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Collaborative Research on the Evolution of Key Technology Cooperation in the Integrated Circuit Industry Supply Chain

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Abstract: The improvement of the technical level of China's IC industry can provide technical support and guarantee for the upgrading of the whole industrial chain, which is of great significance in upgrading the scientific and technological level of China's industry. It can be of great significance for improving the technological level of China's industries. At present, China's technological development is relatively lagging behind, and the problem of core technology being constrained by humans is still very prominent. Enhancing the modernization of the industrial chain is a major strategic policy for China to coordinate the development of industrial safety and quality under the new situation. Industrial chain upgrading is collaboration between various production factors such as technology, capital, talent, and enterprises, as well as upstream and downstream links in the industrial chain. It is a system integration concept that combines horizontal and vertical collaboration. To achieve the modernization of the core performance index of the industrial chain, it is necessary to optimize the technological path, competitive advantages, industrial chain structure diagram, improve industrial chain governance and ecology, enhance government investment efficiency, and improve talent availability through research and corresponding improvements. Based on the above issues, this article also proposes a supply chain logistics optimization model based on GA (genetic algorithm) algorithm. Experiments have shown that the total transportation costs of local search algorithm, taboo search algorithm, and genetic algorithm are 14.1 million yuan, 13.54 million yuan, and 9.27 million yuan, respectively.

1. Introduction

In the collaborative research on the evolution of key technology cooperation in the integrated circuit industry supply chain, it is necessary to focus on promoting technological innovation and research and development cooperation. Through technological innovation and R&D cooperation, the R&D cycle of products can be accelerated, the competitiveness of products can be improved, and the long-term sustainable development of the industrial chain can be achieved. In summary, the collaborative research on the evolution of key technology cooperation in the integrated circuit industry supply chain is a complex and important topic. Through continuous in-depth research and practice, this article can continuously improve the mode and mechanism of key technology cooperation in the supply chain, and promote the development and growth of the entire industry chain. This article hopes that more scholars, enterprises, and government departments can participate in this research field in the future, and jointly promote the development and growth of the integrated circuit industry.

In Chapter 3, this article introduces the current situation of the integrated circuit industry, the key to vigorously developing the integrated circuit industry is to break through core technology bottlenecks, supply chain cooperation and collaboration strategies, and supply chain optimization strategies based on genetic algorithms. In Chapter 4, the experimental results of a supply chain optimization model based on genetic algorithm were applied, and a summary of the entire article was made.

2. Related Works

Experts have long conducted specialized research on the issue of supply chain collaboration. Shi X took China's mobile communication industry as the research object and constructs a 2D process model of the emergence of the mobile communication industry ecosystem based on vertical and quantitative research methods. He revealed the underlying mechanism of the evolution of mobile communication networks [1]. Sarafrazi A proposed an uncertainty model based on sustainable development, establishing four optimization objectives: cluster economic benefits, transportation costs, employment, and environmental benefits, reflecting the horizontal and vertical collaboration of enterprises in the network. Research has been conducted on model clustering using the efficiency of nearest neighbor clustering and individual clustering [2]. Ekanayake E aimed to develop a multi-stage mathematical model to evaluate the adoption of supply chain capabilities in Hong Kong's industrial buildings [3]. Bhattacharya S proposed a comprehensive framework for digital project driven supply chain to achieve multiple goals in the value chain of architecture, engineering, construction, operation, and maintenance [4]. Zhang G proposed intelligent supply chain architecture based on multi-level intelligence. Finally, he discussed the supply chain issues in the context of Industry 4.0 [5]. Chen J C focused on circuit chip design enterprises and studies the multi-objective ordering guarantee problem of hybrid flexible manufacturing systems based on MTO (Make To Order). This method helps decision-makers choose the optimal optimization model based on different environmental factors, thereby obtaining the optimal benefits [6]. Choung E applied an improved forward reference indicator to test the attractiveness of China's increase in the total semiconductor industry in attracting foreign industries. The study finds that although China has accelerated its competition in the chip sector, the distance between China and the world's advanced level is still very large [7].

