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Research on Governance Mechanisms and Supply Chain Efficiency Optimization of the Smart Home Enterprise Ecological Collaboration Platform

Wen Peng*

Sarrlend Comfort Home (Wuhan) Technology Co., Ltd., Hubei, Wuhan, China

**Author to whom correspondence should be addressed.*

Abstract: This paper focuses on the core challenges of the smart home enterprise ecological collaboration platform, and deeply discusses the absence of a governance mechanism and the inefficiency of the supply chain. The purpose is to improve the overall efficiency by constructing an effective collaborative governance framework and optimizing the supply chain process. It is found that the implementation of multi-agent dynamic contract governance, the construction of an open data sharing middle platform, the introduction of AI-driven elastic supply chain planning, and the establishment of a distributed cloud manufacturing network are the key paths. From the research conclusion, these measures can significantly improve the transparency of cross-agent collaboration, break the data barriers, and achieve the accurate matching of supply and demand, and finally promote the ecological collaboration efficiency of the smart home industry to achieve a substantial leap.

Keywords: Smart home; Ecological collaboration platform; Governance mechanism; Supply chain efficiency; Optimization research

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1. Introduction

Smart home (home automation) is a residential platform that integrates wiring technology, network communication, security systems, automatic control, and audio-visual technologies to unify all home-related facilities. It aims to establish an efficient residential infrastructure and family agenda management system, enhancing home security, convenience, comfort, and aesthetics. Additionally, it promotes an environmentally friendly and energy-saving living environment. However, the effective collaboration between brands, suppliers, and service providers has fallen into a dilemma. The governance rules and the responsibilities of each party are unclear, the data is in an island state, and there are differences in technical standards, which further hinder the smooth flow of information. Exploring and solving the governance mechanism and supply chain efficiency bottlenecks in the ecological collaboration platform has urgent practical significance for releasing the collaborative potential of the smart home industry and building an agile and efficient value network.

2. Theoretical basis of governance mechanism and supply chain management of ecological collaboration platform

2.1. Theoretical framework of platform governance

In the development of a smart home ecological collaborative platform, the exquisite design of the rule system guides the consistency of the behavior of various participants and reduces potential friction by constructing unified behavioral norms and interaction standards. Its systematic basis then facilitates the realization of the power and responsibility allocation mechanism, which carefully divides the power boundaries and responsibility categories of platform owners, suppliers, and users, to ensure the predictability and collaborative stability of the actions of all parties. On this basis, the benefit distribution scheme encourages resource exchange and value sharing through a fair incentive mechanism. For example, in the process of supply chain integration in the field of smart home, the key elements are described in **Table 1** in detail.

Table 1. Key component dimensions of the governance framework of the ecological collaborative platform

Governance dimensions	Description of innovation function	Impact of supply chain optimization
Rule system construction	Establish a pre-specification based on intelligent algorithm to regulate the interaction mode of participants	Improve the transparency of order execution and reduce the risk of information asymmetry
Power and responsibility allocation mechanism	The responsibility module was dynamically allocated, and the smart contract right confirmation mode was integrated	The response delay was shortened and the responsiveness of cooperative decision-making was strengthened
Benefit distribution scheme	A multi-dimensional value sharing model was introduced to balance ecological profit and loss sharing	Resource sharing was encouraged to reduce inventory overstocking and cost redundancy

2.2. Evaluation dimensions of collaborative efficiency

When evaluating the operational effectiveness of smart home ecological collaboration platforms, collaboration efficiency constitutes a key measurement metric. Its meaning focuses on the overall ability of the platform to integrate multi-party resources and drive value flow. Specifically, it can be broken down into three interrelated and mutually reinforcing observation dimensions (as shown in **Table 2**). The response speed profoundly reflects the agility of the whole chain from information perception to decision-making conduction to service delivery in the face of terminal market demand fluctuations or emergencies, which is the immediate pulse of ecological health. Inventory turnover rate reveals the smoothness and economy of the flow of raw materials, work-in-process, and finished products in the complex collaboration network. Efficient turnover means the reduction of resource occupancy cost and the release of capital vitality [1]. Resource integration measures the degree to which the platform breaks traditional enterprise boundaries and connects decentralized capability units such as design, manufacturing, logistics, and service. High-level integration is represented by the seamless connection of cross-subject resource on-demand call and complementary advantages, and its multilateral network coupling strength directly shapes the overall resilience of the platform.

