The driving role of biotechnology in the freight logistics industry and the strategic adjustment of transportation economy under the “dual circulation” development model

Abstract: Under the "dual circulation" development model, the transformation and development of the freight logistics industry faces both challenges and opportunities. The growing demand for intelligence, digitalization and low carbonization highlights the potential of biotechnology to transform logistics. Biometric recognition technology and biosensors achieve real-time and accurate monitoring of goods through molecular-level biomolecular recognition and mechanical conduction mechanisms, ensuring safety and reliability from production to consumption. Environmentally friendly packaging materials are designed with specific molecular and cell structures, which not only reduce plastic pollution but also enhance the protection of goods during transportation. Bioenergy production based on microbial biomechanical processes provides a sustainable alternative to fossil fuels, effectively reduces carbon emissions, and promotes the realization of green logistics goals. For example, biosensors monitor temperature, humidity and vibration in real time during transportation, triggering alarms when conditions deviate from acceptable ranges, minimizing economic losses and ensuring the quality of goods. These innovations have both improved efficiency and protected the environment. This paper first explains the connotation of the new development model of "dual circulation" and its requirements for economic, efficient, intelligent and low-carbon transportation. Then it analyzes the current situation of the freight logistics industry and emphasizes the key role of the freight logistics industry in the mutual promotion of domestic and international dual circulation. Then, the role of intelligent, digital construction and green logistics in promoting the transportation economy, especially the new progress in the application of biotechnology, was discussed in depth. In addition, the potential of biotechnology in reducing logistics costs, improving efficiency and reducing environmental impact was fully explored. This paper also clarifies the challenges faced by the freight logistics industry, such as policy and regulatory adaptability, technical application bottlenecks, market competition pressure, including standardization and regulatory issues in the application of biotechnology. In response to the above problems, this paper proposes strategic adjustment directions such as accelerating digital and intelligent transformation, optimizing regional logistics layout, promoting multimodal transport and supply chain collaboration, and strengthening policy support and industrial collaboration. At the same time, it is encouraged to increase investment in biotechnology research and development and accelerate its commercial application in the logistics industry. In order to better illustrate the viewpoints and conclusions of the argument, the article is attached with relevant charts to assist in the explanation. Finally, this paper summarizes the research results and looks forward to future research directions, hoping to provide theoretical guidance and practical reference for the healthy development of my country's freight logistics industry, especially to explore the broader application prospects of biotechnology in the logistics industry.

Keywords: Dual cycle, freight logistics, transportation economy, intelligent and digital, green logistics and low-carbon economy, multimodal transport and supply chain collaboration.

I. INTRODUCTION

With the changes in the global economic landscape and the transformation and upgrading of China's domestic economic structure, China's economy is gradually moving towards a new development pattern of "dual circulation". The "dual circulation" strategy refers to a new development model with domestic circulation as the main body and the mutual promotion of international and domestic circulations[1]. The strategy aims to expand domestic demand, improve domestic market consumption capacity, optimize the supply system, while maintaining openness to the outside world, deepening international cooperation, and achieving smoother circulation in domestic and foreign markets[2]. In this context, the freight logistics industry plays an indispensable role as an important link connecting production, circulation and consumption. Freight logistics not only directly affects the operational efficiency of upstream and downstream enterprises in the industrial chain, but also has a profound impact on the quality of the

country's overall economic development[3]. However, for small and medium-sized enterprises in the logistics industry, the transformation to a digital, intelligent and low-carbon business model remains a major challenge. Many small and medium-sized enterprises face difficulties in obtaining necessary funds and acquiring advanced technological capabilities. To address these issues, it is crucial to provide targeted solutions. For example, the government and financial institutions can work together to provide dedicated financial support to small and medium-sized enterprises seeking to invest in digital technologies. An example of this approach can be seen in local logistics zones, where small companies receive low-interest loans to upgrade warehouse management systems and adopt transportation optimization software. Furthermore, SMEs often struggle with a lack of technical expertise. To bridge this gap, regional training centers can be established to provide hands-on training on digital tools such as IoT devices, data analytics software, and advanced tracking systems. One successful example is a logistics company that participated in a government training program that enabled them to integrate a real-time cargo monitoring system, reduce spoilage of perishable goods, and improve overall operational efficiency.

Incorporating advanced biotechnologies, such as biosensors and biodegradable materials, offers great potential for improving the sustainability and operational efficiency of logistics operations. For example, biosensors for freight monitoring use biomolecules such as antibodies or enzymes to detect specific environmental changes, thereby triggering signals that help ensure that cargo remains within safe limits during transportation. To achieve this in practice, companies can work with biotech companies to integrate biosensor technology into existing logistics systems. In addition, biodegradable packaging materials derived from microbial processes, such as polylactic acid (PLA), offer a sustainable alternative to traditional packaging. These materials naturally degrade in the environment, supporting the logistics industry's efforts to reduce its carbon footprint.

