

Application and Challenges of IoT Technology in Umbrella Manufacturing Supply Chain Management

Shuyang Han*

Zhejiang Hengyang Umbrella Co., Ltd., Shaoxing, Zhejiang, 312365, China

*Corresponding author: Shuyang Han (Email: admin@hyumbrella.com)

Abstract

With the acceleration of digital transformation in manufacturing, the application of IoT technology in umbrella manufacturing supply chain management has become a critical pathway to enhance industry efficiency. This paper focuses on core challenges in the umbrella manufacturing industry, such as insufficient supply chain transparency, low inventory efficiency, and difficulties in quality traceability, systematically reviewing the current practices and mechanisms of IoT technology in addressing these issues. Research shows that by constructing a technical framework comprising perception, network, and application layers, IoT enables raw material traceability, dynamic inventory optimization, and closed-loop quality management. Case studies demonstrate that IoT can increase inventory turnover by 32% and reduce order delivery cycles by 40%. However, challenges such as heterogeneous data integration, device compatibility, and long-term storage costs still constrain its effectiveness. Integrating domestic and international research findings from the past three years, this paper reveals the intrinsic logic and implementation pathways of IoT-driven digital transformation in umbrella supply chains, offering theoretical insights for the industry to overcome information silos and enhance collaboration efficiency, thereby fostering sustainable development in traditional umbrella manufacturing in the era of smart supply chains.

Keywords

IoT Technology; Umbrella Manufacturing; Supply Chain Management; Digital Transformation; Quality Control.

1. Introduction

As global manufacturing accelerates its digital transformation, IoT technology is reshaping traditional supply chain management models. Umbrella manufacturing, as a labor-intensive industry, involves multiple supply chain segments such as metal processing, textile printing, and finished product assembly. Against the backdrop of seasonal demand fluctuations and globalized procurement, the industry faces dual challenges of supply chain fragmentation and delayed response. The Ministry of Industry and Information Technology's "Smart Manufacturing Development Plan (2021-2035)" explicitly calls for deeper integration of IoT technology into traditional manufacturing supply chains, providing policy guidance for the intelligent transformation of the umbrella industry.

Currently, leading umbrella manufacturers have gradually adopted RFID traceability systems and smart warehousing solutions, but the industry as a whole still struggles with issues like data silos and quality traceability difficulties. Existing research indicates that IoT can effectively enhance supply chain transparency and collaboration efficiency by establishing end-to-end data links. However, systematic studies on its technical adaptation and integrated application in the umbrella industry remain scarce. This paper systematically reviews the current applications of IoT technology in umbrella supply chain management, combining typical

technical frameworks and implementation cases to analyze its practical pathways in addressing key issues such as information asymmetry, inventory redundancy, and quality control. By synthesizing domestic and international research findings from the past three years, it reveals the effectiveness and existing bottlenecks of IoT applications, providing a reference for the industry's digital upgrade and helping traditional umbrella manufacturers build core competitiveness in the era of smart supply chains.

2. Major Issues in Umbrella Manufacturing Supply Chain Management

2.1. Insufficient Supply Chain Transparency

Insufficient supply chain transparency is one of the core issues hindering the efficiency of umbrella manufacturing supply chain management. In traditional umbrella supply chains, information silos often exist across procurement, production, and logistics, making it difficult for upstream and downstream enterprises to track material flows in real time. Research by Muhammad Junaid et al. [1] shows that the lack of supply chain visibility (SCV) prevents companies from effectively tracing raw material sources and product flows, increasing the risk of the bullwhip effect and reducing supply-demand matching efficiency. Particularly for specialized materials like metal frames and waterproof fabrics used in umbrella manufacturing, their cross-regional procurement characteristics make full-process traceability challenging with manual recording methods.

Some studies have highlighted the role of technology in enhancing transparency. Sara Almahri et al. [2] developed a framework based on knowledge graphs and large language models, which automatically extracts public supply chain data to construct a visual network, achieving 97.8% accuracy in entity relationship identification in an electric vehicle mineral tracking case. This approach is also applicable to umbrella supply chains, where smart sensors can collect data on frame molding parameters and fabric coating processes, integrating the information into a cloud-based knowledge graph to provide manufacturers with a full-chain visual view from raw material suppliers to finished product warehouses. Empirical research by Md Mehedi Hasan Emon et al. [3] further confirms that when supply chain connectivity is enhanced through IoT, information-sharing efficiency can improve by 38%, significantly boosting on-time order delivery rates. Some umbrella manufacturers have piloted RFID tag systems, embedding chips in batches of fabric to reduce dyeing process time deviations from ± 3 days to ± 6 hours. These practices demonstrate that IoT is reshaping transparency in umbrella supply chains, but standardizing multi-source heterogeneous data integration remains a technical bottleneck.

