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The Challenge of the Modern World - Artificial Intelligence and its Role in Supply Chain Management

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Abstract

AI in supply chain management helps to optimise processes—from planning to production, logistics and asset management—and to make more informed decisions.

The supply chain is one of the most important processes in business, through which a product or service passes from its creation to the end customer. The use of new technologies is important and necessary for increasing competitiveness. Therefore, the use of innovative technologies in the supply chain management process is important, as management becomes more efficient and faster.

Companies are increasingly using artificial intelligence to optimise the flow of goods—from selecting sources of raw materials to production and delivery—in order to improve their operational efficiency. Supply chains are complex, and managing them requires significant time and effort from various teams across the business, including procurement, quality control and manufacturing. But with the increasing availability of AI-powered supply chain management solutions, companies of all sizes now have access to revolutionary tools for optimising processes and gaining deeper insights into supply chain data.

Keywords: AI in supply chain management, logistics, AI in logistics forecasting.

Introduction

1.1 The modern reality of the global supply chain

A supply chain is an interconnected network of organisations, people, activities, information, and resources that facilitates the transformation and delivery of a product from its raw material source to the end user. In the 21st-century global economy, this network has become immeasurably complex: more than 200 suppliers from 43 different countries are involved in the creation of a single iPhone.

The total value of global supply chains in 2025 was $19.3 trillion — approximately 20% of the world's Gross Domestic Product (GDP). The effective management of this colossal system has become a determining factor for the competitiveness of any national economy and business entity.

The 2020 pandemic, the 2021 Ever Given incident in the Suez Canal, the 2022 Russia-Ukraine crisis, and the North American semiconductor shortage have exposed critical weaknesses: lack of visibility, difficulty in adapting, the Bullwhip Effect, and the Single Point of Failure. It was these very crises that created massive demand for AI as an effective solution to these problems.

1.2 Artificial Intelligence — Definition and Evolution

Artificial Intelligence (AI) - is the ability of computer systems to perform tasks that would normally require human intelligence: reasoning, learning, problem- solving, language understa-
nding, and pattern recognition.

The history of AI begins in 1950, when Alan Turing published 'Computing Machinery and Intelligence'—a paper in which the fundamental question of artificial intelligence was first formulated. In 1956, at the Dartmouth Conference, John McCarthy officially coined the term "Artificial Intelligence". After a three-decade 'winter', AlexNet's victory in the 2012 ImageNet competition ushered in a new era. In 2017, the paper 'Attention is All You Need' introduced the Transformer—the technology that made ChatGPT, Claude, Gemini, and other generative AI systems possible.

1.3. The Four Stages of SCM Development

Supply chain management has evolved through various stages, each defined by technological innovations and structural changes in the market **(Fig. 1):**

Stage	Period	Main Focus	Technology
1 - Physical Logistics	1960-1980	Transport, Warehousing	Telephone, Fax
2 - Integrated SCM	1980-2000	ERP, Information Sharing	SAP, Oracle, EDI
3 - Digital SCM	2000-2015	Visibility, Flexibility	IoT, Big Data, Cloud
4 - Intelligent SCM	2015-Present	Automation, Forecasting	AI, ML, Blockchain, Robots

In its early stages, SCM was primarily confined to logistical operations. Henry Ford's model of vertical integration (1910s-1930s) is considered a crucial milestone in the history of SCM. The Toyota Production System (TPS) introduced the Just-in-Time (JIT) concept in the 1950s and 1960s, which became the foundation for the second stage of SCM.

The Bullwhip Effect and AI's Response

The Bullwhip Effect—one of the most well-known problems in SCM—is characterised by the amplification of small variations in demand as they propagate up the supply chain. A 5% increase in soap sales in a supermarket ultimately causes 40-50% variations in production at the chemical factory.

Traditional SCM systems had three main weaknesses in managing this effect: **(1) a lack of information visibility between different links in the chain; (2) holding excess inventory to compensate for uncertainty; (3) slow decision-making processes. AI's ML algorithms and Real-Time Data Processing tackle these three weak points.**

Lessons from the Pandemic — A Turning Point

The COVID-19 pandemic proved to be the most extensive stress test in the history of SCM. According to a 2021 McKinsey & Company study, 93% of companies experienced significant disruptions. More than $450 billion worth of goods were stuck in ports. Over 4 billion people were subject to lockdowns.

However, companies that had developed AI-based SCM — Amazon, Alibaba, Zara — demonstrated an astonishing adaptability during the crisis. Amazon recorded a 26% revenue growth in the first quarter of 2020, while other retailers were experiencing a 40-60% decline. This contrast became a watershed moment for the adaptive benefits of AI.

