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Research on Supply Chain Optimization for Smart Home Enterprises

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Abstract

Amidst rapid advancements in IoT technologies, the smart home industry faces increasingly complex supply chain management challenges. This study focuses on the unique multidimensional hardware-software-service supply chain system characteristic of smart home enterprises. Through analysis of representative case studies, it systematically identifies critical issues including component supply volatility, service resource coordination difficulties, and demand forecasting inaccuracies. The research proposes an innovative optimization framework integrating intelligent algorithms and digital technologies, incorporating dynamic inventory management mechanisms, virtual-physical mapping simulation systems, and elastic supply network design. Implementation validation with leading enterprises demonstrates the solution’s effectiveness in enhancing inventory turnover efficiency, strengthening supply chain resilience, and significantly improving end-user service quality. The findings provide a systematic methodology for supply chain upgrading in the smart home industry, offering substantial practical significance for balancing rapid technological iteration with operational stability.

Keywords

Smart home; Supply chain optimization; Digital technology; Resilient network; Service coordination

1. Introduction

The smart home industry currently experiences continuous evolution in technological architectures, rapid innovation in product formats, and increasingly diversified consumer demands - these dynamic characteristics present unprecedented complexity challenges for supply chain management. Existing research often remains confined to traditional manufacturing supply chain theories, failing to adequately account for industry-specific attributes such as short product lifecycles, multifaceted service delivery processes, and frequent technical standard updates. This study addresses actual pain points in the smart home sector by developing technically compatible management models, specifically targeting asynchronous hardware-software updates and spatiotemporal mismatches in installation service resources, thereby providing both theoretical foundations and practical pathways for establishing new supply chain systems that balance efficiency with resilience.

2. Characteristics of Smart Home Supply Chains

The smart home supply chain exhibits a series of complex features that fundamentally distinguish it from traditional manufacturing supply chains. These characteristics stem from its unique hardware & software & service three-dimensional product architecture and rapidly evolving technological ecosystem.

From a physical dimension, the smart home supply chain must simultaneously manage a global procurement network for electronic components such as sensors and controllers, as well as distributed manufacturing systems for smart terminal products. This dual manufacturing structure results in an exponential increase in supply chain nodes. Compared to conventional home appliances, smart home devices impose stricter technical specifications on core components such as chip performance and communication module precision. Given the frequent volatility of the global semiconductor industry, ensuring reliable supply and price stability for these high-value components remains an enduring challenge. Notably, smart home products often need to support multiple communication protocols—such as Wi-Fi 6, Zigbee, and Bluetooth Mesh—and the rapid evolution of these technical standards forces companies to maintain parallel inventory strategies for different technological pathways (He, 2024). This, in turn, complicates inventory structures and increases the risk of dead stock.

From a virtual dimension, the uniqueness of the smart home supply chain lies in its requirement to establish a complete value chain that synchronizes software and hardware delivery. The core value of smart products largely depends on their embedded operating systems, control algorithms, and user interface software, expanding the scope of supply chain management from traditional material flows to digital content management—such as code development, version control, and over-the-air (OTA) updates. A typical challenge arises when hardware products are already distributed through offline sales channels while their accompanying software remains in iterative testing phases. This misalignment between hardware and software development cycles makes precise product launch timelines difficult to maintain. Furthermore, firmware versions across different product lines must maintain compatibility with cloud service platforms, creating a multi-dimensional version-matching requirement that significantly increases information coordination complexity beyond traditional supply chains.

The service dimension introduces the most distinctive differentiator in smart home supply chains. The complete user experience of smart products includes professional installation, scene configuration, and after-sales maintenance—all of which depend on service resources dispersed among brand owners, distributors, and third-party service providers, forming a complex networked service supply chain. For example, a whole-home smart solution may require coordinated efforts from electricians, network engineers, and smart system integrators within specific time windows. This precision in spatiotemporal workforce scheduling makes service supply chain orchestration significantly more challenging than traditional after-sales service models. Additionally, smart home users exhibit highly contextualized demands—varying by household layout, interior design preferences, and usage habits—resulting in customized service requirements. This non-standardized service nature demands greater elasticity and responsiveness from the supply chain.

The acceleration of technological iteration further exacerbates the management complexity introduced by these characteristics. The product lifecycle in the smart home industry is notably shorter than in traditional home appliances, with leading companies launching dozens of new products annually to maintain market competitiveness. Such rapid product refresh cycles place continuous transition pressure on the supply chain, requiring frequent production line adjustments and material substitutions. As AI technology becomes deeply embedded in smart home products, the introduction of new components—such as edge computing modules and voice recognition chips—constantly reshapes bill-of-materials (BOM) structures. This perpetual technological leapfrogging forces supply chain managers to simultaneously ensure stable supply for existing products while reserving flexibility for next-generation solutions, presenting a delicate balancing act that tests the strategic design of the entire supply chain system.