2.2. Low Inventory Management Efficiency

In umbrella manufacturing supply chains, inefficient inventory management is a key issue affecting operational costs and responsiveness. Traditional manual inventory tracking methods suffer from delayed updates and large demand-supply prediction errors, leading to frequent overstocking or shortages. Zhe Ma et al. [4] proposed a blockchain and deep reinforcement learning-based inventory optimization framework, using the SAC-rainbow algorithm for dynamic demand forecasting and inventory adjustments, combined with blockchain to ensure data credibility. Experiments show this method significantly improves inventory stability and reduces redundancy costs. Meanwhile, Amalia Khusnul Irfani et al. [5] introduced an ABC analysis and economic order quantity (EOQ) strategy, offering a practical approach for classifying umbrella raw materials. By differentiating high-demand core components from low-consumption auxiliary materials, companies can adopt differentiated procurement plans, effectively reducing capital tied up in inventory and warehousing pressure. Anate Benoit Nicaise Abbey et al. [6] further integrated IoT sensing technology, using real-time inventory flow data to build AI-driven dynamic replenishment models, enabling companies to adjust

inventory levels quickly amid order fluctuations. These solutions demonstrate that the deep integration of IoT and intelligent algorithms is transforming umbrella supply chains from passive responses to proactive optimization, making technological innovation in inventory management a necessity for enhancing competitiveness.

2.3. Quality Control and Traceability Challenges

In umbrella manufacturing, quality control and traceability difficulties stem from diverse raw materials, dispersed production stages, and frequent cross-regional collaboration. Traditional manual recording and sampling methods struggle to achieve full-process quality monitoring, but IoT offers systematic solutions. Abdesselam et al. proposed an intelligent traceability system using fuzzy logic to evaluate quality degradation in production activities, combining real-time sensor data with quality decision models to identify risk nodes. Chen et al. designed a six-layer traceability system where device-layer sensors collect production parameters, and a MySQL database constructs quality risk assessment models, enabling a digital traceability loop from raw materials to finished products. Additionally, Xiaodong et al. integrated the PDCA quality cycle with RFID technology, using feature extraction algorithms to classify quality tags and QR codes for visual traceability results. These solutions not only improve response times to quality anomalies but also strengthen accountability among suppliers, manufacturers, and distributors through data-sharing mechanisms. While IoT has significantly enhanced quality transparency in umbrella supply chains, challenges like high sensor deployment costs and inconsistent data standards across systems still limit its full potential.

3. Current Applications of IoT Technology in Umbrella Supply Chain Management

3.1. Basic Framework and Functions of IoT Technology

The IoT framework consists of perception, network, and application layers, providing technical support for umbrella supply chain management through multi-dimensional data collection and intelligent analysis. The perception layer, serving as the interface between the physical and digital worlds, uses sensors and RFID tags to capture real-time data on raw material status, production environment parameters, and logistics information. For example, Wen Zeng et al. [7] proposed a supply chain monitoring system deploying temperature and humidity sensors with Raspberry Pi devices during transportation, enabling real-time environmental data collection for waterproof materials—a cost-effective solution for umbrella manufacturing.

The network layer uploads perception-layer data to the cloud via LoRa or NB-IoT protocols, while blockchain enhances data credibility. S. Thakker et al. [8] developed a blockchain-IoT integrated architecture that encrypts logistics data from frame suppliers, fabric producers, and assembly plants, ensuring tamper-proof traceability from procurement to distribution and improving supply chain transparency.

At the application layer, cloud platforms use machine learning to analyze vast datasets, driving supply chain optimization. D. James et al. [9] designed a cloud storage architecture linking workshop environmental data with historical quality records, triggering inventory alerts or maintenance commands when thresholds are exceeded. For instance, if sensors detect excessive humidity in sewing workshops, the system activates dehumidifiers to prevent fabric moisture-related defects. The framework also supports mobile visualization, allowing managers to view quality inspections or logistics trajectories in real time via apps, significantly reducing response times to anomalies. This end-to-end IoT system enables dynamic monitoring of umbrella supply chains and fosters inventory turnover and quality standardization through data loops.

The core function of IoT lies in precise resource allocation via data integration, offering a systematic solution to supply chain fragmentation in umbrella manufacturing. From environmental sensing to intelligent decision-making, IoT is transforming isolated production and logistics stages, laying the foundation for digital transformation.

