

# The Application of Machine Learning in E-commerce Supply Chains and Guiding Consumer Green Behavior

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**Abstract:** As the digital economy and green development concepts advance in parallel, e-commerce supply chains are facing the dual challenges of improving efficiency and transitioning to a low-carbon economy. A Gartner survey shows that 70% of supply chain leaders report experiencing more frequent business disruptions. Traditional supply chain models, relying on manual decision-making, are finding it increasingly difficult to keep up with complex and volatile market demands and meet environmental requirements. At the same time, consumer demand for sustainable products continues to grow. McKinsey research indicates that over 70% of consumers are willing to pay a 5% premium for green products, providing a solid market foundation for e-commerce platforms to encourage green consumption. The maturity of machine learning technology offers a new avenue for resolving this conflict. By integrating data from across the entire supply chain, machine learning enables intelligent decision-making in demand forecasting, inventory optimization, and logistics scheduling, improving operational efficiency while reducing resource waste. For example, Amazon leveraged cloud technology and machine learning to restructure its forecasting system, helping it to smoothly navigate demand fluctuations during the pandemic. JD Logistics launched the "Jingtanhui" platform, which visually displays the carbon footprint of its entire logistics chain. Cainiao Network's intelligent algorithms have helped reduce packaging material consumption by 15%. These real-world examples demonstrate that machine learning is not just a tool for improving supply chain efficiency but also a core force driving its green transformation. Based on real-world application cases from e-commerce companies, this article systematically analyzes the application of machine learning in areas such as supply chain inventory management, logistics optimization, and carbon footprint tracking. It focuses on how it can guide consumers' green behavior through data empowerment. The goal is to clarify the path to sustainable development in the e-commerce supply chain driven by technology, and to provide valuable references for industry practice and academic research.

**Keywords:** Machine learning; E-commerce supply chain; Green consumption; Supply chain optimization; Carbon footprint tracking; Consumer behavior guidance.

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## 1. Introduction

Driven by the digital economy and green development, e-commerce supply chains are facing the dual challenges of improving efficiency and transitioning to a low-carbon economy. According to a Gartner survey, 70% of supply chain leaders report experiencing more frequent business disruptions. Traditional supply chain models, reliant on manual decision-making, are struggling to adapt to complex and volatile market demands and environmental requirements. At the same time, consumer demand for sustainable products continues to grow. McKinsey research shows that over 70% of consumers are willing to pay a 5% premium for green products, providing a market foundation for e-commerce platforms to encourage green consumption. The maturity of machine learning technology offers new solutions to these challenges. By integrating data from across the entire supply chain, machine learning can enable intelligent decision-making in demand forecasting, inventory optimization, and logistics scheduling, improving operational efficiency while reducing resource waste. Amazon leveraged cloud technology and machine learning to restructure its forecasting system, successfully managing demand fluctuations during the pandemic. JD Logistics developed the "Jingtanhui" platform to visualize the carbon footprint of its entire logistics chain. Cainiao Network's intelligent algorithms have reduced packaging material use by 15%. These practices demonstrate that machine learning is not only a tool for improving supply chain efficiency but also a core driver of green transformation. Drawing on real-world application cases from e-commerce

companies, this article systematically analyzes the application of machine learning in supply chain inventory management, logistics optimization, and carbon footprint tracking. It focuses on how it can empower consumers with data to guide green behavior. The goal is to reveal technology-driven paths to sustainable development in e-commerce supply chains and provide a reference for industry practice and academic research.

## 2. Machine Learning-Driven Demand Forecasting and Inventory Optimization

Demand forecasting and inventory management are core components of the e-commerce supply chain. Traditional models rely on historical data statistics, which can be slow to react to market fluctuations and easily lead to overstocking or shortages. Machine learning, on the other hand, can integrate multi-dimensional data and build adaptive models, improving both forecasting accuracy and inventory efficiency. During the COVID-19 pandemic, Amazon faced a surge in demand. Rather than relying on traditional empirical judgment, it employed a scenario-based planning system, capturing real-time data such as user browsing and purchasing, to build dynamic forecasting models. Leveraging cloud computing power, the system can process batch data in near real time, significantly increasing the automation of inventory placement. This not only prevented some product overstocks but also ensured the supply of in-demand items, thus stabilizing the supply chain during this challenging period.

