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Enhancing the Modernization Level of Value Chain, Supply Chain, and Industry Chain in Telecommunications Smart Card for Operators: A Case Study on China Unicom

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Abstract: *This study explores strategies to enhance the modernization of value chains, supply chains, and industry chains in China Unicom's telecommunications smart card operations. Through a combination of quantitative risk assessment models, supply chain optimization frameworks, and empirical data analysis, we identify key challenges such as low value chain efficiency (32% resource redundancy) and weak independent R&D capabilities (only 15% of core technologies are domestically developed). By implementing a restructured value chain model and digital twin-based supply chain management, China Unicom achieved a 28% reduction in production costs and a 40% improvement in supply chain resilience. The results demonstrate the effectiveness of integrating data-driven decision-making and collaborative innovation in industrial ecosystems.*

Keywords: *Telecommunications Smart Card; Value Chain Optimization; Risk Assessment Model; Supply Chain Resilience; Digital Twin*

1. Introduction

China Unicom, as a central enterprise in the telecommunications industry, is fully implementing the spirit of the 20th National Congress, requirements of central inspection and rectification, and the overall layout plan of Digital China construction. In line with its development reality, it optimizes its strategic planning system, formulates the "China Unicom 'Fourteenth Five-Year Plan' Strategic Planning Outline (Revised)", coordinates development and security, serves the strategy of a networked power and Digital China, and accelerates the construction of a modern industrial system, high - level scientific and technological self - reliance, and the enhancement of national strategic security capabilities. It aims to strengthen and optimize its development, enhance core functions and competitiveness, and build a modern new central enterprise.

Vsens Company, a professional subsidiary of China Unicom in charge of terminal and telecommunications card operations, focuses on its main responsibilities. It deeply implements the "China Unicom Internet Communication Development Action Plan" and market - line key tasks. Committed to deepening internet communication business, enhancing business scale and value, it actively implements the group's professional line strategy, deepens innovative transformation, enhances "specialized and innovative" capabilities, implements technology - strong enterprises, strengthens core technology R&D, increases independent product R&D innovation, deepens digital transformation, and expands industry chain cooperation.

In recent years, with the rapid development of information technology and the expansion of the global communication market, the importance of telecommunications smart cards has grown. However, their operation faces many challenges. In terms of the value chain, supply chain, and industry chain, there are issues such as inefficient resource integration due to operational models, inaccurate supply - demand matching due to insufficient digital capabilities, and low industry discourse power due to insufficient innovation driving force. The telecommunications smart card industry also faces intensified global competition, market fragmentation, and technological barriers that threaten supply chain stability.

This study by China Unicom aims to enhance industrial control through modernization. It focuses on three core challenges: low value chain efficiency with 32% resource redundancy in card production; fragmented industry collaboration with only 22% of upstream suppliers integrated into Unicom's digital

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platform; and high R&D dependency with over 85% of COS (Card Operating System) technologies relying on foreign patents. By integrating quantitative models and empirical data, the study proposes solutions to strengthen China's position in the global smart card industry.

2. Literature Review

This study will combine the operation and management of China Unicom's telecommunications card and conduct an in - depth discussion on how to enhance the modernization level of operators' telecommunications smart card value chain, supply chain, and industry chain. The telecommunications smart card market has witnessed substantial growth in recent years, with its pivotal role in the communication ecosystem becoming increasingly prominent. However, it also confronts a host of complex challenges in the value chain, supply chain, and industry chain, which demand a comprehensive and in - depth exploration. The specific research content is as follows:

2.1. Value Chain Analysis and Optimization

The current composition of the telecommunications smart card value chain encompasses multiple links, including raw material procurement, chip manufacturing, card production, software development, packaging, and distribution[1]. Each link contributes differently to the overall cost, efficiency, and value - added potential. For instance, in the raw material procurement stage, the price fluctuations of key materials like semiconductor wafers can significantly impact production costs. In the card production link, traditional production techniques may lead to a 32% resource redundancy, as evidenced by in - house data from China Unicom, which not only increases costs but also reduces overall efficiency[2].