The production process of bioenergy reveals the cell-mechanical behavior of microorganisms in bioenergy development. During the fermentation process of some microorganisms, changes in intracellular pressure can affect the fluidity of the fermentation liquid, thereby changing the efficiency of energy generation. At the same time, the mechanical properties of microbial cell walls play a key role in tolerating high osmotic pressure environments and maintaining metabolic activity. For example, in the production of bioethanol, osmotic pressure regulation in yeast cells directly affects the rate at which glucose is converted to ethanol. In addition, by optimizing the structure of the cell wall during fermentation, companies can improve the stability of microorganisms, thereby increasing the overall yield and efficiency of bioenergy. This in-depth understanding of the mechanical behavior of cells provides important theoretical support for improving production processes. It is particularly important to explore the role of biomechanics in environmentally friendly packaging materials from a microscopic perspective. Environmentally friendly packaging materials designed using microbial principles usually provide the required strength and toughness through the biofilm structure formed by microorganisms. From the molecular and cellular scale analysis, the mechanical properties of these biofilms are derived from the synergistic effects of biomacromolecules such as polysaccharides, proteins and lipids secreted by microorganisms in the membrane. These macromolecules give materials the ability to resist external pressure and impact by forming a network structure with elasticity and strength. For example, in the process of logistics transportation, the compressive resistance of these biofilms ensures that the packaging materials are not easy to break during stacking and transportation, while their toughness enables them to withstand vibration and impact. In addition, microscopic mechanical properties such as the elastic modulus and shear strength of the biofilm also directly affect the stability of the material under various temperature and humidity conditions. These properties are crucial for extending the shelf life of perishable goods and reducing transportation losses in actual logistics scenarios.

From a forward-looking perspective, biomechanics brings a wide range of innovative application prospects to the future freight logistics industry. Based on the principles of biomechanics, the development of new intelligent packaging materials is a potential research hotspot. Such materials can automatically adjust the mechanical properties according to the state of the goods (such as weight, shape or vibration level) by embedding responsive biofilm structures. For example, when the goods are impacted by the outside world, the biofilm in the packaging material can dynamically adjust its internal structure to increase the impact resistance, thereby achieving more accurate cargo protection. This

intelligent packaging can not only improve logistics safety, but also significantly reduce economic losses caused by transportation damage.

Another important direction is the biosensor network based on cell mechanics. This type of network can use the mechanical response characteristics of cells under different environmental conditions to monitor key parameters such as temperature, humidity, vibration, etc. in the logistics environment in real time through highly sensitive biosensors. In addition, by combining biomechanics with artificial intelligence, these sensor networks can also achieve intelligent regulation of the logistics environment. For example, when it is detected that the transportation conditions are beyond the safe range, the sensor network can actively send out warning signals or automatically adjust the transportation conditions (such as temperature control equipment or anti-vibration system) to ensure the quality and safety of the goods.

In the future, as the research on biomechanics deepens, its application in the freight logistics industry can be extended to many fields. For example, by studying the mechanical properties of microbial biofilms, logistics materials with high toughness and self-healing ability can be developed; or flexible transportation carriers can be designed using biomechanical properties to reduce the impact on the environment. By promoting the research and development and commercialization of these cutting-edge technologies, the freight logistics industry will be able to further improve efficiency and sustainability, thereby better serving the overall goal of the "dual circulation" strategy.

To promote the use of such innovative technologies, companies can cooperate with bioenergy research and development institutions and material science companies to carry out pilot projects to evaluate their performance under different logistics conditions. By providing financial support, promoting technical training, and promoting the integration of biotechnology into logistics operations, small and medium-sized enterprises can better adapt to the digitalization and low-carbon transformation required by the "dual circulation" strategy. This article explores how these strategies can help logistics companies improve efficiency, sustainability, and technological competitiveness in the changing global and domestic economic environment [4].

II. THE RELATIONSHIP BETWEEN THE NEW DEVELOPMENT PATTERN OF "DUAL CIRCULATION" AND TRANSPORTATION ECONOMY

A. Connotation and requirements of dual circulation pattern

The new development pattern of "dual circulation" emphasizes the domestic great cycle as the main body, that is, to promote economic growth by expanding domestic demand, optimizing supply structure, and improving consumption capacity [5]. This not only means strengthening the emphasis on the domestic market, but also requires deepening supply-side reform, improving product quality and service levels, and meeting the people's growing needs for a better life. Specifically, the domestic cycle includes: strengthening the domestic market, through policy guidance and support, cultivating and developing a number of internationally competitive local enterprises and brands; Optimize the supply chain, strengthen the collaboration between the upstream and downstream of the industrial chain, and build an efficient and stable domestic supply chain system; Promote consumption upgrading and encourage the development of new consumption models, such as e-commerce and sharing economy [6].

