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REVIEW

Towards smart logistics: the role of artificial intelligence in operational optimization

Hacia una logística inteligente: el papel de la inteligencia artificial en la optimización operativa

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ABSTRACT

This study aims to analyze the transformative impact of Artificial Intelligence (AI) as the new operational core of the modern supply chain. The research shows that AI transcends its role as a complementary tool to become an integrated ecosystem that redefines traditional logistics paradigms. The analysis focuses on four pillars of application: predictive intelligence (demand forecasting and inventory management), intelligent automation (robotics and warehouse management), dynamic logistics (route and fleet optimization), and strategic sourcing (supplier risk management). The analysis reveals synergies between these pillars, leading to exponential improvements in operational efficiency, cost reduction, and strategic resilience. The future points toward autonomous supply chains driven by the convergence of AI with IoT and blockchain, where the human role will evolve toward strategic oversight and exception management. While significant challenges are identified—such as initial investment, data quality, and the talent gap—the study concludes that the tangible ROI and strategic benefits justify progressive adoption.

Keywords: Artificial Intelligence; Supply Chain; Smart Logistics.

RESUMEN

Este estudio tiene como objetivo analizar el impacto transformador de la Inteligencia Artificial (IA) como nuevo núcleo operativo de la cadena de suministro moderna. La investigación demuestra que la IA trasciende su función de herramienta complementaria para convertirse en un ecosistema integrado que redefine los paradigmas logísticos tradicionales. El análisis se centra en cuatro pilares de aplicación: inteligencia predictiva (pronóstico de demanda y gestión de inventarios), automatización inteligente (robótica y gestión de almacenes), logística dinámica (optimización de rutas y flotas) y abastecimiento estratégico (gestión de riesgos con proveedores). El análisis revela la existencia de sinergia entre estos pilares, lo cual genera mejoras exponenciales en eficiencia operativa, reducción de costos y resiliencia estratégica. El futuro apunta hacia cadenas de suministro autónomas impulsadas por la convergencia de IA con IoT y blockchain, donde el rol humano evolucionará hacia la supervisión estratégica y la gestión de excepciones. Si bien se identifican desafíos significativos -como la inversión inicial, la calidad de datos y la brecha de talento- el estudio concluye que el ROI tangible y los beneficios estratégicos justifican la adopción progresiva.

Palabras clave: Inteligencia Artificial; Cadena De Suministro; Logística Inteligente.

INTRODUCTION

Global logistics is at a turning point, driven by the need for efficiency, resilience, and adaptability in an increasingly complex environment.[1,2] In this context, Artificial Intelligence (AI) is emerging not as just another tool, but as the new operational core capable of redefining the paradigms of supply chain management. Far from being an abstract technology, AI is establishing itself as a driver of systematic optimization, analyzing, predicting, and acting on each link in the chain to maximize its effectiveness.

The primary function of AI in logistics lies in its ability to process massive volumes of data, identify complex patterns, and facilitate intelligent, real-time decision-making.[3] Unlike traditional systems based on fixed rules, AI algorithms—especially those involving machine learning (ML) and neural networks—can learn and adapt, giving logistics operations unprecedented agility and precision.[4,5] This evolution marks the critical transition from mere automation (execution of repetitive tasks) to cognition (the ability to learn and decide in dynamic environments).

This qualitative leap is reflected in the shift from descriptive to predictive and prescriptive analysis. For example, while a traditional system reports inventory levels, an AI-powered system can predict future demand by integrating variables such as weather conditions or market trends, simulate the impact of a stockout, and automatically prescribe an optimized replenishment order.[3,5] The central impact of AI is therefore the delegation of routine data-based decisions to the machine, freeing up human capital to focus on strategy, innovation, and exception management.[4]

Consequently, the paradigm is evolving from a human-operated, system-assisted model to a system-operated, human-supervised model. This article analyzes this transformation, examining how AI is applied across the interconnected ecosystem of the supply chain—demand forecasting, warehouse management, transportation, and procurement—the tangible benefits it generates, the challenges to its implementation, and the future horizon of autonomous logistics.

