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Research of Intelligent Logistics and High-Quality Economy Development for Yangtze River Cold Chain Shipping Based on Carbon Neutrality

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Abstract: The current status of intelligent logistics and cold chain shipping research is a hot topic worldwide. Meanwhile, the study of regional logistics and regional economy, shipping logistics and regional economic theory and application methods, and the empirical analysis of the correlation between the Yangtze River shipping and the Yangtze River shipping economy have attracted a lot of attention. This research has revealed that the Internet of Things of Yangtze River shipping has a great impact on the Yangtze River and the importance of inland river economic development. This study presents the empirical analysis on the correlation between shipping logistics and the inland river economy, starting from qualitative and quantitative aspects, and taking Yangtze River shipping as the representative. The proposed mathematical models and qualitative data analysis are made on the relevant effects of intelligent logistics and cold chain shipping on an inland river economy including its impact on the industrial layout, international trade, and urbanization. The research results provide administrative decisions or guidance values for the economic development of inland river ports in the Yangtze River.

Keywords: intelligent logistics; cold chain shipping; carbon neutrality; mathematical models; inland port container logistics

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1. Introduction

In recent years, with large-scale container ships and the vigorous development of the container transportation industry, container terminals are facing the pressure of centralized operation, labor and resource costs, how to improve the container in the terminal space resources, labor resources and limited resources under the operating efficiency, and optimizing the existing allocation of resources as today's terminal operators encounter serious problems. For example, recently, Tiago A. Santos et al., studied the possibilities of a closer integration of short sea shipping with other components of the Trans-European Transport Networks, shifting a significant share of road freight onto rail corridors and inland waterways [1]. Sung-Ho Hur et al., designed a new intermodal automated container transport system (ACTS) via a roll-on/roll-off method that connected a logistics hub between a port and inland. Furthermore, they presented the development of a simulation model and the results of the simulator development [2]. Yingying Bian et al., analyzed the decision-making of container transportation businesses in feeder companies operating between Shanghai Port and inland ports along the Yangtze River in China [3,4].

Regarding the study of regional theory, the main perspectives that have been studied include the concept and meaning of regional logistics, the regional logistics system, the regional logistics development model, regional logistics planning, and regional logistics informatization construction. The following are some representative research works: Dong Qianli et al., provided the earliest research on regional logistics theory in China. The earliest document is 'Research on the Application of Regional Logistics Theory in China'. They proposed the meaning of regional logistics, a regional logistics system and the framework structure, and the regional logistics operation mode. 'How to Understand Regional Logistics' combines the meaning of logistics itself, describes the basic connotation of regional logistics, and puts forward several major characteristics of regional logistics: regionality, centrality, adaptability, distance economy, and influence. Regarding the factors of regional logistics, he believes that the geographical location of the region is the primary factor. Previous studies have shown that 'Thoughts on the Construction of China's Logistics System', which proposed that the regional logistics system includes the regional logistics infrastructure, regional logistics enterprises, regional logistics information platforms, regional logistics management, and mediation of four subsystems, while at the same time, this study expounds the regional logistics development of international experience, and puts forward the countermeasures of the regional logistics development in China [5,6]. Previous studies have shown that 'Theoretical Analysis and Research on Regional Logistics', through the introduction of the connotation and characteristics of regional logistics, analyzes the development status and existing problems of China's regional logistics. Based on the selection and construction of regional logistics in a central city, this study puts forward some countermeasures to promote the healthy development of regional logistics in China.

Jin Suk Park and Young-Joon Seo revealed the economic impact of seaports on regions in Korea. The econometrics analysis showed that cargo ports without sufficient throughput obstructed regional economic growth, whilst cargo ports contributed to regional economic growth only when they had sufficient throughput [7]. Jin Suk Park et al., attempted to examine the role of various types of transport infrastructure in OECD and non-OECD countries by employing a hybrid production approach that combines macroeconomic growth with the supply of and demand for transportation [8]. Previous studies have shown that there are four different types of regional logistics modes in the 'Discussion on Regional Modern Logistics Mode'. Namely, regional integrated logistics mode based on industrial agglomeration, regional supply chain integration logistics mode based on industrial chain, multi-functional service logistics mode based on regional cargo hub (such as ports), and transaction service warehousing and distribution logistics mode based on regional trading market, etc. Previous studies have shown that a research summary of regional logistics informatization construction pointed out that regional logistics informatization construction was based on regional logistics theory and regional logistics informatization theory. The cold chain is a supply chain with temperature control. The type of cold chain is categorized by the temperature requirements of the products involved. Maheshwar classified refrigerated cargoes as food or nonfood items and as chilled cargoes and frozen cargoes according to the storage environment. Chilled cargoes, also known as perishable cargoes, are stored above −10 °C. Correspondingly, frozen cargoes are stored under −10 °C, usually under −18 °C [9,10].