At the same time, the "dual circulation" also focuses on the coordinated development of the international and domestic markets, aiming to achieve a more smooth circulation of the internal and external markets through a higher level of opening up [7]. This means: further deepen international cooperation, actively participate in the reform of the global governance system, promote the Belt and Road cooperation, and expand the international market space; Better introduce advanced technology, attract foreign investment and technology transfer, and promote industrial structure upgrading and technological innovation; We will improve our ability to respond to trade barriers, actively respond to the trend of international trade protectionism, safeguard the multilateral trading system, and ensure the stable development of export-oriented enterprises.

In the context of "dual circulation", the transportation economy is facing higher requirements: first, to ensure efficiency improvement, speed up transportation, reduce logistics costs, and improve resource allocation efficiency. The second is intelligent transformation, using big data, Internet of things, artificial

intelligence and other technologies to achieve intelligent traffic management and logistics service innovation. Third, low-carbon green development, the promotion of new energy vehicles, the application of clean energy technology, reduce carbon emissions, and respond to the national "two-carbon" goal (carbon peak, carbon neutrality) [8].

B. *The status of freight logistics industry in transportation economy*

Freight logistics is an important part of the national economy. It is not only a bridge between the production place and the consumption place, but also an important carrier of information flow and capital flow [9]. Especially under the new development pattern of "dual circulation", the role of freight logistics is more prominent, which is reflected in the following aspects: ensuring the timely supply of raw materials and parts, the rapid distribution of finished products to the hands of end users, and ensuring the smooth operation of all links of the industrial chain; Promote regional economic development, promote resource exchange and market docking between different regions through efficient logistics networks, and drive local economic growth; Enhance consumer experience, provide convenient, fast and reliable delivery services to meet consumers' needs for diversification and immediacy of goods. With the development of information technology, data has become one of the core assets of modern logistics and transportation industry [10]. Through the mining and analysis of massive data, we can achieve:

Accurate demand prediction, that is, based on historical transaction records, market trends and other factors, the use of machine learning algorithms to accurately predict cargo transportation demand and plan shipping capacity in advance; Optimize route selection, can combine real-time road conditions, weather conditions and other information, using intelligent algorithms to dynamically adjust transport routes, avoid congested sections, save time and fuel; Enhance the transparency of operations, use the Internet of Things technology and blockchain platform to realize the full track and trace of goods, and improve the visibility and security of the logistics process [11.12].

III. THE ROLE OF FREIGHT LOGISTICS INDUSTRY IN PROMOTING THE TRANSPORTATION ECONOMY

A. *Intelligent to improve transportation efficiency*

The application of intelligent technology in the freight logistics industry has greatly improved the transportation efficiency. By introducing advanced intelligent algorithms, such as route optimization algorithm and vehicle scheduling algorithm, transportation costs can be significantly reduced and service response speed can be improved. First, the path optimization algorithm, based on graph theory and combinational optimization theory, combined with actual traffic conditions (such as road network structure and real-time road condition information), plans the optimal route for each truck to reduce the empty driving rate and waiting time. Second, vehicle scheduling algorithm, considering the type of goods, weight and volume restrictions, distribution time window and other factors, reasonable arrangement of vehicle loading and distribution order, maximize the carrying capacity of each vehicle.

Let C(x) represent the cost function from the starting point to the end point, and (x) be a possible path, then the path optimization problem can be expressed as:

$$\min x \in X \quad C(x) \tag{1}$$

Where X is the set of all possible paths.

The development of autonomous driving technology and driverless vehicles has also brought new breakthroughs in transportation efficiency. They not only reduce safety hazards caused by human error, but also enable more efficient traffic flow management through precise control, further reducing transit times.

B. *Digitization and information construction*

Digital transformation is one of the important trends in the development of modern freight logistics industry. In particular, the application of deep convolutional neural network (DCNN) in transportation demand forecasting can provide more accurate demand forecasting and help logistics enterprises to better allocate resources and service planning.

The DCNN model extracts the spatial features of the input data (such as historical order volume, weather conditions, holiday effects, etc.) through the multi-layer convolutional layer, and outputs the

forecast results through the fully connected layer. The model can capture complex nonlinear relationships and improve the prediction accuracy.