Ishak S explored the impact of an adaptive supply chain strategy combining robustness, flexibility, and resilience on the performance of semiconductor companies during the Covid-19 outbreak [8]. Rahman T established an agent based model to predict the impact of unstable factors in panic buying on supply chain members, and provided corresponding improvement measures [9]. Zhang T proposed a blockchain based technology to promote the authenticity and integrity of FPGA (Field Programmable Gate Array) supply chains, achieving reliable traceability. The proposed method is revolutionary and can utilize state-of-the-art blockchain technology to detect forged FPGA chips and bitstreams [10]. Considering the price dependent degradation products with a leader follower relationship, Das R constructed a supply chain management model for producers' retailers. He used the Stackelberg game method to optimize the distribution pricing and distribution period of each distributor until the manufacturer's inventory was zero, in order to maximize their profits. Research has found that when the retail price is higher than the manufacturer's price, the manufacturer's profit is much higher than the retailer's profit [11].

Wang C found that both supply chain capital and relationship capital promote supplier complementarities and moderates the impact of supply chain capital on supplier performance through the aforementioned capabilities [12]. Chien C F explored the impact of factors such as product pricing, demand planning, capability combination, and cost structure on a company's revenue by analyzing the key factors in the "pricing demand capability funding cost benefit" model, and thereby reveals their impact on intelligent manufacturing enterprises [13]. Taheri H E applied an efficient hardware Trojan detection technology developed in the integrated circuit industry based on evaluating changes in integrated parasitic capacitance. The detection circuit consists of a capacitor coupled, low-power, low noise, and operational transconductance amplifier, which can detect capacitance fluctuations within the range of 10 aF [14].

Wang D mainly studied the supply chain collaboration problem of VMI (Vendor managed inventory) under asymmetric information conditions. The research results indicate that when there is asymmetric information between the two parties, a penalty contract can reveal the private information of the manufacturer, thereby achieving coordination of the supply chain [15]. Kocabasoglu-Hillmer C explored the contradictory tension between change and stability in the upstream supply chain [16]. The above research on optimizing industrial supply chains is not specific enough, and the decision-making is of little practical significance.

3. Methods

3.1 Current Situation of Integrated Circuit Industry

Overall, the technology content and technical barriers in the integrated circuit industry are relatively high. From the perspective of the industry chain, it can be divided into upstream chip design, chip manufacturing and packaging, and downstream applications. Among them, chip design owners need to engage in integrated circuit design, layout design, semiconductor device model research and development, and have high requirements for talent. In the chip manufacturing and testing sub industry, there is a greater need for personnel with high reliability, strong equipment operation ability, and skilled technology. Data shows that by 2022, China's demand for chips can reach over 200000, which is a very serious problem. The training period for IC (Integrated Circuit) design talents is very long, usually 10-12 years, and usually requires a doctoral degree level to have the ability to independently develop circuits. The process from the development of a chip to quantitative production is relatively long, taking about two to five years, while developing an independent chip takes one to three years, and the flow of a chip usually takes three months to find the existing problems in the first flow. Therefore, this requires all integrated circuit workers to put forward very high requirements.

3.2 Key to Vigorously Developing the Integrated Circuit Industry is to Break through Core Technological Bottlenecks

Although China's IC industry has achieved great success after 10 years of development, its overall independent innovation ability is relatively weak, and some core technologies are still under control, and a complete industrial ecosystem has not yet been formed. Firstly, the ability for independent innovation is weak, and some key technologies have been mastered. The biggest shortcomings are IC equipment, high-end manufacturing technology, and IC materials. In the field of IC design, world leading IC design companies have formed a complete industrial ecosystem, while Chinese IC design companies not only face the problem of complete control over the design environment and core intellectual property. More importantly, its design platform technology is still difficult to support its new products and the overall system development needs of users. In terms of chip manufacturing, China's main 14 nm process is still in the mass production stage, and there is still a gap of 2-3 technological generations compared to the world's advanced level. On this basis, international leading enterprises have strengthened their control over the global IC market by forming industry chain alliances. In the past decade, with the support of major national projects and integrated circuit industry funds, China has significantly improved its equipment manufacturing level, and made significant progress in independent design, electronic design automation technology, and core intellectual property.