In the 20th century, China began to study regional logistics and the regional economy. Among these studies, important representative viewpoints are 'point-axis development theory', which explains the dynamic effect of regional logistics on economic development. Previous studies have shown the relationship between regional logistics and the regional economy in China. Since then, many scholars have also begun to study regional logistics and the regional economy. Representative studies include 'Research on Regional Logistics System and Its Relationship with Economic Growth', which analyzed the structure and function of the regional logistics system and demonstrated the internal interaction mechanism between the regional logistics and the regional economy and its coordinated development model. Other studies have shown that 'Research on the Contribution of

Logistics Capability to the Regional Economy' used Jiangsu Province's passenger and freight turnover and Jiangsu Province as indicators to perform regression analysis and marginal analysis to obtain the contribution rate of the province's logistics capabilities to the economy. Emphasizing the strengthening of the logistics infrastructure and the information construction of the logistics system and the rational adjustment of the logistics system structure are important tasks for Jiangsu Province. A previous study on 'Research on the Coordinated Development of Regional Logistics and Regional Economy-Taking Nanjing City as an Example' discussed the interaction mechanism between the regional logistics and regional economy, and pointed out that the development of regional logistics and the regional economy requires mutual cooperation between the two. On this basis, the content and form of collaboration were proposed to empirically analyze the status quo of regional logistics and the regional economic development in Nanjing through an econometric model [11–14].

Currently, the application of the Internet of Things (IoT) in inland port logistics has incrementally developed for many years. Particularly of interest to researchers is how to reduce the emission of greenhouse gases during the inland port's logistics operations by formulating mathematical models and solving them with an intelligent algorithm. In this study, we carried out profound research in the field of IoT and logistics in inland waterway shipping that contains intelligent logistics, carbon neutrality, cold chain shipping, and energy conservation with less emission aspects, etc. Busy shipping and logistics on the golden waterway of the Yangtze River are shown in Figure 1 [3]. The background and necessity of the research and development of Yangtze River shipping are as follows. The trunk and tributaries of the Yangtze River have been China's major water traffic arteries traversing the east and west and connecting the north and south since ancient times, with a total length of more than 10,000 km. The Yangtze River's main circulation has a mileage of many kilometers and is known as the 'golden waterway'. The inland Yangtze River flows through seven provinces and two cities and runs through the eastern, central, and western regions of China. It is an important part of China's comprehensive transportation system. Its advantages in water transportation have strongly supported the economic development of the regions along the Yangtze River and contributed to the formation of the Yangtze River Economic Belt. It plays an important role as the region along the Yangtze River is rich in resources and is densely populated with industries. It has amassed economic aggregates above that of China and occupies a very important position in China's economic development. According to the statistics, at present, large and medium cities above Hubei Province are concentrated along the Yangtze and Han Rivers, and bulk cargoes such as coal and crude oil above the province need to be transferred by water from outside the province. As such, the international trade containers above need to be transferred by water. Relying on the golden waterways of the Yangtze River, China has formed the most dynamic and competitive economic zone, the Yangtze River Economic Belt, which is dominated by high-tech industries, with metallurgy, electronics, machinery, automobiles, crude oil, and chemical industries as the mainstay. The Yangtze River Economic Belt accounts for more than the total amount of China, and it has gathered close to China's strongest enterprises. The transportation of coal and iron ore along the Yangtze River as well as the transportation of the international trade goods in the upper and middle reaches of the Yangtze River is borne by Yangtze River shipping. The direct contribution of Yangtze River shipping to the economic and social development along the Yangtze River has reached 100 million yuan, and the indirect contribution 1 trillion yuan; the direct employment of more than 10,000 people will bring more than 10,000 indirect job opportunities. China and the provinces and cities along the Yangtze River have always attached great importance to the construction and development of shipping on the Yangtze River. The construction and development of the Yangtze River and other inland shipping is the focus of national transportation at present and will be for a period of time in the future, and the development of the Yangtze River shipping has risen to the national strategic level. In this context, it is particularly necessary to study the relationship between shipping logistics and inland river economy for the development of the Yangtze River shipping and the social and economic development of China's inland [15–18].