Whole Foods Market's implementation further demonstrates the value of machine learning. As a company with 12 regions and 10 distribution centers, its supply chain is complex. After integrating with Amazon Web Services' supply chain solution, data integration tasks that once took months can now be completed in days. The system uses machine learning algorithms to predict future inventory levels, enabling procurement personnel to proactively identify potential shortfalls and identify alternative supply sources, effectively mitigating inventory risk [1]. This process reduces unnecessary inventory overstocking and, at the source, reduces energy consumption and resource waste in warehousing. According to industry estimates, improved inventory turnover can directly reduce warehousing carbon emissions by 15%-20%. On a technical level, modern inventory optimization systems employ gradient boosting algorithms such as LightGBM, incorporating seasonal factors, promotional activities, and macroeconomic indicators to build predictive models. JD Logistics, for example, utilizes over 200 optimization modeling methods to achieve 20%-30% higher forecast accuracy in complex scenarios than traditional methods. Furthermore, incorporating mixed integer programming algorithms, this system reduces inventory holding costs and carbon emissions while meeting order fulfillment deadlines. This intelligent management model not only helps e-commerce companies improve operational efficiency but also implements the concept of a green supply chain by reducing the storage and scrapping of unsaleable goods. The revised content emphasizes the natural flow of case studies and reduces the clutter of rigid technical terminology. If you feel a section needs adjustment or would like additional details, please let us know.

### **3. Intelligent Reconstruction of Logistics Networks and Low-Carbon Transformation**

As the primary source of carbon emissions in the supply chain, the green transformation of logistics relies on the technical support of machine learning. Through the application of intelligent algorithms such as route optimization, capacity scheduling, and intermodal transport, e-commerce logistics is achieving a synergistic development of efficiency improvements and carbon emission reductions. JD Logistics' "road-to-rail" solution is a prime example. Its machine learning-based optimization algorithm models multiple parameters such as transport distance, cargo matching, and timeliness requirements to accurately plan intermodal transport solutions for rail and road transport. Following implementation, JD will fully implement rail transport on all of its trunk routes over 800 kilometers long. By 2024, rail freight volume is expected to increase by over 30% year-on-year, reducing carbon emissions by tens of thousands of tons annually. This solution alone has been selected by the National Development and Reform Commission as one of the first batch of exemplary cases for cost reduction and efficiency improvement. Machine learning algorithms have also yielded significant results in last-mile delivery. Cainiao Network's Greed Solver logistics optimization engine can implement delivery solutions with the fewest vehicles and shortest mileage in 26 logistics scenarios. By analyzing historical delivery data, traffic conditions, weather factors, and other variables, the system plans the optimal delivery route for each courier, improving

door-to-door delivery efficiency by 10%. Cainiao's intelligent voice assistant automatically completes 100 million calls annually, saving couriers nearly 700,000 hours of call time and indirectly reducing carbon emissions from idling vehicles. This intelligent scheduling not only improves delivery efficiency but also reduces the environmental impact of logistics by minimizing inefficient travel. The large-scale deployment of green transportation capacity is another key to the low-carbon transformation of logistics. JD Logistics uses machine learning algorithms to optimize the scheduling of new energy vehicles and plans to deploy over 10,000 self-operated new energy vehicles by 2024. This includes the launch of 64 hydrogen truck routes in the Beijing-Tianjin-Hebei region, reducing diesel consumption by 600,000 liters and carbon emissions by nearly 1,000 tons annually. The system monitors vehicle energy consumption data in real time and dynamically adjusts delivery ranges and charging plans, increasing the utilization rate of new energy vehicles by 25%. Xi'an's "Asia No. 1" Smart Industrial Park, through photovoltaic power generation and dark-light operations, has become my country's first "zero-carbon" logistics park, generating over 61,000 megawatt-hours of electricity annually and reducing carbon emissions by 50,900 tons. These practices demonstrate that machine learning can effectively address operational pain points of new energy logistics vehicles and accelerate the green transformation of the logistics industry [2].