Let f represent the activation function, W and b represent the weight matrix and bias vector respectively, then the output of the l-th layer a[l] can be expressed as:

$$a_l = f(W_l a_{l-1} + b_l) \qquad (2)$$

In order to train the DCNN model, a large amount of historical transportation data needs to be collected as a sample set. These data are cleaned, normalized and then used for model training.

In performance evaluation, mean square error (MSE) [13], mean absolute error (MAE) [14] and other indexes were used to evaluate the prediction effect of the model, and the best model parameters were selected by cross-validation method.

Below is a deep convolutional neural network (DCNN) model [15] architecture diagram drawn on request for transportation demand forecasting. The plot contains input layers (such as historical order volumes, weather conditions, holiday effects, etc. [16]), multiple convolution and pooling layers, as well as a fully connected layer and an output layer.

TABLE I. PERFORMANCE COMPARISON TABLE OF DIFFERENT PREDICTION MODELS

Model type	MSE	MAE
Linear regression	0.05	0.05
Support vector machine	0.04	0.02
DCNN	**0.02**	**0.01**

Table 1 shows the performance of the three different prediction models in terms of linear and absolute errors. It can be seen that the deep convolutional neural network (DCNN) achieves optimal performance on both evaluation indicators.

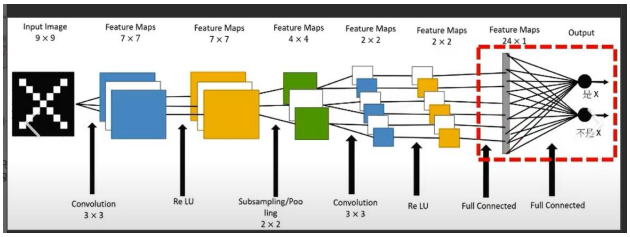

Fig. 1. Deep convolutional neural network (DCNN) model [17] architecture diagram

Figure 1 reveals the demand forecast for transportation. The plot contains input layers (such as historical order volumes, weather conditions, holiday effects, etc. [18]), multiple convolution and pooling layers, as well as a fully connected layer and an output layer.

Each layer in the model performs a specific function to process and transform the input data for accurate demand forecasting: The input layer receives the raw data, including historical order volumes, weather conditions, and holiday effects, which are critical factors influencing transportation demand. This data is preprocessed using normalization techniques to ensure consistent scaling and reduce computational overhead. The convolution layers extract temporal and spatial features from the input data. By applying filters with sizes such as 3× (where represents the number of input features), these layers capture patterns like sudden spikes in demand due to holidays or gradual trends influenced by weather changes. Each filter outputs a feature map, and the activation function, typically ReLU, introduces nonlinearity, enabling the model to learn complex relationships within the data.

The pooling layers downsample the feature maps from the convolution layers, reducing their dimensions while retaining essential features. This not only decreases computational load but also makes the model more robust to minor variations or noise in the input data. Commonly, a pooling size of 2×1 is employed, halving the temporal resolution without affecting the feature count.

Following the feature extraction stages, the fully connected layer integrates the processed data into a compact representation. Each node in this layer is connected to every node in the preceding layer, enabling the model to combine features from various dimensions and derive insights that influence the demand forecast. Finally, the output layer delivers the predicted transportation demand. For single-step forecasting, the layer has one neuron representing the forecasted value. For multi-step forecasting, it contains multiple neurons, each corresponding to a specific future time step. The linear activation function is typically used here to ensure the predictions remain continuous and interpretable.

The overall architecture ensures that both short-term fluctuations and long-term trends in transportation demand are captured, providing a reliable foundation for decision-making in logistics and supply chain management.

With the above chart, we can better understand the application of the DCNN model in transportation demand forecasting and its advantages over other models. If you need more detailed explanation or have other questions, please feel free to let us know.

C. *Green logistics and low-carbon economy*

Green logistics refers to reducing the impact on the environment as much as possible under the premise of ensuring the quality of logistics services. Promoting the use of new energy vehicles is one of the key measures to achieve this goal. New energy vehicles have zero or low emission characteristics, helping to improve urban air quality and reduce carbon footprint.

To achieve this goal, on the one hand, the government has issued a series of policy measures to encourage the development of new energy vehicles, including car purchase subsidies, tax incentives, etc., to promote the wide application of new energy vehicles in the field of logistics; On the other hand, there is technological innovation, and the progress of battery technology has made the driving range of electric vehicles continue to increase, and the charging facilities are increasingly perfect, providing a solid technical guarantee for the large-scale application of new energy vehicles.