DEVELOPMENT

Pillars of optimization

Artificial Intelligence constitutes an ecosystem of complementary technologies that specifically impacts each link in the supply chain. Its value is manifested through four pillars of optimization that, when interconnected, generate a more intelligent, agile, and resilient logistics system.

Predictive Demand and Inventory Intelligence

Demand planning has traditionally been the Achilles heel of logistics due to its reliance on ineffective historical models in volatile markets. AI revolutionizes this process by transforming forecasting into real-time "demand insight" through the analysis of vast and heterogeneous datasets that include market trends, macroeconomic data, weather conditions, special events, and social media sentiment.[6,7] This capability allows companies to adjust production and inventory management with superior accuracy dynamically.

Technologies such as Machine Learning algorithms (ARIMA, Random Forests) for time series analysis and Artificial Neural Networks for identifying nonlinear patterns drive this capability. These models continuously learn and adjust in real time, making forecasts more dynamic and reliable.[8]

Predictive intelligence integrates directly with inventory management by accurately predicting when, where, and what customers will buy. AI optimizes stock levels to prevent shortages (which lead to lost sales) and excesses (which tie up capital). Advanced systems automate replenishment, continuously monitor stock, and detect anomalies such as theft or damage, enabling rapid intervention.[9,10]

Landmark cases demonstrate its effectiveness: IKEA implemented ML models that integrate historical data, promotions, and local variables such as weather.[11] Amazon forecasts daily demand for more than 400 million products during peak seasons, a feat impossible without AI.[12]

The Smart Warehouse: AI in Automation and Robotics

The warehouse has evolved from a static facility to a dynamic fulfillment center, with AI as its central brain. AI powers advanced robotics, including Autonomous Mobile Robots (AMRs) that navigate intelligently without predefined routes, collaborative robots ("cobots") for picking and packing, and high-precision robotic arms.[13]

Beyond robotics, AI provides superior intelligence to Warehouse Management Systems (WMS). These systems dynamically optimize warehouse layout (strategically placing high-demand products), intelligently assign tasks to humans and robots based on location and workload, and plan efficient picking routes.[14]

Computer vision is another critical application: it automates code scanning, product identification and classification, quality control, and order verification, drastically reducing human error.[15]

Dynamic Logistics and Smart Transportation

Transportation, one of the most complex and costly components, is transformed by AI through intelligent, real-time route optimization. Algorithms simultaneously analyze variables such as real-time traffic, weather conditions, road closures, delivery windows, vehicle capacity, and fuel costs.[16]

Optimization is dynamic: systems adjust routes on the fly in response to unforeseen events such as accidents or weather changes, always ensuring maximum efficiency. This capability is crucial at the last mile, where optimization in congested urban environments delivers faster, more reliable deliveries.[17] In addition, AI manages fleets through predictive maintenance (with IoT sensors that monitor vehicle status) and driving pattern analysis to improve fuel efficiency.

Strategic Sourcing and Supplier Relationship Management

Supplier management has evolved from a transactional function to a strategic discipline focused on risk and collaboration. AI enables in-depth assessments by analyzing internal data (timeliness, quality) and external data (financial strength, news), creating dynamic risk profiles that facilitate proactive diversification of the supply base.[13,18]

It also automates repetitive tasks, such as generating purchase orders, monitoring shipments, and processing invoices, freeing professionals for higher-value activities, such as negotiation and strategy.[19]

Synergy between the Four Pillars

These pillars operate as an interconnected ecosystem where improvements in one area enhance the others. Accurate demand forecasting (Pillar 1) optimizes inventory, making the warehouse more efficient (Pillar 2). An agile warehouse speeds up order preparation, benefiting transportation (Pillar 3). Optimized routes provide reliable delivery data that feeds back into the inventory system (Pillar 1). This virtuous cycle generates exponential improvements throughout the supply chain.

Benefits of Implementing AI in the Logistics Chain

The adoption of Artificial Intelligence transcends the technological sphere, becoming a strategic driver that redefines the parameters of efficiency, resilience, and competitiveness. Its impact manifests itself in three key dimensions: operational excellence, strategic advantages, and sustainability.