By closely examining each link, bottlenecks such as slow - moving inventory in the distribution phase and waste points like over - production in the manufacturing stage can be identified[3]. To optimize the value chain, strategies like implementing lean production methods in manufacturing, enhancing demand - forecasting accuracy in distribution, and promoting vertical integration between key links can be adopted[4]. For example, through better demand - forecasting, companies can reduce inventory levels, thus cutting down on storage costs and minimizing the risk of product obsolescence.

2.2. Supply Chain Management and Risk Prevention

The existing supply chain management model of telecommunications smart cards often follows a traditional linear structure, with multiple tiers of suppliers and complex logistics routes[5]. Operational efficiency is hampered by issues such as long lead times and inconsistent quality control. Potential risk points in the supply chain are numerous. Unstable suppliers, for example, may suddenly face production disruptions due to financial difficulties or natural disasters[6]. Logistics delays can occur due to unforeseen events like port strikes or extreme weather conditions. Inventory backlogs can be caused by inaccurate market demand forecasts.

To design a more robust and flexible supply chain management system, techniques such as dual - sourcing strategies for key components, real - time supply chain monitoring using IoT (Internet of Things) technology, and the establishment of strategic safety stock levels can be employed[7]. A dual - sourcing strategy ensures that there is always an alternative supplier in case of disruptions from the primary one. Real - time monitoring enables companies to quickly respond to any emerging issues, and strategic safety stock can buffer against short - term supply shortages[8].

In the telecommunications smart card industry chain, the cooperation mode between upstream and downstream enterprises is often fragmented. For example, only 22% of upstream suppliers are integrated into Unicom's digital platform, which limits the seamless flow of information and resources. The collaborative innovation mechanism also faces challenges. In the technological innovation aspect, there is a lack of joint R&D efforts between chip manufacturers and software developers. In product development, there is a disconnect between the design of smart cards and the actual market needs.

To strengthen industry chain collaborative innovation, platforms for resource sharing can be established, where upstream and downstream enterprises can exchange technological know - how and market insights. Technical exchange meetings can be regularly organized to promote the cross - fertilization of ideas[9]. In terms of market development, joint marketing campaigns can be carried out to expand the market share of telecommunications smart cards.

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2.3. Independent Research and Development and the Promotion Strategy of COS Nationalization

Independent research and development play a crucial role in enhancing the modernization level of telecommunications smart cards. Currently, over 85% of COS (Card Operating System) technologies rely on foreign patents, which poses a significant threat to information security and technological sovereignty[10]. By promoting independent research and development and chip COS nationalization, China can reduce its technological dependence and enhance its competitiveness in the global market.

Specific strategies for promoting independent research and development include increasing investment in R&D, attracting top - tier talent in the field, and establishing industry - university - research cooperation mechanisms. For the promotion of COS nationalization, policies can be formulated to encourage domestic enterprises to develop and use domestic - made COS. Standards for domestic COS can be established to ensure compatibility and quality[11].

This study aims to provide feasible solutions and development suggestions for enterprises through in - depth analysis of the above content, to promote continuous innovation and upgrading in the field of telecommunications smart cards for operators.

2.4. Hypotheses Development

The global industry chain is in a period of accelerated restructuring, with a push towards the high - end leap of the value chain[11]. Economic globalization, which has long been a driving force for international trade and cooperation, has encountered strong headwinds. Trade protectionism has been on the rise, with countries imposing higher tariffs and non - tariff barriers. Geopolitical games, such as the trade disputes between the United States and China, have further complicated the international trade environment[12].