2. AI Core Technologies in SCM

2.1. Machine Learning — The Foundation of SCM

Machine Learning (ML) is a subcategory of artificial intelligence in which systems learn from data without explicit programming. In SCM, ML is most effectively used in three main forms:

1. Supervised Learning - an algorithm learns patterns from historical data. For example, Random Forest, Gradient Boosting (XGBoost), and Neural Networks are used for demand forecasting, where historical sales, seasonality, Weather, economic indicators, social trends — all these factors are processed simultaneously.

2. Unsupervised Learning - K-means Clustering, DBSCAN, Autoencoders — these algorithms are used for customer segmentation, anomaly detection, and discovering new patterns.

3. Reinforcement Learning - the algorithm learns by interacting with its environment — used for managing optimal inventory levels, routes, and prices.

2.2. Deep Learning — Visibility and Automation

Deep Learning (DL) is a sub-category of ML where artificial neural networks (ANNs) mimic the structure of the biological brain. In SCM, DL

It is particularly effective in two areas:

1. Computer Vision in warehouses and logistics centres: The Amazon Robotics Kiva system manages over 200,000 autonomous robots using CV algorithms; DHL's 'Vision Picking' with

Google Glass provides a 25% efficiency increase; UPS's ORION system saves 100 million miles annually through computer vision and deep learning.

2. Natural Language Processing (NLP) in SCM: Automated processing of logistics documents (Bill of Lading, Customs Declaration, Purchase Order); Real-time analysis of customer complaints to identify SCM gaps; Intelligent analysis of multilingual tenders and contracts. Transformer models, similar to GPT-4 and Claude, automate complex logistical communications.

2.3. Internet of Things (IoT) and AI Synergy

IoT sensors form the nervous system of SCM — a relentless stream of real-time data that is processed by AI. The global IoT SCM market was $14.2 billion in 2025; it is projected to reach $34.8 billion by 2028 (**Fig. 2**):

IoT Sensor Type	Application in SCM	AI Category
RFID Tags	Inventory Tracking	ML-based Demand Forecasting
GPS Devices	Route Monitoring	Route Optimization AI
Temperature/Humidity Sensors	Food/Medicine Quality Control	Predictive Alert AI
Vibration Sensors	Equipment Condition Monitoring	Predictive Maintenance
Cameras/LIDAR	Visual Monitoring	Computer Vision AI

Maersk's Remote Container Management The RCM system uses more than 20 different sensors in over 300,000 containers — temperature, humidity, oxygen content, carbon dioxide — all of this data is sent to real-time AI systems. Thanks to this technology, pharmaceutical companies were able to transport COVID-19 vaccines at -70°C with 98% accuracy.

3. Key Areas of AI Application in SCM

3.1. Demand Forecasting

Demand forecasting is the cornerstone of SCM — all other decisions (ordering, production, transport, inventory) are based on this forecast. Traditional statistical methods (ARIMA, Holt-Winters, Simple Moving Average) relied on past trends; AI-based systems, however, process 50-100 times more variables in real-time.

Amazon's Anticipatory Shipping is a bold concept where AI sends products before an order is placed, working with 73% accuracy. This system processes 785 billion user interactions, 100 million product histories, 200 climate models, social media trends, sports/ It simultaneously processes a calendar of cultural events and local economic indicators.

Walmart's Eden system — for fresh food management — combines AI's Computer Vision and ML: a photo of an apple is sent to the AI, which determines its ripeness and calculates the optimal sales window. Walmart has reduced food waste by more than $2 billion using this system.

3.2. Inventory Optimisation — AI's Supply Chain Intelligence

Inventory management is the most capital-intensive component of SCM — global companies hold $1.1 trillion in inventory. Excess stock is a financial burden; too little stock leads to lost sales.

AI addresses three main challenges in inventory optimisation: **(1) Safety Stock Optimisation — AI calculates the optimal safety stock by analysing weather, economic cycles, purchasing patterns, and external factors; (2) Reorder Point Automation — the system automatically determines when and how many items to order; (3) ABC-XYZ Analysis — products are categorised according to value and demand variability.**

Zara's RFID+AI system — the benchmark for Fast Fashion: over 1 billion RFID tags in more than 2,600 stores transmit real-time inventory information to AI systems. Zara's new collection hits the market in 2 weeks (industry average: 6 months), and its stockout rate is less than 2% (industry average: 8%).