Operational excellence and direct economic impact

AI generates measurable improvements in critical operational and financial indicators. Cost reduction is an immediate benefit of identifying and mitigating process inefficiencies. Intelligent inventory optimization lowers maintenance costs,[19] while efficient route and fleet management drastically reduces fuel and transportation expenses.[1]

Efficiency and productivity experience substantial improvements. Automating repetitive tasks (document processing, inventory tracking) frees up human capital for higher-value activities. In warehouses, workflow optimization and intelligent management of robots and workers increase order processing capacity.[17,19]

AI's ability to detect anomalies enables early identification of operational failures, product defects, and human errors, resulting in greater order fulfillment accuracy, fewer returns, and less waste.[17,18]

Resilience and customer focus

Beyond quantitative metrics, AI strengthens fundamental strategic capabilities. Decision-making is transformed through predictive analytics and scenario simulations, enabling proactive responses to disruptions and sudden changes in demand.[20]

Comprehensive supply chain visibility is enhanced by integrating AI and IoT, enabling real-time end-to-end tracking that improves coordination, planning, and compliance with ethical and sustainability standards.[10,13]

These benefits converge into a superior customer experience: faster, more reliable deliveries, fewer stockouts, and personalized service through virtual assistants. This customer focus is establishing itself as a key competitive differentiator.[1]

Logistics sustainability

AI is an essential tool for environmental objectives. Resource optimization is achieved through more efficient routes and better load management, reducing fuel consumption and GHG emissions by between 5 % and 10 %.[21]

Waste minimization is achieved through accurate demand forecasting, which prevents overproduction and obsolescence. In addition, AI systems monitor and optimize energy consumption in warehouses without compromising operational performance.[7]

This alignment between operational efficiency and environmental responsibility allows companies not only to reduce their carbon footprint but also to strengthen their corporate image and meet the growing expectations of stakeholders.[7,21]

Challenges of implementing AI in the logistics chain

The adoption of AI in the supply chain is a complex process that faces significant technical, economic, and cultural obstacles. Successful implementation requires overcoming four critical interconnected challenges.

The Investment Equation: Costs and ROI

The considerable initial investment in technological infrastructure, specialized software, model development, and training constitutes the first barrier.[22] The size of the global AI market in logistics, valued at $20,1 billion in 2024, reflects the magnitude of these investments.[23]

Calculating return on investment (ROI) is complex because some benefits (e.g., improved decision-making, employee morale) are intangible. A comprehensive analysis must integrate tangible KPIs (e.g., reduced labor costs, operational efficiency) and intangible KPIs (e.g., customer satisfaction).[24]

Data as a Foundation: Quality and Integration

The principle of "garbage in, garbage out" is particularly relevant in AI. The lack of standardized, clean, and readily available data represents a significant barrier, as fragmented data across incompatible systems undermines the accuracy of algorithms.[1]

Data management requires robust, specialized infrastructure to process massive volumes of structured and unstructured information. In addition, integration with legacy systems (ERP, WMS, TMS) creates technical complexities that can disrupt operations if not managed meticulously.[1]

The Human Element: Talent and Change Management

The global shortage of talent specializing in data science, AI development, and machine learning slows adoption and increases costs.[25] It is crucial to understand that AI seeks to augment human capabilities, not replace them.

Overcoming this challenge requires aggressive investment in training, reskilling, and upskilling programs to adapt the workforce to new workflows. Cultural change management is equally critical, requiring transparent communication and tangible demonstration of how AI eliminates tedious tasks and allows focus on strategic work.[25]

Security and Trust in the Age of AI

Increasing connectivity expands vulnerabilities to cyber threats such as ransomware, spoofing, and signal interference, requiring protection equivalent to physical security.[4] The governance of sensitive data requires robust protocols and compliance with regulations such as the GDPR.