Countries' industry chain layouts are undergoing a significant shift. The focus is no longer solely on cost, efficiency, and technology but has expanded to include safety, stability, and politics[13]. For example, some developed countries are bringing back certain manufacturing processes to their home countries to ensure supply chain security. This has led to an increasing "security anxiety" about their own industry chains. The international industry chain is showing new characteristics and trends such as localization, regionalization, and diversification. Localization efforts are aimed at reducing dependence on foreign suppliers, regionalization promotes closer cooperation within a specific region, and diversification allows for a wider range of sourcing options[14]. These trends have further intensified the global fragmentation trend.

According to the World Trade Organization's forecast, the global goods trade volume will grow by 1.7% in 2023, significantly lower than the average level of 2.6% over the past 12 years[15]. The trade trend of the world's major economies is even weaker. In the future, global competition will be centered around value chains[16]. As the value chain is one of the most critical elements in the global economy and trade pattern, major economies are now fully engaged in value chain competition. Global trade competition is evolving into a "rule competition" based on value chain competition. China, in this context, faces a double squeeze of "high - end blockade" and "low - end lock - in". Developed countries are blocking China's access to high - end technologies and markets, while at the same time, low - cost competitors in other developing countries are locking China in the low - end manufacturing segment[17].

3. Methodology

3.1. Value Chain Optimization Model

In order to address the issue of resource redundancy in the value chain of telecommunications smart cards, a linear programming model was developed. The core objective of this model is to minimize the overall cost and inefficiencies within the value chain operations.

The mathematical representation of the model is as follows:

$$C=\sum i=1m(pi+\sum j=1nrij+\sum k=1lqik)$$

pi represents the production costs associated with the i-th production - related activity. These costs cover various aspects, such as raw material expenses, labor expenditures, and equipment operation costs. For example, in a smartphone manufacturing plant, pi could include the cost of purchasing components like batteries, screens, and the wages paid to assembly line workers.

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rij is the resource-allocation variable for activity i. It determines the quantity of resource j allocated to different production processes. For instance, in a semiconductor fabrication process, rij might denote the number of semiconductor wafers allocated to produce a specific type of chip.

qik is not defined in the original text, but assuming it relates to other relevant factors in the model, it likely represents a variable associated with a particular aspect of the production or operational process.

The objective is minC, and it is subject to a series of constraints (the text does not mention the specific constraints, and in practical applications, there will be constraints such as resource limitations).The resource constraints are:

$$\sum_{i=1}^{m} r_{ij} \leq B_j, j=1,2,\cdots,n$$

And the non - negativity constraints for the resource allocation variables are:

$$r_{ij} \geqslant 0, i=1,2,\cdots,m; j=1,2,\cdots,n$$

Implementation and Results:

After implementing the linear programming model, remarkable improvements were observed. The production costs per card were reduced by 28%, dropping from 0.37. This significant cost reduction can be attributed to optimized resource allocation, where the model accurately determined the most cost - effective way to distribute resources across different production activities.

The delivery accuracy also improved substantially, reaching 98.5%. This was achieved by better managing logistics - related variables in the model. By factoring in potential logistics delays and implementing risk mitigation strategies, the model was able to ensure that products were delivered on time more consistently.

The following table 1 visually represents the reduction in production costs before and after the implementation of the value chain optimization model:

Table 1: Production Cost Reduction Before and After Value Chain Optimization

Time Period	Production Cost per Card ($)
Before Optimization	0.52
After Optimization	0.37

3.2. Risk Assessment Framework

To comprehensively evaluate the risks in the supply chain of telecommunications smart cards, a quantitative risk scoring model was applied. This model provides a systematic way to assess the potential risks and their impacts.

The formula for the risk scoring model is expressed as $R=\sum_{i=1}^{n} P_i \times I_i$. This formula serves as a robust and efficient tool for comprehensive risk evaluation. By aggregating the probabilities and impacts of multiple risk factors, it condenses complex risk information into a single, interpretable score. Here, R represents the overall risk score of the evaluated system or project. A higher R value indicates a more critical and perilous situation, which demands immediate attention and the implementation of more robust risk mitigation strategies.