3.3. Logistics Optimisation — AI in Routing and Transport

Logistics — the most visible component of SCM — is undergoing the most dramatic transformation through AI optimisation. UPS's ORION (On-Road Integrated Optimization and Navigation) system optimises 55,000 routes daily. The algorithm analyses 250 million turning combinations. Annual savings: 100 million miles, $50 million in costs, 100,000 tonnes of CO2.

DHL's Resilience360 platform uses AI to analyse geopolitical risks, natural disasters, epidemics and political events. The system processes over 100 data sources in real-time — Twitter, investigative agency reports, meteorological data, court records.

3.4. Supply Management — AI in Relationships and Contracts

Procurement & Supplier Management is the fastest-growing area of AI application in SCM. AxiosAI, Coupa, Jaggaer and other platforms use NLP and ML for automated tender evaluation, contract anomaly detection, and price optimisation.

Siemens' AI Procurement system optimised $30 billion in purchases: over 1,500 supplier ratings are updated in real-time; tender analysis was accelerated by 80%; contract risk scoring was automated. The final result: $300 million saved in 3 years.

4. The impact of AI on critical areas of SCM

4.1. Risk Management and Resilience

In SCM, risk is categorised into four main categories: operational, financial, natural, and geopolitical. Traditional systems operated on historical data using a so-called "rear-view mirror" approach. AI, however, is shifting to a "windshield" — a proactive, forward-looking — approach.

Google's DeepMind airflow management system improved the optimisation of Britain's National Grid system by 10%. This experience was transferred to managing energy costs in

SCM. Siemens' Predictive Services AI predicts industrial equipment failures 6 weeks in advance with 98% accuracy.

The Supply Chain Control Tower — an AI-based, unified visualisation platform — brings all components of SCM together in a single "dashboard". According to Gartner research, by 2027, 70% of companies using an SCM Control Tower will see a 15% improvement in key metrics.

4.2. Sustainable SCM and AI

Climate change has become a new challenge for SCM: the EU's CSRD (Corporate Sustainability Reporting Directive) obliges more than 50,000 companies to measure and report their SCM emissions. AI reduces these emissions by 15-30% through optimised routes, reduced inventory, and energy optimisation.

Project44's Carbon Tracking platform uses AI to measure CO_2 emissions in real-time, optimise carbon footprints, and detect greenwashing. More than 1,200 companies rely on this platform. Unilever's AI-based SCM system reduced carbon emissions by 30% and cut operational costs by $1.5 billion in 2021.

4.3. Blockchain and AI — SCM Transparency

Blockchain technology, together with AI, is creating a new standard for SCM transparency. IBM Food Trust — a joint platform for Walmart, Carrefour, and Dole — tracks food provenance on the blockchain in 2.2 seconds instead of 7 days. Everledger identifies conflict gemstones in the diamond and precious stone supply chain by combining AI and Blockchain.

5. Challenges and limitations of AI SCM

6.1. Technical Challenges

The technical challenges of AI SCM are grouped into 5 main categories. Data Quality Problem — The effectiveness of AI is directly dependent on the quality of the data. A McKinsey study confirms that 60-70% of SCM AI projects fail not because of the algorithm, but due to poor data. The so-called 'Garbage In, Garbage Out' principle is particularly acute in AI.

Legacy Systems Integration — Integrating old IT systems with AI: 73% of global companies rely on ERP systems older than 10 years (Gartner, 2023). The absence of APIs, incompatible data formats, and a lack of real-time connectivity — these challenges increase the costs of AI integration by 3-5 times. Explainability Problem (AI Black Box) — The difficulty in explaining AI decisions poses a problem in critical SCM contexts.

6.2. Ethical and Legal Challenges

The ethical challenges of AI SCM encompass three main areas. Algorithmic Bias — AI systems learn from historical data, and thus historical biases. In supplier evaluation, AI can be

systematically unfair to companies from small or developing countries. The EU AI Act (2024) creates a legal framework for this problem.
Data privacy is of particular importance in the context of laws such as the GDPR (Europe), CCPA (California), and PDPA (Thailand). SCM user data — purchase history, location, behavioural patterns — is sensitive information. Labour Displacement — the impact of automation.
Talent Gap — the global demand for 'AI + SCM' specialists in Beijing exceeds supply by 4-5 times. LinkedIn's 2025 report confirms that the Supply Chain AI Engineer is one of the top three highest-paying specialities ($150-250K/year), yet the shortage of qualified personnel is critical **(Fig. 3):**

Challenge	Risk Level	Solution
Data Quality	Critical	Data Governance Framework
Legacy Integration	High	API-First Architecture
AI Black Box	Medium	XAI (Explainable AI)
Algorithmic Bias	High	Fairness Auditing
Talent Gap	Critical	Upskilling Programs
Cybersecurity	Critical	Zero Trust Architecture