Table 2. Innovation analysis of the smart home ecological collaboration platform efficiency observation dimension

Observation dimension	Connotation extension	Ecological synergy value orientation	Analysis of innovation
Speed of response	The timeliness and accuracy of the ecological network for the closed loop of the demand signal from perception, decision to action	Market adaptability and instant guarantee of consumer satisfaction	Niche sensitivity coefficient
Inventory turnover	The economic efficiency and time and space optimization level of the movement of materials and products in cross-agent supply chain networks	Capital efficiency, operating cost optimization, risk buffer capacity	Dynamic balance coefficient
Degree of resource integration	The platform solves organizational barriers and promotes the depth of on-demand combination and collaborative innovation of heterogeneous capabilities such as design, manufacturing, and service	Economies of scope, emergence of innovation capabilities, and system resilience	Multilateral network coupling strength

3. Problems faced by smart home ecological collaboration platform

3.1. The absence of a cross-subject collaborative governance mechanism

Multiple types of agents, including brand owners, hardware suppliers, and service integrators, constitute a complex collaboration network. There is still room for improvement in the fine definition of the role positioning of each party. Such an inaccurate definition of rights and responsibilities can easily lead to functional overlap or responsibility vacuum in the process of business connection.

3.2. Data islands and technical standard barriers

The lack of a unified technical language between heterogeneous systems poses deep challenges. The independent technical routes of brands lead to natural barriers in product interconnection. The differentiated design of communication protocols is like an invisible digital tower of Babe, which hinders the smooth dialogue ability between devices and makes it difficult to truly achieve the seamless scene linkage expected by users. Data assets are imprisoned in an independent ecosystem due to insufficient system compatibility, cross-platform information flow is interrupted physically, a complete user behavior portrait and device running state cannot be effectively mapped in each link of the industrial chain, and the value mining chain is broken at key nodes.

3.3. Distortion of demand forecast and inventory imbalance

There is a natural hysteresis and asymmetry in the information transmission among the participants of the platform, and it is difficult for upstream manufacturers to capture the subtle changes in the terminal market in real time. Sales data provided by retailers is often lagging and fragmented, resulting in a lack of sensitivity in production plan adjustment. Long-tail products with frequent demand fluctuations are especially faced with forecasting difficulties. Their sales trajectories lack regularity, and it is difficult for the platform to establish accurate data models.

3.4. Sluggish response cycle of customized production

In the process of transformation from traditional large-scale manufacturing mode to customization, the complexity of multi-node collaboration leads to the consumption of time factors when order information is transmitted among brand owners, designers, parts suppliers, and production units, and there is a natural rhythm difference in the chain from demand instructions to production instructions [2]. The structural mismatch of flexible production capacity makes it difficult for small batch orders to quickly integrate into the existing scheduling system. The coordination gap between the procurement cycle of special components and the inventory strategy of general parts objectively prolongs the preparation stage, and the scheduling of manufacturing resources shows the characteristics of local optimization and global fragmentation.

4. The governance mechanism of the ecological collaborative platform and the core measures of supply chain efficiency optimization

4.1. Multi-subject dynamic contract governance system

The multi-subject dynamic contract governance system clearly defines the function of the platform party's overall data center through the list of rights and responsibilities. The manufacturing enterprise bears the main responsibility for capacity flexibility adjustment, and the sales terminal needs to perform the obligation of real-time market information feedback. The system takes the risk-sharing mechanism as the core to construct the capital pool operation mode. When the inventory of long-tail products is overloaded, the three parties share the storage cost according to the preset proportion, and jointly inject capital to start the emergency supply chain response procedure in the face of a sudden shortage of explosive products. The contract clause sets a dynamic adjustment window period and recalibrates the responsibility boundary every quarter according to the sales fluctuation coefficient and inventory turnover efficiency index. For example, the manufacturing enterprise can apply to reduce the short-term inventory responsibility proportion in the new product launch cycle, and the sales terminal needs to improve the accuracy of demand forecast data and bear the corresponding deviation risk in the promotion season. Ping island continuously optimizes its intelligent algorithms, using blockchain technology to solidify each operational link. When delays in raw material procurement cause disruptions in production, an automatic responsibility traceability process is triggered. Based on an accrual list, an executable loss compensation scheme is generated, enabling the entire supply chain to possess self-repair capabilities.