The following table 2 details the identified risk factors, their respective probabilities of occurrence, impact scores, and the resulting risk scores:

Table 2: Contribution of Each Risk Factor to the Total Risk Score

Risk Factor			
Supplier Instability	0.65	8.2	5.33
Technology Leakage	0.45	9.1	4.10
Logistics Delay	0.72	7.5	5.40

By calculating the contribution percentage of each risk factor to the total risk score, it was found that logistics delays contribute the most, accounting for 36% of the total risk. This indicates that addressing logistics - related risks should be a top priority in supply chain management.

3.3. Supply Chain Digital Twin

A digital twin platform was developed to enable real - time monitoring and optimization of the supply

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chain. This platform integrated IoT (Internet of Things) sensors and block-chain technology[18].

IoT sensors were deployed at various key points in the supply chain, such as in production facilities, transportation vehicles, and warehouses. These sensors collect real - time data on production processes, inventory levels, and logistics movements. For example, sensors in production facilities can monitor the production speed, quality parameters, and equipment status. Sensors in transportation vehicles can track the location, speed, and temperature (if applicable for temperature - sensitive components)[19].

Block chain technology was used to ensure the integrity and security of the data collected by IoT sensors. It provides an immutable record of all supply chain transactions and events, which enhances transparency and trust among all parties involved in the supply chain.

Key Metrics Improvement:

Production cycle time: The production cycle time was reduced from 14 days to 9 days. This was achieved by real - time monitoring of production processes, allowing for quick identification and resolution of bottlenecks. For example, if an IoT sensor detects that a particular production machine is operating at a slower - than - expected speed, maintenance can be scheduled immediately, reducing the overall production cycle time.

Inventory turnover rate: The inventory turnover rate improved by 44%, increasing from 3.2 to 4.6 cycles/year. Real - time inventory data provided by the digital twin platform enabled better demand forecasting and inventory management. By having accurate information on inventory levels and demand patterns, companies could optimize their inventory levels, reducing the amount of capital tied up in inventory and improving overall operational efficiency.

The following table 3 shows the improvement in production cycle time and inventory turnover rate over time:

Table 3: Improvement in Production Cycle Time and Inventory Turnover Rate

Time Period	Production Cycle Time (days)	Inventory Turnover Rate (cycles/year)
Before Digital Twin	14	3.2
After Digital Twin	9	4.6

3.4. Value Chain Model Restructuring

Transforming from single-point management of card manufacturers to ecological management, with COS independent research and development and laboratories as the starting point, gradually enhancing independent research and development capabilities and telecommunications card testing capabilities, cooperating directly with upstream chip manufacturers to jointly formulate telecommunications smart card production plans, selecting OEM manufacturers for contract manufacturing, and VsensCompany, as a telecommunications smart card supplier, opens up cooperation to the market[20]. See table 4 for the details.

Table 4: Strategic Plan Overview

Objective	To clarify the strategic plan, determine the position and role of the new model in the overall strategy of the telecommunications card segment, and set clear long-term and short-term goals.
Resources	Allocation of resources and steps required to achieve goals.
Organizational Structure	Adjustment to adapt to the new cooperation model, including project management, quality control, logistics coordination, etc.

First, strategic restructuring is needed. It is necessary to clarify the strategic plan, determine the position and role of the new model in the overall strategy of the telecommunications card segment, and set clear long-term and short-term goals, as well as the resources and steps required to achieve these goals; adjust the organizational structure, adjust internal processes to adapt to the new cooperation model, including project management, quality control, logistics coordination, etc.

Second, operational restructuring is needed. It is necessary to optimize the product design and development process, cooperate closely with chip manufacturers, jointly participate in the product design and development process to ensure that the product meets market demands; strengthen supply chain management, establish a supply chain integration mechanism with chip merchants and OEM manufacturers to achieve collaborative management of raw material procurement, production planning,

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logistics and distribution, and other links.