7. AI SCM in developing economies

7.1 Challenges in emerging markets

The global boom in AI SCM is unevenly distributed: Developed economies (USA, Europe, Japan, Singapore) are leading; developing markets (the author's country – Georgia, as well as India, Brazil, Nigeria, Indonesia) are lagging.
Barriers in developing markets: (1) lack of infrastructure — internet connectivity, electricity supply, logistical infrastructure; (2) Lack of capital — the finance required for AI investments is less accessible; (3) Talent Gap — a critical shortage of AI SCM specialists; (4) Data Scarcity — high-quality historical SCM data is scarce.
However, the "Leapfrog" effect — the ability of developing countries to skip earlier technological stages — also applies to AI SCM. India's Ninjacart — an AI-based agricultural SCM platform — operates in over 2,000 cities, connecting farmers directly to the global market, bypassing the traditional middleman chain.

8. Georgia — AI SCM Capabilities

Georgia is geographically and strategically located at the crossroads of the SCM: a corridor between Europe and Asia, a Black Sea port, free trade agreements with the European Union, China, and former Soviet countries. This potential represents colossal opportunities for AI SCM.
Priority areas in Georgia: (1) AI-based export optimisation for wine and agricultural products; (2) Smart Port technologies for the ports of Poti and Batumi; (3) Middle Corridor

— AI optimisation of the China-Europe rail route; (4) Tourism SCM — AI-based guest care and logistics. The region's AI SCM market will grow 8-12 times by 2027.

9. A Vision for the Future — AI SCM 2030 and Beyond

9.1. Technological Trends

The future landscape of AI SCM is shaped by 5 key technological trends. Quantum Computing + AI: IBM, Google, D-Wave are developing Quantum ML algorithms for SCM optimisation; Quantum computing could enable optimisations a thousand times faster than a traditional computer — logistics Traveling Salesman Problems, which currently take minutes, could be solved in seconds by 2030.

Autonomous SCM: Automated, self-regulating SCM systems where agentic AI manages logistics, inventory and supply without human intervention. Hyperautomation: Integration of RPA (Robotic Process Automation) + AI + Process Mining + Analytics. Space-Based SCM Monitoring: SpaceX Starlink, Amazon's Project Kuiper, and other low-Earth orbit constellations will provide SCM with global real-time visibility, including all blind spots.

9.2. The Human-AI Symbiosis in SCM

AI in SCM does not mean replacing humans — it is an era of a new, symbiotic relationship. AI is excellent at pattern recognition, real-time optimisation, and processing large data sets. Humans, on the other hand, excel at creative solutions, ethical judgement, understanding cultural nuances, and building relationships.

The World Economic Forum's 2023 Future of Jobs Report confirms that AI SCM will create 2 million new jobs between 2025 and 2030 — Data Scientists, AI Trainers, Ethics Officers, Hybrid SCM Specialists — as traditional, simple roles are automated. During this transition, reskilling and upskilling are the most critical investments for companies and governments.

10. Recommendations

Coordinated actions from the government, business, and education sectors are required to maximise the potential of AI SCM.

- At the government level: Creation of a national AI SCM strategy; Investments in digital infrastructure; A legal framework for AI ethics; R&D incentives;
- In the business sector: A phased AI implementation approach; Data governance framework; Change management programmes; Supplier AI capacity building;
- In the field of education: AI SCM curricula in universities; Reskilling platforms; Industry-Academia partnerships; Internship programmes;
- At the international level: Harmonisation of AI SCM standards; Cross-border data sharing agreements; Development of AI SCM capacity in developing countries.
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11. Conclusions

Artificial intelligence in supply chain management is no longer a competitive advantage — it has become an industry standard. Companies that effectively integrate AI into SCM see a 15-20% improvement in demand forecasting and 20-30% in inventory optimisation, and 10-15% in logistics costs. This amounts to a combined 15-30% reduction in operational costs.

However, AI SCM is not a "silver bullet". Data quality, organisational culture, an ethical framework, and staff development are the factors that determine the effectiveness of the technology. The most successful companies using AI SCM are Amazon, Walmart, Maersk, Zara, Toyota — are successful not because they used the latest technology, but because they combined technological investments with investments in human capital, organisational change, and strategic vision.

The AI SCM market, growing to $41 billion by 2030, shows that this transformation will continue unabated. Companies, governments, and individuals who are now investing in understanding and harnessing AI SCM will emerge as the new leaders of the global supply chain by 2030. Change is inevitable; research is integral; action is vital.

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