3.3 Supply Chain Collaboration Strategy

To build a model of searching and screening specialized, refined, and innovative reserve enterprises in the IC industry chain, firstly, it needs to increase financial support, including policy consultation, financing docking, financing guidance, and training. The second is to strengthen the supervision and management of grassroots cadres, conduct regular visits to enterprises entering the park, timely grasp the dynamics of enterprises entering the park, and coordinate to solve existing problems and difficulties. Thirdly, it needs to strengthen the docking services between the upstream and downstream of the industrial chain, industry, academia, and research. Based on leading enterprises and technology service enterprises, a long-term industrial chain and industry university research docking mechanism can be established to continuously increase the proportion of localized supporting facilities in the IC supply chain and promote the integrated development of large, medium, and small enterprises. An information database can be established to attract high-quality enterprises in the integrated circuit industry. With the support of big data, it can actively promote the strong chain of industrial clusters by focusing on attracting investment in the industry chain and attracting talents through big data. The fourth is to sort out high-quality integrated circuit enterprises and grasp their external announcements, investment and other dynamics. This can promote the linkage development between enterprises that enter the industry chain and upstream and downstream enterprises in the industry chain. On the one hand, it should focus on key projects and regions, and analyze the direction, key links, and key elements of leading enterprises and specialized, refined, and innovative breakthroughs in the key industrial chain. Dynamic updates can be made to target enterprises to provide guidance for attracting integrated circuit industry chain projects and on-site investment. On the other hand, it is to highlight the supply chain "main" enterprises and the upstream and downstream, left and right banks of the industrial chain, and lock in a number of key industrial chain projects. It can develop targeted recruitment projects for major projects, coordinate and solve policy support, element guarantee, and high-level promotion issues involved in the project promotion process, and promote project signing and registration.

The issue of upstream and downstream resource coordination.

The collaboration of upstream and downstream resources is a huge driving force for the IC design industry. Upstream chip production, packaging testing, downstream module and whole machine manufacturers can greatly promote the development of the IC design industry. If upstream raw materials can be obtained locally, it can accelerate the development of the entire local industry chain. Having downstream channels and close relationships with customers can better understand their needs.

2) The issue of the effectiveness of local support policies

The effectiveness of local support policies is of great significance for entrepreneurial IC design companies. IC design is a high investment, light asset, and high-risk industry, and investors are usually very cautious, which is why startups are so difficult. The cost of film production varies from tens of thousands to tens of millions, and without sufficient funding; it may not be possible to sustain the official release of the product. Therefore, if supported by the local government, it is equivalent to a newborn baby, which can quickly grow and thrive with sufficient nutrition. Not all startup companies know where good policies are provided, nor do they know if their place of registration can provide them with sufficient support.

3.4 Supply Chain Optimization Strategy under Genetic Algorithm

Supply chain optimization uses genetic algorithm to evaluate the allocation ability of distribution centers on various paths and the demand on each path. A logistics network optimization model based on genetic algorithm is established, and the optimal network construction plan is solved through genetic algorithm on this basis. From equation (1), it can be seen that in this case, both transportation volume and capacity need to be considered, which is also a nonlinear optimization problem [17-18].

(1) Objective function

Assuming the business priority for selecting the jth distribution route is w_j, the delivery volume of the i-th distribution center to the jth distribution route is p_{ij}, and the efficiency value that each distribution center needs to meet for each distribution route is $c_{ij} = w_j p_{ij}$, then:

$$f(D) = \max(\sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}) \tag{1}$$

(2) Fitness function

The essence of genetic algorithm optimization is to continuously search for individuals with higher fitness values through selection and crossover operations based on the fitness level of each individual in the population, in order to obtain the optimal solution. The fitness function is used to measure whether each individual in the population is excellent, and it is used to simulate natural selection. Therefore, selecting the appropriate fitness function can directly affect the convergence rate of GA and whether the optimal solution can be found [19-20]. In the case of minimizing the cost as the objective function, use the fitness function to map the objective function to a fitness function in a minimized manner:

$$F(x) = \begin{cases} C_{\max} - f(x) & f(x) < C_{\max} \\ 0 & others \end{cases} \tag{2}$$

In the formula, $F(x)$ is the fitness function, $f(x)$ is the objective function, and $C_{\max}$ is an appropriate relatively large number, with a value of the maximum objective function value in the current or recent generations of the population.