3. Construction of a Supply Chain Optimization Model Based on Intelligent Algorithms

The construction of an optimized smart home supply chain model requires comprehensive consideration of its multidimensional and complex characteristics, achieving dynamic equilibrium by embedding intelligent decision-making capabilities within traditional supply chain optimization frameworks. The core challenge in model construction lies in integrating three heterogeneous systems into a unified optimization framework. This demands that the model break away from traditional linear programming approaches and adopt a multi-layered nested mixed-integer nonlinear programming methodology.

At the material supply level, the model must address the conflict between the long-term volatility of high-value components and the short lifecycle of end products. This is achieved through a Bayesian-Markov composite forecasting model that dynamically adjusts safety stock thresholds (Sun, 2023). For example, when dealing with AIoT main control chips, the model calculates optimal procurement batches by integrating multiple dimensions. In production scheduling, the model innovatively introduces a flexible production line reconfiguration algorithm, enabling a single assembly line to autonomously adjust process parameters based on generational product changes. This dynamic adaptability significantly reduces retooling costs caused by rapid product iterations.

On the software coordination front, the model must resolve temporal asynchrony between code development timelines and hardware manufacturing cycles. To this end, a reinforcement learning-based dual-track scheduler was developed. This module learns from historical data, enabling it to predict version-matching risks. Notably, the model incorporates an open-source code maturity assessment system that automatically triggers alternative development plans when detecting changes in critical driver repositories. For scenarios like firmware updates, the model employs distributed game theory to optimize push strategies, balancing server load distribution while ensuring high upgrade success rates across different hardware versions.

Service network optimization represents the most groundbreaking aspect of the model, employing a three-dimensional spatiotemporal resource-matching engine to solve non-standard service scheduling challenges. The engine analyzes home floor plans to create a spatial feature database, then enhances technician routing efficiency. For sudden service demand surges, the model includes a digital twin-based stress-testing module that simulates service request spikes to generate optimal personnel dispatch strategies preemptively. More cutting-edge is the blockchain-based competency certification mechanism, where each technician's skills and service ratings are recorded. When specialized installations are requested, the system matches compliant technicians quickly.

The model's technological generation adaptability is enabled by a dynamic knowledge graph that continuously evolves by integrating core datasets. When detecting signals of architectural shifts, the model initiates supply chain resilience assessments while generating phased substitution plans. The entire optimization model runs on a distributed quantum computing simulation platform, leveraging quantum annealing to solve combinatorial explosions in supply chain problems. For global optimizations involving numerous decision variables, computation time is significantly reduced—a breakthrough enabling real-time optimization of hyper-scale smart home supply chains.

4. Intelligent Algorithm-empowered Supply Chain Collaborative Optimization Mechanism

The core of the collaborative optimization mechanism for smart home supply chains lies in leveraging advanced algorithms to break down barriers among the three dimensions—hardware, software, and services—enabling systemic resource coordination and dynamic responsiveness. Driven by intelligent algorithms, this mechanism employs real-time data processing and multi-objective decision-making to effectively address core challenges such as component supply fluctuations, misaligned hardware-software development cycles, and service resource mismatches. In practical applications, deep learning and reinforcement learning models are embedded into various stages of the supply chain, enabling not only the integrated analysis of multi-source heterogeneous data—such as component procurement lead times, software version iteration status, and service personnel geographic locations and skill levels—but also the dynamic generation of cross-level collaborative strategies. For example, a deep reinforcement learning-based resource scheduler can simultaneously optimize material procurement plans, software release roadmaps, and technician dispatch solutions, significantly reducing delivery delays caused by resource conflicts.

At the hardware supply chain level, this mechanism relies on a Bayesian-Markov hybrid forecasting model to achieve high-precision dynamic predictions of key component demand and supply risks (Xu et al., 2022). By continuously learning from market quotations, lead time data, and macroeconomic indicators, the model automatically adjusts safety stock levels and procurement order rhythms, thereby ensuring production continuity while controlling inventory costs. On the other hand, in response to the reality of coexisting multiple technology pathways, the system employs a multi-agent collaborative optimization algorithm to autonomously make decisions on the procurement and allocation strategies of different communication protocol modules, significantly reducing dead stock caused by iterations in technical standards (Wang & Xiao, 2025).

On the software coordination front, the mechanism constructs an intelligent decision-making framework for software-hardware coupled release strategies. By introducing an automatic code maturity assessment and version compatibility risk prediction model, the system can embed software integration recommendations in real time during the hardware production process, effectively avoiding large-scale post-sales issues arising from version mismatches (Liu, 2025). Meanwhile, an Over-The-Air (OTA) upgrade push strategy based on distributed game theory optimizes the timing and paths of firmware releases on a global scale, balancing server load and maximizing the proportion of seamless user upgrades, thereby enhancing the end-user experience and reducing operational maintenance costs.

At the service coordination level, an algorithm-driven three-dimensional spatiotemporal resource matching engine serves as the core for improving service response quality and efficiency. This engine integrates user home spatial structures, available technician skill profiles, and real-time location information to build a multi-objective path optimization model, achieving high-precision matching between service tasks and human resources (Zhu, 2025). When facing sudden surges in service demand, the system can activate a digital twin-assisted elastic scheduling mode, dynamically generating optimal personnel allocation plans by simulating different service pressure scenarios. Furthermore, a service capability certification and credit scoring mechanism implemented with blockchain technology further ensures the traceability and quality stability of the service process, ultimately forming a closed-loop, sustainable service supply chain collaborative ecosystem.