### **4. Full-Chain Carbon Footprint Tracking and Visualization Based on Machine Learning**

Carbon footprint tracking is fundamental to the green transformation of the supply chain, but traditional accounting methods have been plagued by data fragmentation and insufficient accuracy. The combination of machine learning and blockchain technology addresses this pain point, enabling full-chain tracking and trusted management of carbon data in the supply chain. JD Logistics' "Jingtanhui" platform utilizes its independently developed MRV-T digital carbon reduction technology and has built a distributed carbon ledger model encompassing 140 types of transport vehicles and over 2,000 carbon emission factors. It integrates real-time data collected by IoT devices, order information in the ERP system, and supplier energy bills. Using the LightGBM algorithm, it calculates carbon footprints at the order level in real time—a 30% improvement in accuracy over traditional LCA methods. This technology has been included in China's Green Technology Promotion Catalogue, making it a benchmark in the industry. In cross-border supply chains, carbon footprint transparency has become a key competitive advantage in international trade. Cainiao Network has developed a blockchain carbon footprint service specifically for cross-border parcel delivery. An organic tea brand uses this system to record data from tea picking to delivery to European consumers [3]. The resulting carbon footprint reports are tamper-proof, ultimately leading to an increase of 5% in orders from EU customers. Furthermore, the system uses spatiotemporal AI prediction models to dynamically adjust carbon emission factors during transportation, increasing carbon transparency in cross-border logistics by 90%. Walmart and IBM have collaborated on a blockchain traceability system that reduces pork traceability from 7 days to 2.2 seconds, allowing consumers to directly access 23 key

data points. This transparency not only improves food safety but also paves the way for carbon footprint data to reach consumers. JD's Carbon Footprint API utilizes a multi-tiered architecture: The Flink streaming computing framework refreshes data every five minutes to ensure dynamic carbon footprint updates. The hash value of the carbon data is then synchronized to a forensic authentication center through blockchain evidence storage, meeting international certification requirements such as the EU CBAM. It also includes an emissions reduction simulator that generates optimization plans based on different carbon reduction targets. Data from home appliance brands connected to this API shows a 22% increase in click-through rates for Class 1 energy-efficient products, significantly improving green conversion rates. This comprehensive "monitoring-accounting-optimization-display" approach not only provides standardized tools for carbon management in the e-commerce supply chain, but also provides clear information support for consumers to make green decisions [4].

## 5. Personalized Green Recommendations and Consumer Behavior Guidance Mechanism

The key to guiding consumers to adopt green behaviors lies in accurately meeting their needs and clearly conveying the value of green practices. Machine learning, through personalized recommendations and scenario-based incentives, helps consumers make decisions more environmentally friendly. The green product labeling system established by e-commerce platforms is fundamental. Taobao and Tmall launched the "Low-Carbon Friendly Product System," incorporating 29 authoritative low-carbon certification standards. By March 2023, 1.91 million products from 409 brands will be included in the system. Consumers can quickly find eligible green products through dedicated tags when searching for keywords. JD.com's "Green Plan" has a dedicated sustainable consumption section, screening over 3.56 million low-carbon products and labeling them based on four criteria, including product qualifications and packaging materials. Green products like the Magnum co-branded products are made with sustainable ingredients and feature recyclable packaging, making "green" more than an abstract concept and making it tangible. Intelligent recommendation algorithms further help green products improve conversion rates. Amazon's "Climate Pledge Friendly" section uses machine learning to analyze users' purchase history and browsing preferences, precisely recommending certified products to those likely to be green consumers [5]. It also provides third-party sustainability information query services. This system has increased the exposure of green products by 30% and driven a 40% increase in sales of categories such as organic coffee. JD.com also built an energy efficiency recommendation model based on carbon footprint API data, prioritizing top-tier energy-efficient appliances. One brand's air conditioner sales increased by 18% after integration. In the apparel category, the company prioritized recycled polyester products, increasing the sales share of these eco-friendly lines from 12% to 25%. Gamified incentives also lower the barrier to entry for green consumption. Taobao's "Green Park" platform has implemented a "Little Green Flower" points system, converting behaviors like purchasing green products and choosing minimalist packaging into redeemable rewards. Consumers can use these points to redeem eco-friendly

products and participate in public welfare projects. During the 618 shopping festival, the platform partnered with over 40 brands to promote minimalist packaging, using these incentives to help consumers develop green habits. McKinsey research shows that if the price premium for green products is kept within 5% and is accompanied by clear environmental labeling, consumer acceptance will reach 70%, and personalized recommendations can increase this percentage by another 15%. These practices demonstrate that machine learning can not only accurately match consumer needs but also reduce the decision-making costs of green consumption through scenario-based design, forming a sustainable closed loop of "guidance-consumption-habit formation."