In addition to new energy vehicles, other clean energy technologies are also being explored, such as solar auxiliary power systems and hydrogen fuel cells. The application of these new technologies will further optimize the carbon emission path of the logistics industry and promote the development of a low-carbon economy.

IV. CHALLENGES FACING THE FREIGHT LOGISTICS INDUSTRY

A. *Policy and regulation adaptation problem*

Under the new development pattern of "dual circulation", the national level has introduced a series of policies and measures to support the development of freight logistics. However, in the specific implementation process, the policy differences between different regions and the difficulty of coordination have become a major obstacle to the development of the industry. It is mainly reflected in: First, there may be great differences in logistically related policies formulated by local governments according to local actual conditions, such as tax incentives, environmental protection standards, etc., which may lead to inconsistent management requirements for enterprises operating across the country. Second, the lack of coordination mechanism, insufficient cross-regional cooperation, especially in the inter-provincial border zone, due to the lack of effective communication and coordination mechanisms, prone to duplication of construction, waste of resources and other problems.

In order to solve the above problems, it is suggested that: first, a unified policy framework should be established, led by the central government, and relevant departments should jointly develop a unified national logistics policy system to ensure the consistency and coherence of local policies. Second, strengthen inter-regional cooperation, promote information sharing and technology exchange through signing cooperation agreements and establishing regional alliances, and realize complementary advantages and coordinated development.

With the change of the global economic situation, the international trade rules are also constantly adjusted. Factors such as new tariff barriers, non-tariff barriers (such as technical standards, environmental certification) and multilateral trade agreements have brought uncertainty to international

freight logistics: some countries have taken unilateral measures to increase tariffs or set up other trade restrictions, directly affecting the logistics costs and supply chain stability of multinational enterprises. In order to meet more stringent international standards, logistics companies need to invest more money in equipment upgrades, personnel training and other aspects, increasing the operational burden.

The coping strategies include: actively participating in the formulation of international rules, representing the interests of Chinese logistics enterprises through platforms such as industry associations, and striving for a favorable international environment; Enhance their own competitiveness, accelerate technological innovation and service model transformation, and improve the ability of enterprises to resist risks in complex international markets.

B. Technical application bottleneck

Although digital technology can greatly improve logistics efficiency and service quality in theory, it has encountered many difficulties in the actual promotion process. The lack of network coverage in some areas, especially in remote areas, has affected the application effect of technologies such as the Internet of Things and cloud computing. With the advent of the era of big data, how to ensure the security and privacy of user data has become an important issue, especially in cross-border logistics. Many small and medium-sized logistics enterprises, due to limited funds, lack of talent and other reasons, are difficult to keep up with the pace of rapid development of science and technology, resulting in a slow digital transformation process.

To solve the above problems, the following solutions are needed: to increase infrastructure investment, the government should increase investment in communications infrastructure, especially in rural and remote areas, to narrow the digital divide; Strengthen the protection of laws and regulations, improve relevant laws and regulations, strengthen the protection of data security and personal privacy, and provide a healthy digital ecological environment for enterprises; Provide technical support and training, through the establishment of special funds, training courses and other forms, to help traditional logistics enterprises master new technologies, smooth transformation and upgrading.

Although the automation and intelligent technology has broad prospects, it also faces many challenges in practical application: high initial investment cost, shortage of technical and human resources, and system compatibility problems. Ways to overcome these obstacles are:

First, the phased implementation, according to the actual situation of the enterprise, gradually introduce their own automation and intelligent technology, to avoid the one-time large-scale investment caused by financial pressure. The second is to strengthen personnel training, and cooperate with universities and scientific research institutions to cultivate compound talents who understand logistics and are familiar with information technology to meet the development needs of the industry. The third is to optimize the technology integration scheme, select technology and product suppliers with good compatibility, and ensure seamless docking between various systems.

C. Market competition and globalization pressure

In the context of globalization, China's freight logistics industry is not only facing fierce competition in the domestic market, but also must deal with new challenges from the international market: on the one hand, trade barriers have intensified, tariff barriers and non-tariff barriers set by some countries and regions make Chinese logistics enterprises encounter difficulties in expanding overseas markets. On the other hand, geopolitical factors, such as fluctuations in international relations and local conflicts, may interrupt key transportation routes, affecting the security and stability of the global supply chain.

The countermeasures are as follows: First, we should actively explore emerging markets, reduce dependence on the single market, and spread risks. The second is to strengthen emergency response capabilities, establish and improve emergency plans, improve the response speed and processing capacity of enterprises in emergencies, and ensure the continuous chain of supply chains. In order to gain a firm foothold in the global market, China's freight logistics industry also needs to continuously improve its competitiveness and service level: standardize service processes in accordance with international standards, and improve the consistency and reliability of service quality. Use big data to analyze customer needs and provide customized logistics solutions to enhance customer stickiness. Actively respond to the

global climate change initiative, promote green logistics concept, reduce carbon emissions, and establish a good corporate image.

