Audit Performance)

- Regulatory Compliance Rate (RCR)
- Number of Compliance Violations (NCV)
- Audit Pass Rate (APR)
- Documentation Accuracy for Inventory Records (DAIR)
- Export Compliance for Parts (ECP)
- Customs Clearance Lead Time (CCLT)
- Hazardous Materials Storage Compliance (HMSC)
- Training Compliance for Warehouse Staff (TCWS)

Spare Parts Management

(Strategic Dimension: Maintenance Support, Availability)

- Aircraft-on-Ground Response Time (AOGRT)
- Mean Time Between Stockouts (MTBS)
- Spare Parts Availability Rate (SPAR)
- Rotable Inventory Turnover (RIT)
- Repairable Parts Cycle Time (RPCT)
- Mean Time to Supply (MTTS)
- Parts Reliability Index (PRI)

Performance Monitoring and Reporting

(Strategic Dimension: Data Visibility, Reporting Accuracy)

- Inventory KPIs Dashboard Accuracy (IKDA)
- Monthly Stock Status Report Timeliness (MSSRT)
- KPI Reporting Accuracy (KPIRA)
- Real-time Inventory Tracking Utilization (RITU)
- Data Accuracy for Inventory Systems (DAIS)
- KPI Alignment with Business Goals (KPIABG)
- Use of Predictive Analytics for Inventory (UPAI)

Risk Management and Contingency Planning

(Strategic Dimension: Risk Mitigation, Business Continuity)

- Stock Risk Exposure (SRE)
- Risk Mitigation Plan Effectiveness (RMPE)
- Contingency Stock Level (CSL)
- Emergency Stock Order Fulfillment Rate (ESOFR)
- Risk Assessment Frequency (RAF)
- Crisis Response Time for Stock Incidents (CRT)
- Supplier Risk Diversification (SRD)

Sustainability and Environmental Impact

(Strategic Dimension: Sustainability, Environmental Stewardship)

- Reduction in Inventory Waste (RIW)
- Sustainable Packaging Usage (SPU)
- Carbon Footprint of Logistics Operations (CFLO)
- Recycling Rate of Stock Packaging (RRSP)
- Use of Environmentally-friendly Transportation (UEFT)
- Compliance with Environmental Regulations (CER)
- Reuse of Rotable and Repairable Parts (RRRP)