4.2. Open data sharing middle office building

The platform operator takes the lead in establishing a unified API interaction specification, which covers core data field definitions and transmission protocols such as device status collection, user preference analysis, and production instruction transmission, so that intelligent gateways of different brands can interpret heterogeneous device information flow in standardized languages. The infrastructure layer is compatible with data access of multiple communication protocols. The service layer encapsulates public algorithm modules such as user portrait generation and production capacity prediction. The blockchain certificate storage mechanism is embedded in key data flow nodes, and the full link operation traces from raw material purchase order generation to terminal installation completion are generated into an immutable distributed ledger. Participants must comply with the certificate storage rules when they obtain data call permissions. The access enterprise obtains a real-time capacity map and regional inventory distribution through the authorization key. The parts supplier can adjust the stock plan according to the dynamic demand prediction, and the logistics service provider can accurately schedule the service resources based on the installation progress data verified by the blockchain. The multi-party realizes the second-level synchronization of manufacturing instructions and resource status under the premise of ensuring data sovereignty [3].

4.3. AI-driven elastic supply chain planning

Within the framework of the smart home ecological collaboration platform, artificial intelligence algorithms deeply integrate online and offline multi-channel consumption data, continuously capture social media public opinion and seasonal consumption preference changes, and form a highly sensitive demand prediction model [4]. The model dynamically outputs the expected sales range of different product lines, directly drives the production unit to flexibly configure raw material purchase batches and production beats, so that the traditional rigid production line has the ability to quickly switch between different product models. The production scheduling system automatically generates the optimal equipment utilization plan based on the real-time updated forecast data. When the supply of specific parts fluctuates, the alternative material scheduling procedure is immediately triggered, and the priority order of the assembly process is synchronously adjusted to minimize the risk of production interruption [5]. Based on the evolving production and marketing plan, the logistics collaboration module intelligently plans the distribution routes and storage resources, and comprehensively considers the real-time storage capacity of the regional distribution center, the load status of the transport vehicle in transit, and the order density of the end outlets to generate the immediate replenishing instructions with the optimal cost. The whole supply chain planning system has a self-iterative learning mechanism, and the actual shipment data and planning deviation after each sales cycle are automatically fed back to the algorithm core, which is used to calibrate the parameter weights of the subsequent prediction model, so as to build a continuously strengthened dynamic balance between the demand end and the supply end [6].

4.4. Distributed cloud manufacturing resource sharing network

The platform operator abstracted the heterogeneous equipment of small and medium-sized manufacturing enterprises in the region, such as injection molding machines and patch production lines, into schedulable virtual manufacturing cells. The real-time updated capacity map was generated through the digital twin technology and the idle time of equipment and process accuracy parameters were marked [6]. The intelligent engine of the platform automatically disassembles the process route according to the geographical distribution and delivery time requirements of the order, and gives priority to matching the idle equipment cluster combination closest to the end user. The metal case stamping task may schedule the idle 2000-ton hydraulic press in factory A at noon, while the circuit board patches are assigned to the redundant SMT production line in enterprise B at night. The resource scheduling instructions were pushed to the corresponding equipment control terminal synchronously. The regional service alliance designated a three-hour delivery circle based on the physical distance, and the blockchain inspection procedure of the logistics service provider was triggered immediately after the manufacturing node completed the process. The semi-finished products were loaded by the circular packaging boxes certified by the alliance and loaded onto the next processing node. Flow from raw materials to the whole process of service delivery at the dynamic optimization of regional collaborative network resources [7].

5. Conclusion

This paper systematically demonstrates the strategy of optimizing the governance mechanism and supply chain efficiency of a smart home ecological collaboration platform. The key is to use dynamic contracts to clarify the responsibilities and risk sharing of multiple subjects, achieve information penetration by means of a standardized data middle office, and use intelligent algorithms to reshape the demand-driven elastic supply chain plan. The distributed cloud manufacturing network is used to activate idle resources, so as to realize regional agile response. In practice, it is suggested that all parties in the industry actively embrace the concept of open collaboration, focus on building transparent and mutual trust governance rules and an efficient data circulation environment, and constantly update intelligent supply chain management tools.

Disclosure statement

The author declares no conflict of interest.

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