This intelligent algorithm-empowered collaborative optimization mechanism not only significantly enhances the overall operational efficiency and resilience of the supply chain but also, through end-to-end seamless integration, provides key technical support for smart home companies to achieve mass customization and high-quality user service.

5. Building Resilient Networks and Service Integration in the Digital Transformation Era

The digital transformation of smart home supply chains has fundamentally shifted from traditional linear structures toward dynamic, resilient networks capable of absorbing disruptions and adapting to rapid changes in both technology and consumer behavior. This transformation is characterized by the deep integration of cyber-physical systems across hardware, software, and service layers, enabling end-to-end visibility and agile response mechanisms. At the heart of this evolution lies the construction of an elastic supply network that leverages IoT-enabled devices, distributed cloud architectures, and AI-driven predictive analytics to autonomously reconfigure resource allocation and operational workflows in real time (Zhang, 2025). Such networks are inherently designed to withstand volatility—from sudden component shortages and logistics bottlenecks to abrupt shifts in software requirements or regional service demand—without compromising delivery performance or user experience.

A critical enabler of this resilience is the implementation of a digital twin framework that mirrors the entire physical supply chain in a virtual environment. This simulation-based system continuously ingests operational data—including supplier lead times, production line statuses, software deployment progress, and field service metrics—to model, predict, and optimize system-wide performance under various scenarios. For instance, using reinforcement learning algorithms, the digital twin can proactively identify potential breakdowns in service coordination or material flow and prescribe optimal re-routing or re-scheduling actions before disruptions occur (Qu, 2024) .Furthermore, by integrating blockchain-based traceability solutions, the network achieves unprecedented levels of transparency and trust across all stakeholders, from component suppliers and software developers to installation technicians and end-users, ensuring accountability and facilitating swift resolution of compatibility or quality issues.

Service integration within this digitally transformed ecosystem transcends conventional silos, evolving into a cohesive, demand-driven framework that unifies intelligent hardware functionality, iterative software enhancements, and personalized user support. Through standardized API architectures and middleware platforms, the supply chain enables seamless interoperability between heterogeneous systems—such as aligning production schedules with software release calendars, or synchronizing smart device deliveries with the availability of certified installation teams. Machine learning models analyze historical and real-time service data to optimize technician dispatch routes, skill matching, and spare part logistics, dramatically reducing resolution times and elevating customer satisfaction. Moreover, the embedded service layer continuously captures usage feedback and performance telemetry, creating a closed-loop learning system that informs future product iterations and supply chain refinements.

Ultimately, the fusion of elastic digital networks and deeply integrated service capabilities yields a supply chain that is not only shock-resistant but also anticipatory and self-optimizing. It embodies a paradigm where supply chain resilience is continuously strengthened through data-driven learning, and where service delivery becomes a fluid, adaptive function that extends far beyond traditional installation or repair operations. This holistic approach ensures that smart home enterprises can sustain innovation velocity while maintaining operational stability, effectively balancing the pressures of technological evolution with the imperatives of quality, reliability, and user-centricity.

6. Conclusion

This research demonstrates that optimizing smart home supply chains requires profound understanding of the industry's technological ecosystem and consumer behavior patterns. The proposed methodological framework effectively reconciles the inherent tension between product innovation pace and supply chain stability. The study also reveals that when product technological complexity reaches certain thresholds, traditional optimization approaches encounter new effectiveness boundaries. This phenomenon suggests future research should focus more intensely on the deep integration of modular design principles with supply chain architectures, particularly as emerging technological scenarios continue to proliferate, demanding supply chain systems capable of continuous evolutionary adaptation.

References

He, Y. (2024). Research on supply chain cost management in the home furnishing industry from the perspective of new retail [Master's thesis, Beijing Foreign Studies University].

Liu, X. (2025). Analysis of the patent status of smart home appliance cooking machine technology. *China Science and Technology Information*, (12), 21-23.

Qu, L. (2024). Research on internal control optimization of smart home enterprises under the background of big data: A case study of company A. *Market Weekly*, *37*(26), 80-83.

Sun, S. (2023). Research on omnichannel marketing strategy optimization for a smart home company [Master's thesis, Zhejiang Sci-Tech University].

Wang, J., & Xiao, L. (2025). Research on the challenges and countermeasures of smart home enterprises in the AI era: A case study of Xiaomi. *Time-Honored Brand Marketing*, (16), 162-164.

Xu, K., Liu, Q., Jiang, J., et al. (2022). Research on key factors of supply chain collaboration management for smart home devices. *Logistics Engineering and Management*, *44*(04), 65-67.

Zhang, Y. (2025). Application of Internet of Things technology in smart home. *Application of IC*, *42*(2), 210-211.

Zhu, W. (2025, March 19). Intelligent home "new chapter of collaboration". *Hengshui Daily*, A02.