4. Results and Discussion

4.1 Experimental Preparation

This article uses a problem testing model and algorithm that includes 12 retailers and 4 optional logistics centers to test the correctness. The numbers of the retail nodes are J1 to J12, and the optional logistics center nodes are I1 to I4. The retailer nodes and logistics center nodes are shown in Table 2, and the relevant parameters of the logistics center are shown in Table 1. The data in Tables 1 and 2 can be used as parameters for genetic algorithms for computation.

Table 1: Logistics center related parameters

Distribution centre	I1	12	I3	14
Fixed cost (yuan/day)	1711	1620	1739	1506
Maximum construction capacity (vehicles)	780	823	796	775
Inventory cost(yuan/day)	5.8	4.2	2.5	2.7
Ordering cost(times)	1563	1550	1610	1549
Out-of-stock penalty cost(yuan/vehicle)	103	106	112	103
Replenishment transport distance (km)	1669	1373	1126	1466
Order lead time(days)	8	12	6	7
Service level	0.95	0.85	0.91	0.84

Table 2: Distance between retailer centers and logistics centers (unit: kilometers)

	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12
I1	43	221	247	193	313	422	405	446	504	428	595	515
I2	114	111	122	227	195	276	368	462	353	533	335	362
I3	435	388	157	426	466	177	158	257	227	167	301	329
I4	907	713	444	141	418	348	135	183	193	397	218	186

4.2 Experimental Results

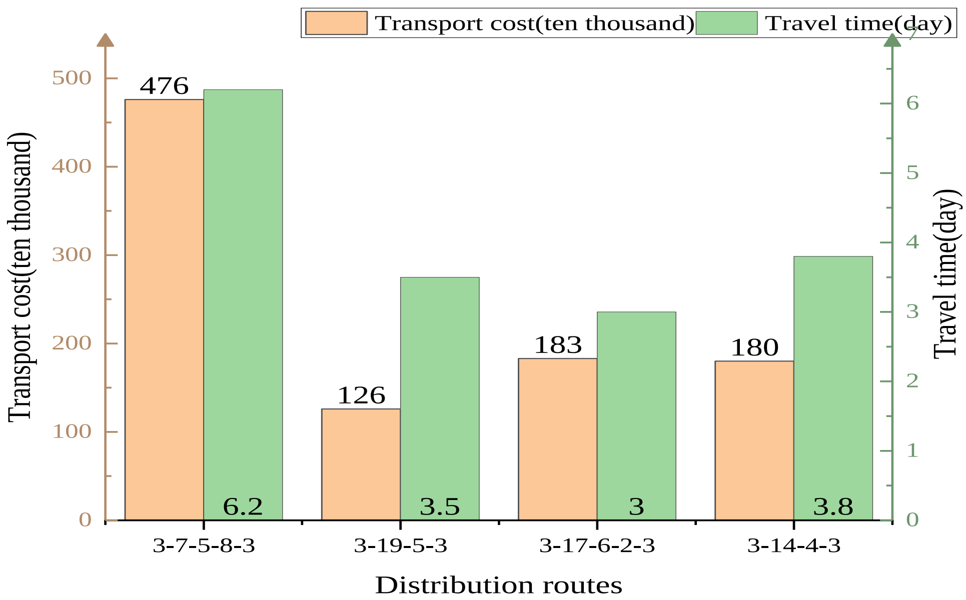

Figure 1: Calculation results of genetic algorithm

From Figure 1, it can be seen that the distribution routes of supply chain logistics optimized by GA algorithm are 3-7-5-8-3, 3-19-5-3, 3-17-6-2-3, and 3-14-4-3, respectively. The transportation costs of the four delivery routes are 4.76 million yuan, 1.26 million yuan, 1.83 million yuan, and 1.8 million yuan, respectively. The travel time for the four delivery routes is 6.2 days, 3.5 days, 3 days, and 3.8 days, respectively.