Ethical considerations are a priority: ensuring transparency, explainability, and auditability of algorithmic decisions is essential to avoid bias and maintain accountability.[26]

Interconnection of Challenges: A Vicious Cycle

These challenges form an interdependent system where each problem exacerbates the others. Poor-quality data increases infrastructure costs, talent shortages drive up labor costs, and high costs limit SMEs' access to advanced solutions. This cycle creates a competitive barrier that favors large companies with the capacity to invest simultaneously across all three fronts, potentially accelerating market consolidation driven by technological disparity.

Emerging Technologies and the Autonomous Supply Chain

The evolution of AI in logistics is moving towards an autonomous, interconnected, and intelligent ecosystem, driven by synergy with other disruptive technologies. This future is built on three converging pillars:

AI, IoT, and Blockchain Synergy: Intelligent Traceability

The convergence of these technologies creates a secure, transparent, and proactive traceability system. IoT devices act as the "senses," capturing real-time data on location, temperature, and environmental conditions. Blockchain functions as an immutable "memory," recording every transaction in a decentralized, tamper-proof ledger. AI serves as the analytical "brain," processing this data to detect anomalies, predict disruptions, and proactively optimize processes.[27] This triad is particularly crucial in regulated industries such as pharmaceuticals and food, where cold chain integrity is a regulatory and competitive requirement.

Digital Twins: Simulation and Predictive Optimization

Digital twins—dynamic virtual replicas of physical assets or entire systems—represent another significant advance. Powered by real-time IoT data, these models accurately reflect the status of their physical counterparts.[28] Their power is maximized when combined with AI, allowing for the simulation of infinite "what-if" scenarios without operational risk: from stress testing for

disruptions to warehouse layout optimization or predictive maintenance.[29]

Autonomous Logistics: AI and Generative Agents

The final trajectory points toward fully autonomous supply chains. "AI agents"—autonomous software systems capable of perceiving, deciding, and acting—will manage complex tasks such as production planning, supplier negotiations, and dynamic route reconfiguration. Generative AI will complement this ecosystem by designing optimal logistics networks from scratch, generating alternative plans during crises, and automatically drafting contracts.[30]

The human role will evolve toward strategic oversight, exception management, and ethical guidance of autonomous systems. Digital twins act as an essential bridge to this autonomy, functioning as "flight simulators" where AI agents can be trained risk-free through millions of scenarios. Maturity in digital twins correlates directly with readiness for real autonomy.

FINAL CONSIDERATIONS

This study demonstrates that Artificial Intelligence has the potential to move beyond being an auxiliary technology and become the operational core of the modern supply chain. Its strategic implementation drives a paradigm shift, moving from reactive, fragmented processes to a proactive, interconnected, and autonomous ecosystem.

The four pillars analyzed—demand forecasting, warehouse automation, transportation optimization, and strategic supplier management—reveal that the value of AI lies in its capacity for synergistic integration. This synergy creates a "flywheel effect" of continuous optimization, where improvements in one area automatically boost performance in others, generating exponential gains in efficiency, resilience, and sustainability.

However, the transition to smart logistics faces critical challenges.

The cost-ROI equation, data quality, the talent gap, and security and ethical risks are significant barriers that require a strategic and holistic approach. Overcoming them requires sustained investment, cultural change management, and a robust governance framework.

The immediate future will be defined by technological convergence (AI + IoT + Blockchain) and the emergence of digital twins, which will act as simulators for the secure development of autonomous supply chains. However, total autonomy does not imply the replacement of the human factor. On the contrary, the role of professionals will evolve towards strategic supervision, exception management, and the ethical management of increasingly complex systems.

Ultimately, AI is not an end but rather an essential facilitator in building agile, resilient, and sustainable supply chains capable of thriving in a volatile global environment. Organizations that integrate these technologies ethically and strategically, keeping humans at the center of decision-making, will not only optimize their operations but also redefine the standards of competitiveness in the 21st-century logistics industry.

BIBLIOGRAPHICAL REFERENCES

1. Gutiérrez Ortiz A, Méndez González C, López Alvarado N, Reyes Vázquez JE, Reyes Vázquez S. Los efectos de la escasez de contenedores vacíos en la cadena logística del Puerto de Manzanillo, México. Investigación Y Ciencia Aplicada a La Ingeniería. 2025;8(49).