V. DIRECTION OF STRATEGIC ADJUSTMENT

A. Accelerate digital and intelligent transformation

In order to better cope with the opportunities and challenges brought by the new development pattern of "dual circulation", the freight logistics industry needs to accelerate the digital and intelligent transformation. Reinforcement learning, as an advanced machine learning method, shows great potential in optimizing logistics management and decision-making process. A reward function is designed to guide the algorithm to learn the optimal strategy. For example, in path planning, arrival time and transportation cost can be set as reward indicators to guide the vehicle to choose the shortest or lowest cost route.

Let $R(s,a)$ represent the immediate reward for taking action a in state s, then the long-term cumulative reward Gt can be expressed as:

$$\mathrm{Gt} = \sum_{k=0}^{\infty} \gamma^k R_{t+k+1} \qquad (3)$$

Where γ is the discount factor, $0<\gamma\leq 10<\gamma\leq 1$, used to balance the importance of immediate rewards and future rewards.

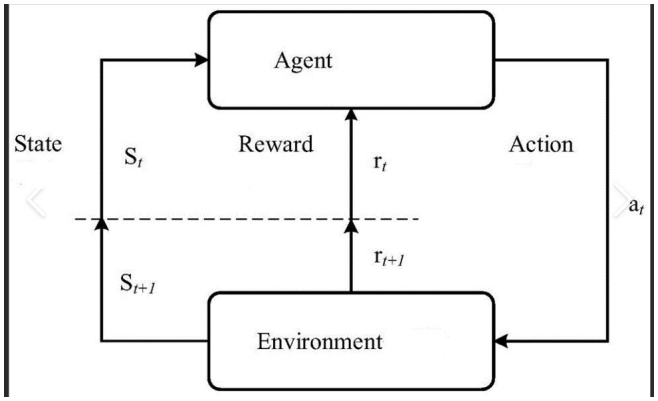

Fig. 2. Application framework of reinforcement learning in intelligent logistics

Figure 2 shows that reinforcement learning is not only applicable to path planning, but also can be applied to inventory management, order allocation and other fields to help logistics enterprises achieve more efficient resource utilization and service response.

In order to demonstrate the advantages of reinforcement learning in optimizing logistics management and decision-making processes in the freight logistics industry, we can create a performance comparison table that compares reinforcement learning with other traditional algorithms (such as linear programming, heuristic algorithms, etc.) on different evaluation indicators.

TABLE II. PERFORMANCE COMPARISON BETWEEN REINFORCEMENT LEARNING AND OTHER TRADITIONAL ALGORITHMS

Evaluation index	Reinforcement learning	Linear programming	Heuristic algorithm
Path planning efficiency	Efficient, able to adapt to dynamic changes in the environment, providing real-time optimal path	Suitable for static problems, poor adaptability to complex or dynamic environments	Fast solution by rules and experience, but not necessarily the optimal solution

	selection		
Transportation cost optimization	Learning health through the reward functionThe best strategy for low transportation costs	The calculation time depends on the size of the problem, and the calculation time is longer for large-scale problems	It can give a feasible solution quickly, but it may not be the optimal cost solution
Response time	Able to quickly respond to environmental changes and adjust strategies in real time	The calculation time depends on the size of the problem, and the calculation time is longer for large-scale problems	The response time is fast, but the long-term effect is not considered
flexibility	Highly flexible and able to deal with uncertainty and complexity	Limited ability to adapt to changes outside the model	Medium flexibility, depending on predefined rule sets
Long-term Cumulative Bonus (Gt)	Consider the importance of future rewards to help maximize long-term benefits	Long-term cumulative rewards are not directly considered	Focus mainly on short-term goals and less on long-term effects

Table 2 can reflect the advantages of reinforcement learning compared with other traditional algorithms, especially in response to the opportunities and challenges brought by the new development pattern of "dual circulation", to accelerate the digitalization and intelligent transformation of the freight logistics industry.

The smart logistics platform is an information hub connecting cargo owners, carriers, storage service providers and other multi-parties, which can promote information sharing and collaborative operation. Specific measures include the establishment of unified data standards and interface specifications to ensure seamless docking and efficient flow of data between participants. Relying on cloud computing technology to provide powerful computing power and storage space, reduce enterprise IT infrastructure construction and maintenance costs. Deploy sensors, RFID tags and other devices to monitor environmental parameters such as cargo location, temperature and humidity in real time, improving logistics transparency and service quality.