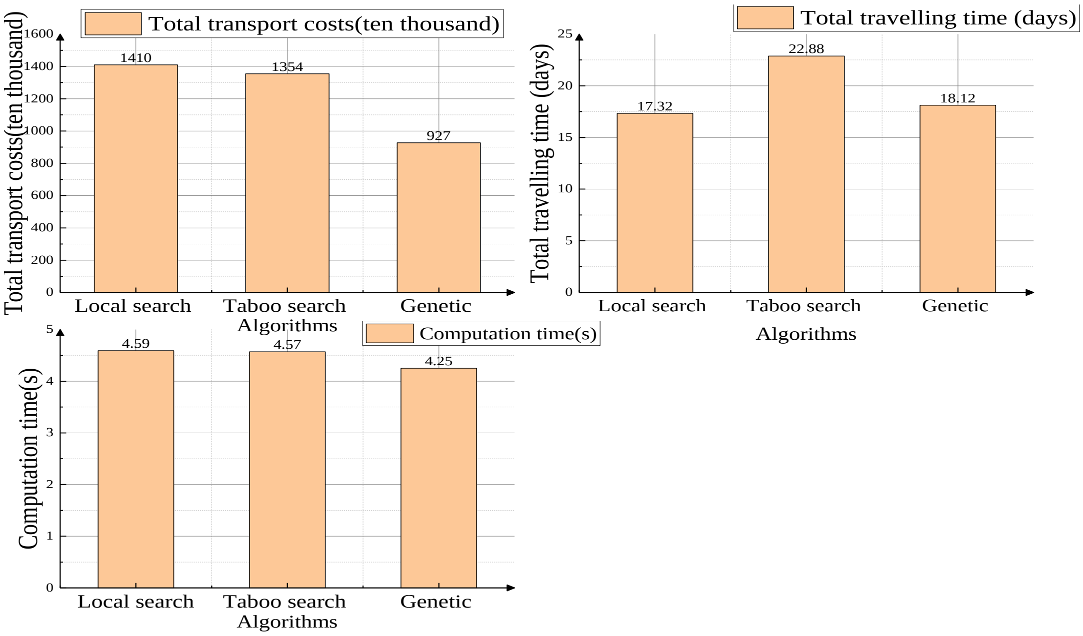

Figure 2: Comparison of results of three different algorithms

The genetic algorithm was compared and analyzed with local search algorithm and taboo search algorithm, and the analysis results are shown in Figure 2. The total transportation costs of local search algorithm, taboo search algorithm, and genetic algorithm are 14.1 million yuan, 13.54 million yuan, and 9.27 million yuan, respectively. The total travel time of local search algorithm, taboo search algorithm, and genetic algorithm is 17.32 days, 22.88 days, and 18.12 days. The computation time of local search algorithm, taboo search algorithm, and genetic algorithm are 4.59s, 4.57s, and 4.25s, respectively. From the above data, it can be seen that genetic algorithms can significantly optimize logistics costs. Although the total travel time is longer than that of local search algorithms, the difference is not significant. Genetic algorithm has a relatively short computation time and high computational efficiency.

5. Conclusions

With the rapid development of information technology, the integrated circuit industry has become an important component of modern technology industry. In this industrial chain, the research on the evolution and collaboration of key technology cooperation in the supply chain is particularly important. This article explores the evolutionary synergy research of key technology cooperation in the integrated circuit industry supply chain This kind of cooperation is not only about unilateral technology transfer, but also about cooperation in technology innovation, research and development, production, sales, and other aspects to achieve efficient operation of the industrial chain. The research on the evolution and collaboration of key technology cooperation in the supply chain aims to explore how to promote the development and growth of the entire industry chain through technology cooperation and collaboration.

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