Third, technical restructuring is needed. It is necessary to standardize and modularize technology, promote the standardization process of telecommunications smart card technology, use modular design to facilitate rapid assembly and customization of products, and improve production efficiency; strengthen research and development and innovation capabilities, maintain sensitivity to new technologies and materials, continuously apply innovation to products, enhance competitiveness, share research and development results with manufacturers, promote technical exchanges and cooperation, and jointly promote industry progress.

Fourth, cooperation restructuring is needed. It is necessary to establish a mutual trust mechanism through contract terms, confidentiality agreements, and other means to ensure that the interests of both parties are protected, establish long-term stable cooperative relationships, set clear boundaries of responsibilities and obligations to reduce friction and disputes in the cooperation process; jointly develop the market, use the operator's market influence and channel advantages, jointly develop the market with all parties, expand product sales, share market information and customer feedback to help manufacturers better understand market demands, and improve product quality and service levels.

Fifth, risk management restructuring is needed. It is necessary to establish a diversified supplier strategy to ensure the stability and flexibility of production capacity, regularly evaluate and adjust suppliers to maintain continuous optimization of the supply chain; establish a risk response mechanism, identify and assess potential risk points, such as technology leaks, production interruptions, quality issues, etc., formulate targeted risk response strategies and plans to ensure rapid response and resume normal production in emergencies. See table 5 for the details.

Quantitative Model for Risk Assessment

R = Total risk score

Pi = Probability of occurrence for each risk factor ii

Ii = Impact score for each risk factor ii

n = Number of risk factors

The risk score for each factor can be calculated using the following formula:

Ri = Pi×Ii

Where Ri is the risk score for factor ii.

The total risk score RR can be calculated by summing up the risk scores for all risk factors:

R=∑i=1nRi

Table 5: Risk Factors and Scores

Risk Factor	P_iPi	I_iIi	R_iRi
Supplier Instability	0.65	8.2	5.33
Technology Leakage	0.45	9.1	4.10
Logistics Delay	0.72	7.5	5.40

Total risk score R = 14.83R=14.83, highlighting logistics delays as the highest contributor (36%).

4. Telecommunications Smart Card Industry: Market Trends and China Unicom's Strategic Responses

4.1. Global Smart Card Market Trends

The global smart card market has been a significant player in the telecommunications and security - related industries. In 2021, the global smart card revenue amounted to a substantial $17.56 billion. This table serves as a testament to the widespread use of smart cards in various applications such as payment systems, identity verification, and access control. Looking ahead, the market is projected to grow at a Compound Annual Growth Rate (CAGR) of 3.45%. This growth can be attributed to several factors. Firstly, the increasing digitization across the globe is driving the demand for secure and convenient identification and authentication methods, which smart cards are well - equipped to provide. For instance, in emerging economies, the expansion of financial inclusion initiatives is leading to a greater adoption

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of smart - card - based payment systems. Additionally, the growth of the Internet of Things (IoT) is creating new opportunities for smart cards, as they are used for device authentication and security in IoT ecosystems.

Traditional SIM cards, which have long been a staple in the mobile communication industry, are facing a significant decline. Due to the growing adoption of eSIM (embedded SIM) technology, the annual shipment of traditional SIM cards has dropped by 12%. eSIMs offer several advantages over traditional SIMs. They are more convenient for users as they can be remotely activated and switched between mobile network operators without the need to physically swap SIM cards. This is particularly appealing to international travelers and those who frequently change their service providers. Moreover, eSIMs are more space - efficient, which is beneficial for device manufacturers aiming to create slimmer and more compact mobile devices.

4.2. China Unicom's Performance Metrics

China Unicom has been making substantial efforts in research and development to enhance its position in the smart card market. From 2020 to 2023, its R&D investment witnessed a remarkable increase, rising from $12 million to $28 million[21]. This increased investment has yielded positive results, especially in the area of Card Operating System (COS) development. The company has achieved a 45% localization in COS development. This localization is crucial as it reduces China Unicom's dependence on foreign - patented COS technologies, which was previously a major concern with over 85% reliance. By developing its own domestic COS, China Unicom can better control the security, functionality, and cost - effectiveness of its smart card products. It also allows the company to tailor the COS to the specific needs of the Chinese market and its customers, giving it a competitive edge in the domestic and potentially international markets[22].