In the data processing stage, the original image is preprocessed first, including gray-scale, denoising and contrast enhancement steps to improve the image quality. Next, image processing technologies such

as edge detection and contour extraction are used to accurately segment the outline of the pig from the image, and further extract key body size features, such as body length, body height and body width. There is a close relationship between these characteristics and the body weight of pigs, which is an important basis for subsequent modeling.

To ensure the generalization ability of the model, we divided the collected data into a ratio of 70% training set, 20% validation set, and 10% test set. The training set is used to train the random forest model, the validation set is used to tune the model's hyperparameters, and the test set is used to finally evaluate the model's predictive performance. By means of cross-validation, we constantly adjust the model parameters until we achieve the best prediction effect. The whole process of data processing and model training fully considers the quality and diversity of data to ensure the effectiveness and reliability of the model.

B. *Optimize regional logistics layout*

Reasonable regional logistics layout is very important to improve transportation efficiency and reduce cost. The clustering algorithm can help identify the demand characteristics of different regions, so as to optimize the location and configuration of logistics nodes: collect multidimensional information such as historical transaction data, population density and economic development level, and use the clustering algorithm to divide the country into several regions with similar logistics demand characteristics.

Let $D=\{d1 \quad ,d2 \quad ,...,dn \quad\}$ is a set of data points,$C=\{c1 \quad ,c2 \quad ,...,ck \quad\}$ is the cluster center,

Then the objective function of K-means clustering can be expressed as:

$$min_C \sum_{i=1}^{n} min_{1\le j\le k} ||d_i - c_j||^2 \qquad (4)$$

C. *Promote multimodal transport and supply chain synergy*

Multimodal transport refers to the comprehensive use of railways, roads, waterways and other modes of transport to complete the entire transportation of goods, and the application of blockchain technology can significantly improve the security and credibility of this process: all transaction records are encrypted and stored on the blockchain, and no party can unilaterally modify the data, ensuring the authenticity and integrity of information; Automatic execution of contract terms through smart contracts without the need for third-party intermediaries, reducing transaction costs and improving efficiency; From loading to final delivery, every step of the operation can be tracked, enhancing the transparency and control of the supply chain.

In order to achieve closer supply chain coordination, it is necessary to strengthen the communication and cooperation between upstream and downstream enterprises in the industrial chain: build an open information sharing platform, so that suppliers, manufacturers, distributors and other parties can timely obtain key information such as market demand changes and inventory status. Enterprises are encouraged to carry out joint research and development projects, jointly overcome technical problems, develop new products or service models, and enhance their overall competitiveness. Establish effective risk sharing mechanisms, such as signing long-term cooperation agreements and setting up mutual funds, to reduce the pressure on enterprises in the face of market fluctuations.

D. *We will strengthen policy support and industrial coordination*

The government plays an important role in the development of the logistics industry, and should increase its support for infrastructure construction and actively guide social capital investment: provide certain financial subsidies to qualified logistics enterprises, reduce related taxes and fees, and reduce enterprise operating costs; Set up a special capital pool to support logistics enterprises to carry out technology research and development, equipment update and other activities to promote technological innovation and development of the industry; Invest in the construction of a number of high-level public service platforms, such as logistics data centers, testing and verification laboratories, etc., to provide necessary technical support and service guarantee for enterprises.

The healthy development of logistics industry is inseparable from the close cooperation between various departments: transportation, commerce, customs and other departments should maintain

consistency in policy formulation, avoid conflicting regulations, and create a good development environment for enterprises; Establish and improve the joint supervision mechanism, strengthen the supervision and management of the logistics market, crack down on illegal behaviors, and maintain market order; Actively participate in international organizations and multilateral trade agreements, share China's experience and practices in logistics development, attract foreign advanced technology and management experience, and promote the common progress of the global logistics industry.

VI. CONCLUSION

Through in-depth analysis of the role of freight logistics industry in promoting transportation economy and the challenges it faces under the new development pattern of "dual circulation", this study concludes the importance of intelligent and digital transformation. The application of intelligent algorithms significantly improves transportation efficiency, reduces costs, and enhances the response speed and service quality of logistics services. At the same time, the promotion of green logistics and low-carbon economy, through the promotion of new energy vehicles and the application of clean energy technology, provides an effective path for reducing carbon emissions and achieving sustainable development goals, which is in line with the national "double carbon" strategy; The synergy between policies, regulations and regions cannot be ignored. Establishing a unified policy framework and strengthening inter-regional cooperation mechanisms can promote the healthy development of the logistics industry, and require enterprises to adapt to changes in international trade rules to enhance competitiveness. The value of multimodal transport and supply chain collaboration is reflected in the blockchain-based system construction, which strengthens the upstream and downstream cooperation of the supply chain, improves the traceability ability and trust of the whole process, and increases the logistics efficiency and supply chain security. The need for infrastructure upgrading and policy support shows that the government has played an important role in technological innovation and service level improvement, and cross-sectoral coordination and international cooperation and exchanges have also created a good external environment. Looking forward to the future, with the deepening of the "dual circulation" pattern and the advancement of technology, it is necessary to further deepen the application of intelligence, expand green logistics practices, strengthen regional integration construction, enhance the resilience of the global supply chain, continue to pay attention to policy dynamics, and promote the standardization process of the industry to ensure the healthy development of China's freight logistics industry. And establish a good image and brand in the global market.