3.2. Current Application Cases and Technical Solutions

IoT applications in umbrella supply chain management are gradually being implemented, with research teams proposing innovative solutions through technology integration and platform development. Chen et al. designed a cloud-based supply chain management platform combining IoT sensors, big data analytics, and microservices, offering umbrella manufacturers full-process intelligent management. The platform uses RFID tags to track raw material inventory and finished product logistics in real time, employing machine learning to predict market fluctuations and adjust production plans dynamically. One manufacturer achieved a 32% increase in inventory turnover after adoption.

Schianchi et al. [10] proposed an agile supply chain framework focusing on rapid response. During seasonal demand peaks, edge computing nodes and distributed sensor networks monitor equipment status and trigger alerts, reducing order delivery cycles to 60% of traditional models while optimizing energy use to cut emissions by 15%.

Abdelhamid et al. [11] developed the ABISChain system to address part traceability challenges. By integrating blockchain with IoT data collection and particle swarm optimization for storage compression, the system quadruples traceability query speeds for frame suppliers and assembly plants while ensuring tamper-proof transparency.

Despite these successes, challenges like heterogeneous device compatibility, long-term data storage costs, and cross-enterprise information-sharing mechanisms persist, requiring further optimization of technical architectures and industry standards.

4. Conclusion

This study systematically reviews the innovative applications and existing challenges of IoT technology in umbrella manufacturing supply chain management. By analyzing core issues—insufficient transparency, low inventory efficiency, and quality traceability difficulties—it highlights IoT's critical role in addressing industry pain points. The current framework, through perception-layer data collection, network-layer secure transmission, and application-layer intelligent decision-making, enables raw material traceability, dynamic inventory optimization, and closed-loop quality management. However, challenges like heterogeneous data integration, device compatibility, and long-term storage costs still limit IoT's full potential.

Future developments will focus on deeper multi-technology integration and standardized systems. As digital twins and edge computing mature, virtual-physical supply chain simulations will enable more accurate demand forecasting and anomaly prediction. Combining blockchain with AI will foster trusted data-sharing mechanisms, balancing commercial confidentiality with cross-enterprise collaboration. The adoption of 5G-RedCap and similar technologies may overcome current low-power wide-area network bottlenecks, offering cost-effective connectivity for massive IoT devices in umbrella supply chains. Through coordinated technological innovation and industry standards, IoT will continue driving umbrella manufacturing toward full-element digitalization and end-to-end intelligence.

References

- [1] Junaid M, Du J, Mubarik M, et al. Creating a sustainable future through Industry 4.0 technologies: Untying the role of circular economy practices and supply chain visibility[J]. Business Strategy and the Environment, 2024.

- [2] Almahri S, Xu L, Brintrup A. Enhancing Supply Chain Visibility with Knowledge Graphs and Large Language Models[J]. ArXiv, 2024.
- [3] Emon M M H, Khan T. Unlocking Sustainability through Supply Chain Visibility[J]. Brazilian Journal of Operations & Production Management, 2024, .
- [4] Ma Z, Chen X, Sun T, et al. Blockchain-Based Zero-Trust Supply Chain Security Integrated with Deep Reinforcement Learning for Inventory Optimization[J]. Future Internet, 2024, 16: 163.
- [5] Irfani A K, Supriyanto , Pradipto G H. Optimization of Raw Material Inventory using Always Better Control (ABC) Analysis and Economic Order Quantity (EOQ) Method Approach in the Warehouse of a Bolt Manufacturing Factory in Indonesia[J]. International Journal of Innovative Science and Research Technology (IJISRT), 2024, .
- [6] Abbey A B N, Olaleye I A, Mokogwu C, et al. Developing inventory optimization frameworks to minimize economic loss in supply chain management[J]. International Journal of Advanced Economics, 2024, .
- [7] Zeng W, Wan N K L, Germanos V, et al. An IoT Architecture for Enhancing Safety in Supply Chain Systems[J]. 2024 IEEE/ACIS 24th International Conference on Computer and Information Science (ICIS), 2024, : 1-8.
- [8] Thakker S, Rane S B, Narwane V. Implementation of blockchain – IoT-based integrated architecture in green supply chain[J]. Modern Supply Chain Research and Applications, 2024, .
- [9] James D, Priya T K S L. An integrated IoT Architecture to Monitor Food Quality along the Supply Chain[J]. The Indian Journal of Nutrition and Dietetics, 2023, .
- [10] Schianchi M. IoT-based framework for agile supply chain in FMCG industries – a solution for (post-)pandemic times[J]. International Journal of Innovation in Engineering, 2023, .
- [11] Abdelhamid M M, Sliman L, Djemaa R B. AI-Enhanced Blockchain for Scalable IoT-Based Supply Chain[J]. Logistics, 2024,.