In an effort to streamline its supply chain, China Unicom has made significant progress in supplier integration. Currently, 78% of its chip suppliers are using the company's block chain - based procurement system[23]. This block chain - enabled system offers several benefits. It provides transparency in the procurement process, allowing both China Unicom and its suppliers to track the movement of goods, verify the authenticity of products, and ensure that all transactions comply with the agreed - upon terms. For example, the block chain can record the origin of the chips, the manufacturing process, and the transportation details, reducing the risk of fraud and counterfeiting. Additionally, the system improves the efficiency of the procurement process by automating many of the manual tasks such as invoicing and payment processing. This not only saves time but also reduces the potential for human - error, leading to a more reliable and cost - effective supply chain.

5. Conclusion

5.1. Managerial Implications

The findings of this study hold substantial implications for managers within the telecommunications smart card industry. First and foremost, the emphasis on modernization, as demonstrated by China Unicom, underscores the importance of strategic investment in advanced technologies and innovative business models. Managers should prioritize the adoption of quantitative models, such as the value chain optimization model and risk assessment framework utilized in this research. By implementing these models, companies can effectively identify and eliminate inefficiencies in their operations. For example, the value chain optimization model enabled China Unicom to reduce production costs per card by 28%, which is a significant achievement in a highly competitive market. This cost - reduction strategy can be replicated by other operators, allowing them to offer more competitive pricing to their customers and gain a larger market share.

Secondly, the success of China Unicom's digital transformation initiatives, particularly the development of a supply chain digital twin, highlights the need for managers to embrace digital technologies for real - time monitoring and optimization. The digital twin platform integrated IoT sensors and block chain technology, leading to a 44% improvement in the inventory turnover rate and a reduction in the production cycle time from 14 days to 9 days[24]. Managers should recognize that such digital solutions can enhance operational efficiency, improve product quality, and strengthen relationships with suppliers and customers. They should allocate resources to develop or adopt similar digital platforms to gain a competitive edge in the market.

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Furthermore, the achievement of 45% localization in COS development by China Unicom through increased R&D investment sends a clear message to managers about the significance of self - reliance in critical technologies. Managers should encourage and support R&D efforts within their organizations to reduce dependence on foreign - patented technologies. This not only mitigates the risk of technological barriers but also enables companies to have more control over their product features and security.

5.2. Empirical Implications

Empirically, this study contributes to the existing body of knowledge in several ways. It provides concrete evidence of the effectiveness of quantitative models in solving complex industry problems. The linear programming model for value chain optimization and the quantitative risk scoring model offer practical tools for researchers and practitioners alike. These models can be further refined and applied in other industries facing similar challenges of resource redundancy and supply chain risks.

The research also validates the positive impact of digital transformation on supply chain performance. The use of IoT sensors and block chain technology in the supply chain digital twin platform has been shown to improve key performance indicators such as production cycle time and inventory turnover rate. This empirical evidence can inspire further research into the integration of emerging technologies in supply chain management.

In addition, the data on China Unicom's R&D investment and its subsequent technological breakthroughs in COS development offer valuable insights for policy - makers and researchers interested in the relationship between R&D investment and technological localization. It can serve as a case study for other countries and companies aiming to enhance their technological capabilities and reduce technological dependence.

Looking ahead, the proposed exploration of AI - driven predictive maintenance and cross - border supply chain integration opens up new areas of research. AI - driven predictive maintenance has the potential to revolutionize equipment management in the smart card industry, reducing unplanned downtime and maintenance costs. Cross - border supply chain integration, on the other hand, is crucial in the context of globalization, and research in this area can help identify best practices for managing international supply chains more effectively.

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