REFERENCES

[1] Trzepieciński T, Najm S M, Ibrahim O M, et al. Analysis of the Frictional Performance of AW-5251 Aluminium Alloy Sheets Using the Random Forest Machine Learning Algorithm and Multilayer Perceptron[J]. Materials, 2023, 16(15): 5207.

[2] Zhao, Yufei, Shixiao Xu, and Hua Duan. "HGNN− BRFE: Heterogeneous Graph Neural Network Model Based on Region Feature Extraction." Electronics 13.22 (2024): 4447.

[3] Sarini N P, Dharmawan K. Estimation of bali cattle body weight based on morphological measurements by machine learning algorithms: random forest, support vector, K-Neighbors, and extra tree regression[J]. J Adv Zool, 2023, 44(3): 1-9.

[4] Wu D, Jennings C, Terpenny J, et al. A comparative study on machine learning algorithms for smart manufacturing: tool wear prediction using random forests[J]. Journal of Manufacturing Science and Engineering, 2017, 139(7): 071018.

[5] Mishra N B, Pani A, Bansal P, et al. Towards sustainable logistics in India: Forecasting freight transport emissions and policy evaluations[J]. Transportation Research Part D: Transport and Environment, 2024, 133: 104267

[6] Mishina Y, Murata R, Yamauchi Y, et al. Boosted random forest[J]. IEICE TRANSACTIONS on Information and Systems, 2015, 98(9): 1630-1636.

[7] Baker D, Briant S, Hajirasouli A, et al. Urban freight logistics and land use planning education: Trends and gaps through the lens of literature[J]. Transportation Research Interdisciplinary Perspectives, 2023, 17: 100731.

[8] Truong Minh Long N, Truong Thinh N. Using machine learning to grade the mango's quality based on external features captured by vision system[J]. Applied Sciences, 2020, 10(17): 5775.

[9] Zermane A, Tohir M Z M, Zermane H, et al. Predicting fatal fall from heights accidents using random forest classification machine learning model[J]. Safety science, 2023, 159: 106023.

[10] Rajesh D, Gupta S K, Ilinich S, et al. An assessment of challenges and factor influencing the freight forwarding business in the logistics industry[J]. Economics, Finance and Management Review, 2023 (2): 4-23.

[11] Y. Zhao, H. Liu and H. Duan, "HGNN-GAMS: Heterogeneous Graph Neural Networks for Graph Attribute Mining and Semantic Fusion," in IEEE Access, doi: 10.1109/ACCESS.2024.3518777.

[12] Zhao Y, Wang S, Duan H. LSPI: Heterogeneous Graph Neural Network Classification Aggregation Algorithm Based on Size Neighbor Path Identification[J]. arXiv preprint arXiv:2405.18933, 2024.

[13] Pan, Jinghui. "Fractional-order sliding mode control of manipulator combined with disturbance and state observer." *Robotics and Autonomous Systems* 183 (2025): 104840.

[14] Zhang, Xugang, et al. "A novel method for state of health estimation of lithium-ion batteries based on fractional-order differential voltage-capacity curve." Applied Energy 377 (2025): 124404.

[15] Wang, Zhenjie, et al. "Finite-time quasi-projective synchronization of fractional-order reaction-diffusion delayed neural networks." Information Sciences 686 (2025): 121365.

[16] Wang, Zhenjie, et al. "Finite-time quasi-projective synchronization of fractional-order reaction-diffusion delayed neural networks." Information Sciences 686 (2025): 121365.

[17] Gong, Zhaohua, et al. "A gradient-based optimization algorithm to solve optimal control problems with conformable fractional-order derivatives." Journal of Computational and Applied Mathematics 454 (2025): 116169.

[18] Kausar, Aneela, et al. "A novel design of layered recurrent neural networks for fractional order Caputo–Fabrizio stiff electric circuit models." Modern Physics Letters B 39.02 (2025): 2450393.