Figure 1. The description of shipping and logistics on the golden waterway of the Yangtze River [3].

2. Investigation and Comparisons on Regional Logistics and Regional Economy

The Yangtze River is known as the longest river in China and the third longest in the world, with a length of more than six kilometers. The channel flows through seven provinces and two cities, from downstream to upstream: Shanghai, Jiangsu, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, and Yunnan. It runs through China's Eastern, Central, and Western regions, and occupies an important position in China's water transportation system. he inland Yangtze River is rich in natural resources; it has a large number of forests and vegetation, water resources, mineral resources, etc., all of which provide an important resource basis for the economic development of the inland river, especially for the development of industry. With the convenience provided, the Yangtze River Economic Belt was born from this region that accounts for China's total industrial output value in the inland Yangtze River. Agricultural development in the inland Yangtze River is also at the forefront in China, with a high output of grain, cotton, and oil, not only meeting the needs of the region, but also providing an important source of food for other provinces, cities, and regions. At the same time, the inland Yangtze River has a large number of natural landscapes, especially in the upper reaches, where the ecological environment is good, and tourism is also one of the important industries in the region. Yangtze River shipping is the main artery of China's east–west economy, and the Yangtze River Economic Belt occupies a pivotal position in the national economy due to its advantageous location and economic strength. At present, it has formed three major economic circles—the Chengdu–Chongqing economic circle upstream, the Wuhan economic circle in the central region, and the Yangtze River Delta economic circle downstream. The Yangtze River Economic Belt is another economic axis that is emerging after the economic construction of the east coast. It forms a structure with the east coast economic belt and traverses the east, middle, and west of China. Large-scale development plays a role in fueling the flames. Relying on its unique natural conditions, abundant natural resources, strong industrial material base, and rapid social and economic development, the Yangtze River Economic Belt is called China's industrial-intensive belt [19–21].

In general, the interaction between the Yangtze River Channel and the Yangtze River Economic Belt is a complex network, and the two systems feedback each other in the process of interaction, so a causal diagram was used for this research. The causal relationship between the Yangtze River Channel and the Yangtze River Economic Belt is shown in Figure 2. The interactive development of the Yangtze River waterway and the Yangtze River Economic Belt is mainly reflected in the promotion of the interconnection of the

Yangtze River Economic Belt, the promotion of the economic development of the basin, the improvement in the ecological environment, and the promotion of the scientific and technological levels.

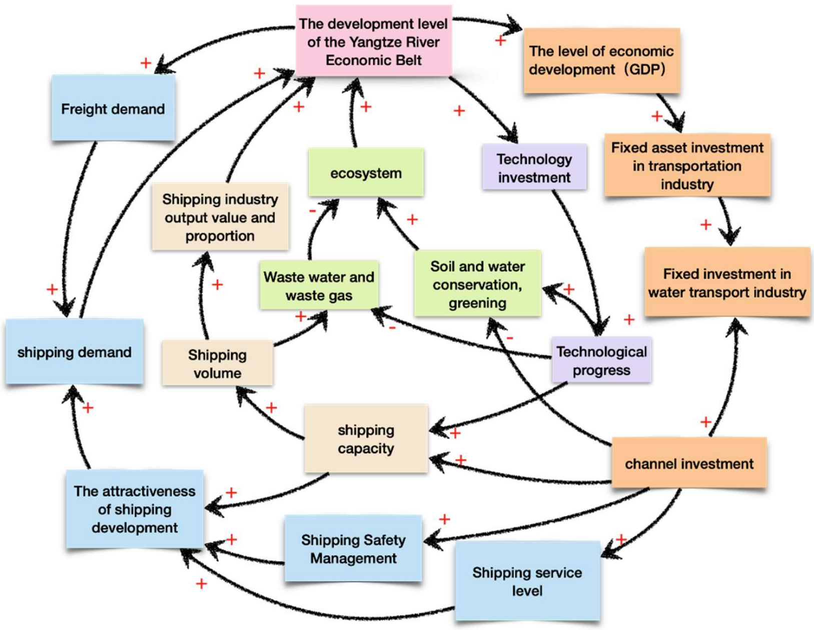

Figure 2. The network relationship diagram of the interactive development of the Yangtze River waterway and the Yangtze River Economic Belt (+ positive influence; − negative influence).