## 6. Challenges and Collaborative Countermeasures for Green Transformation in E-commerce Supply Chains

Machine learning still faces multiple challenges in promoting green transformation in the supply chain: technical, cost, and cognitive. Data silos are a primary obstacle. Supply chain data is scattered across multiple entities, such as ERP systems, logistics nodes, and suppliers, with varying formats and standards. An Amazon Web Services survey shows that supply chain teams spend a significant amount of time integrating disparate data, resulting in 70% of companies missing out on opportunities to unlock data value. JD Logistics has reduced data integration time from weeks to minutes by pre-built connectors to systems like SAP ECC, but small and medium-sized enterprises still face technical limitations. Cost pressures and technical barriers hinder the large-scale application of green technologies. Although JD's "Jingtanhui" platform has achieved a 60% reduction in carbon footprint accounting costs, the initial investment in blockchain evidence storage and IoT device deployment remains prohibitive for many small and medium-sized e-commerce companies. Gartner notes that the widening supply chain talent gap exacerbates the challenges of technology implementation. Inexperienced operators struggle to fully leverage the effectiveness of machine learning models, requiring the transfer of practical knowledge through digital tools. Furthermore, consumer trust in green labels varies widely. A survey shows that only 45% of consumers fully trust the environmental certifications of e-commerce platforms. Insufficient data transparency and third-party endorsements hinder effective guidance. Addressing these challenges requires building collaborative solutions. On a technical level, componentized algorithmic solutions, such as the API and visualization tools provided by Cainiao's Greed Solver, should be promoted to lower the barrier to adoption for small and medium-sized enterprises. On a policy level, unified supply chain carbon accounting standards should be established, drawing on the carbon data disclosure requirements of the EU CBAM mechanism. JD.com's Carbon Footprint API already supports conversion to multiple standards, including PAS2050 and ISO14067, laying the foundation for international integration. On an educational level, scenario-based experiences like "Green Park" should be used to enhance consumer green awareness and strengthen digital skills training for supply chain practitioners. Gartner predicts that by 2025, Agentic AI will become a core supply chain technology, capable of autonomous adaptation and optimization. In the future, we must focus on developing

dual-objective algorithms that optimize carbon emissions and improve efficiency, such as JD.com's mixed-integer programming engine, which simultaneously minimizes costs and carbon emissions [6]. We must also establish a cross-enterprise carbon data sharing alliance, modeled after the collaborative model of Maersk's TradeLens platform, to achieve full-chain emission reductions through data interoperability. Only through the synergy of technological innovation, policy guidance, and market education can we fully unleash the potential of machine learning in the green transformation of the supply chain.

## 7. Conclusion

By analyzing practical cases from companies such as Amazon, JD.com, and Cainiao, this paper systematically explores the application paths and consumer guidance mechanisms of machine learning in the green transformation of e-commerce supply chains. The research demonstrates that machine learning, through technical means such as demand forecasting optimization, logistics network reconstruction, and carbon footprint tracking, has significantly improved the resource utilization efficiency and environmental performance of the supply chain. Case studies such as Amazon's intelligent inventory system, JD.com's "road-to-rail" algorithm, and Cainiao's packaging optimization technology demonstrate the feasibility of technology-driven supply chain cost reduction, efficiency improvement, and low-carbon development. JD Logistics' annual carbon reduction of over 500,000 tons is particularly impressive. In terms of consumer engagement, a combination of carbon footprint labeling, personalized recommendations, and gamified incentives has proven effective. Data shows that conversion rates for products with green labels increase by 15%-20%, and machine learning-driven targeted push notifications further amplify this effect. Taobao's "Green Park" and Amazon's "Climate Pledge Friendly" zones demonstrate that when green information is transparent and incentives are in place, consumers are willing to pay a reasonable premium for sustainable products. Despite challenges such as data silos and cost pressures, the integration of intelligent and green e-commerce supply chains

will become an inevitable trend as Gartner's predicted 2026 machine learning adoption milestone approaches. Future development should focus on technology accessibility, standardization, and awareness-raising. Component-based solutions should lower barriers to adoption, leverage technologies like blockchain to ensure data credibility, and foster green consumer habits through scenario-based design. Machine learning is not only a tool to improve supply chain efficiency, but also a bridge connecting corporate sustainable development with consumers' green needs. Its in-depth application will drive the e-commerce industry to form a virtuous cycle of "efficiency improvement-carbon emission reduction-consumption upgrade", providing important support for achieving the "dual carbon" goals.

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