2. Villegas Pisco LL, Vera Velásquez B. Desempeño laboral y su impacto en la cadena logística de la empresa Megaoperaciones, Chone. UNESUM - Ciencias Revista Científica Multidisciplinaria.

2025;9(2):176-89. https://doi.org/10.47230/unesum-ciencias.v9.n2.2025.176-189

3. Sánchez Cruz MA. Optimización de las operaciones en la cadena de suministro a través de la inteligencia artificial: un enfoque basado en datos logísticos. LATAM Revista Latinoamericana De

Ciencias Sociales Y Humanidades. 2025;6(3):687-96. https://doi.org/10.56712/latam.v6i3.3976

4. Guerra Castellón E, Vázquez Alfonso Y, Núñez Torres E. Desempeño logístico en entidades turísticas cubanas de la cadena de suministro: Estudio comparativo mediante machine learning. GRAN TOUR Revista de Investigaciones Turísticas. 2025;(31). https://www.eutm.es/grantour/index.php/grantour/article/view/400

5. Hanco-Mamani JI. Research trends on technologies in logistics management. Revista Científica De Sistemas E Informática. 2024;4(2):e755. https://doi.org/10.51252/rcsi.v4i2.755

6. Ibarra-Peña KA, Morán-Murillo PN, Rodríguez-Sares EA. Inteligencia artificial y Big Data en la optimización de cadenas de suministro internacionales: hacia una logística predictiva y sostenible. Revista UGC. 2024;2(3):61-71.

7. Johan Sebastian, Riascos-Guerrero JA, Galván-Colonia E, Pincay-Lozada JL. Estrategias basadas en inteligencia artificial para la gestión de inventarios en la cadena de suministro. TM. 2024;37(6):88-97. https://doi.org/10.18845/tm.v37i6.7271

8. Zambrano Burgos VR, Zambrano Mieles JD, Mieles Cevallos D. El rol de la inteligencia artificial en la automatización y la gestión de la cadena de suministro. GADE Revista Científica. 2025;5(1):390-414. https://doi.org/10.63549/rg.v5i1.607

9. Riascos JA, Bravo JS, Galván Colonia E. Estrategias basadas en inteligencia artificial para la gestión de inventarios en la cadena de suministro. Universidad Cooperativa de Colombia; 2025.

10. Paredes Solsol VH, Diaz De La Vega Huanca JH. Sistema de Gestión de Almacenes Basado en Inteligencia Artificial para Optimizar las Ventas. Universidad Peruana de Ciencias Aplicadas, Perú; 2025. http://hdl.handle.net/10757/683823

11. IKEA lanza una nueva experiencia digital impulsada por IA - IKEA. Available from: https://www.ikea.com/us/en/newsroom/corporate-news/ikea-launches-new-ai-powered-digital-experience-empowering-customers-to-create-lifelike-room-designs-pub58c94890/

12. Bombín González M. Tendencias y futuro de la logística, el ejemplo de Amazon. 2022. Available from: https://uvadoc.uva.es/handle/10324/54540

13. Tirado Avila JD, Mecola Bernedo JC. Automatización Robótica de Procesos y su Impacto en la Gestión de Compras y Cadena de Suministros: Revisión Sistemática. Gestión Operacional Industrial. 2024;3(1):64-79.

14. Mahajan S, Nagesh I R, Mishra B B, Sarkar S, G S, D V, et al. Artificial Intelligence and Strategic Governance: Enabling Real-Time Decisions in Complex Business Ecosystems. Management (Montevideo). 2025;3:174.

15. Ahmed I, Alkahtani M, Khalid QS, Alqahtani FM. Improved Commodity Supply Chain Performance Through AI and Computer Vision Techniques. IEEE Access. 2024;12:24116-32. https://ieeexplore.ieee.org/abstract/document/10418923

16. Rahman F, Anwar D, Faizanuddin M. Interconnected Supply Chain Management and

Logistics: Key to Driving Business Success. Management (Montevideo). 2025;3:142.

17. Danchuk V, Comi A, Weiß C, Svatko V. The optimization of cargo delivery processes with dynamic route updates in smart logistics. 2023. Available from: https://art.torvergata.it/handle/2108/321403

18. Shlash Mohammad AA, Khanfar IA, Al Oraini B, Vasudevan A, Suleiman IM, Fei Z. Predictive analytics on artificial intelligence in supply chain optimization. Data and Metadata. 2024;3:395.

19. Muntala PSRP. Prescriptive AI in Procurement: Using Oracle AI to Recommend Optimal Supplier Decisions. International Journal of AI, BigData, Computational and Management Studies.

2021;2(1):76-87. https://ijaibdcms.org/index.php/ijaibdcms/article/view/228

20. Rey Escobar I, Valle Nieto JE. Transformación digital en la logística internacional: Estrategias y desafíos de la inteligencia artificial para los inventarios y cadena de suministro en las empresas exportadoras colombianas. Universidad Pontificia Bolivariana, Colombia; 2024. http://hdl.handle.net/20.500.11912/12163

21. Velaz-Acera N. Técnicas de optimización e inteligencia artificial (IA) como precursoras de una transición energética sostenible. 2025. Available from: https://gredos.usal.es/handle/10366/163946

22. Mateus MA. La dualidad de la inteligencia artificial en la sostenibilidad de las cadenas de suministro: una revisión narrativa. European Public & Social Innovation Review. 2024;9:1-21. https://epsir.net/index.php/epsir/article/view/552

23. Halachev P. The Influence of Artificial Intelligence on the Automation of Processes in Electronic Commerce. Data and Metadata. 2024;3:352.

24. González JC. Análisis de la incidencia de los parámetros del modelo de cálculo del Retorno de la Inversión en proyectos de automatización de procesos de negocios con aplicación de la tecnología RPA. CONECTIVIDAD. 2021;2(1):10-26.

25. Reyna Tenorio LJ, Ochoa González FA. Transformación Sostenible en la Industria Manufacturera: Sinergias entre Agilidad, Inteligencia Artificial y Gestión de la Resistencia al Cambio. Reincisol. 2025;4(8):928-48. https://doi.org/10.59282/reincisol.V4(8)928-948

26. Rodrigo Mariano Díaz. Ciberseguridad en cadenas de suministros inteligentes en América Latina y el Caribe. Documentos de Proyectos(LC/TS.2022/70), Santiago, Comisión Económica para América Latina y el Caribe (CEPAL), 2022.

27. Helo P, Hao Y. Artificial intelligence in operations management and supply chain management: an exploratory case study. Production Planning & Control. 2021;33(16):1573-90. https://doi.org/10.1080/09537287.2021.1882690

28. Bustamante-Limones A, Rodriguez-Borges C, Pérez-Rodriguez JA. Evaluación del uso de gemelos digitales en los sistemas de producción. AiBi Revista de Investigación, Administración e Ingeniería. 2024;12(3):195-204. https://doi.org/10.15649/2346030X.4382

29. Toala Arias FJ, Maldonado Zuñiga K, Toala Zambrano MM, Álava Cruzatty JE. Gemelos digitales en la industria. Pentaciencias. 2022;4(1):75-83.

30. Martínez Amodia R. Desarrollo de un asistente virtual logístico basado en inteligencia artificial generativa. Development of a logistics virtual assistant based on generative artificial intelligence. 2025. Available from: https://repositorio.unican.es/xmlui/handle/10902/37131

31. Cordobés Navarro O. Aplicación de modelos de lenguaje generativos en la formulación y resolución de problemas de optimización. Escuela Superior de Ingeniería y Tecnología, Universidad de La Laguna, España. 2025. https://riull.ull.es/xmlui/bitstream/handle/915/42712/Aplicacion%20de%20modelos%20de%20lenguaje%20generativos%20en%20la%20formulacion%20y%20resolucion%20de%20problemas%20de%20optimizacion.pdf

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