Usually, the IoT for the Yangtze River shipping container logistics are conducted through radio frequency identification (RFID), infrared sensors, sensors, GPS positioning systems, and other information collection equipment to collect the container logistics information, given more to the container intelligence, so that traditional container transport has almost become an 'island', based on intelligence and connections. Specifically, the IoT technology is, through the intelligent container, an electronic label that can help the container automatically realize the record switch box information, specific geographic location, internal temperature, humidity, and pressure as well as other information, and can realize the real-time transmission of information and reach the container cargo shipping of the whole process monitoring, thus improving the transparency and security of the container logistics of Yangtze River shipping.

Based on the analysis of the operation process of the inland river port and the Yangtze River shipping logistics, the operation of inland river port logistics mainly involves the following three objects: the ports' container RFID, logistics shipping, and the port storage area of manufacturing enterprises that need cargo container ship collection services. The IoT device deployment diagrams for the inland river port logistics system are shown in Figure 3.

Usually, cold chain container ships are divided into two types: full cold chain container ships and semi-cold chain container ships, which have the characteristics of fast loading and unloading speed, short stop time, and high speed. As of March 2016, the world's cold chain container fleet has grown to 5230 vessels and 19.8 million twenty feet equivalent unit (TEU). Affected by the trend of large-scale ships, the world's cold chain container ships have experienced rapid development since 2000. Among them, 6000 TEU large ships have increased from 36 ships; from 215,000 TEU in 2000 to 798 ships; and from 7.148 million TEU in August 2013, and the proportion of container space has increased from 4.6% to 42.3%; the growth momentum of large ships above 8000 TEU is even greater. In order to be strong, it increased from 47 ships and 397,000 TEU in 2005 to 529 ships and 5.35 million TEU in August 2013, and the proportion of container slots increased from 4.9% to 31.6%; more strikingly, for 10,000 TEU, the number of super-large ships above the TEU reached

187, 2.407 million TEU, and the container space accounted for 14.2%, which is the fastest growing ship type since the 'Twelfth Five-Year Plan' period (as shown in Table 1).

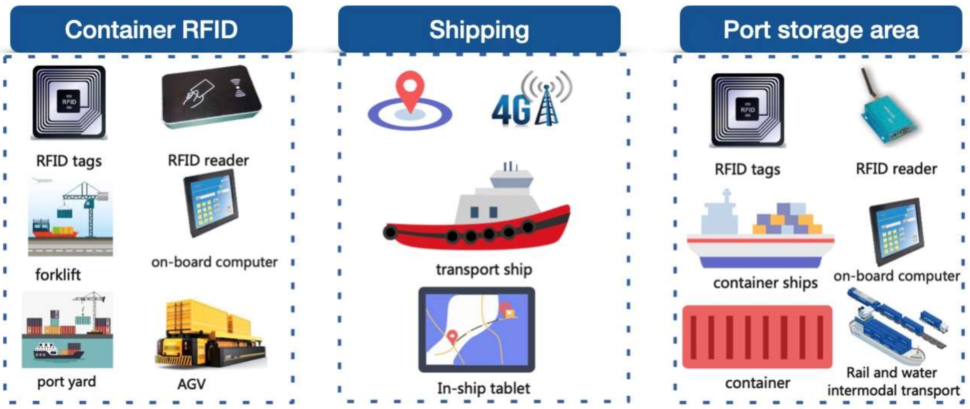

Figure 3. The IoT device deployment diagram for the inland river port logistics system.

Table 1. The development status of the world's cold chain container fleet composition.

Number of Shipping Containers (TEU)	2000		2005		2010		2015		2020	
	NS	TEU	NS	TEU	NS	TTEU	NS	TTEU	NS	TTEU
<5000	2465	410.3	3287	590.5	4118	800.7	4055	2303	3857	778.1
5000~8000	100	57	296	179.2	553	331.5	587	350.9	613	367.1
8000~10,000	0	0	47	39.7	231	198.5	309	268.9	393	339.9
10,000+	0	0	0	0	61	75.4	155	208.3	250	326.3
Total	2565	467.3	3630	809.4	4963	1406.1	5106	1630.4	5113	1811.4

NS = number of ships; TTEU = ten thousand/TEU.

As of December 2016, the number of cold chain container ships ordered worldwide was 452 with 3.317 million TEU. The ships ordered were mainly large ships of 8000 TEU or above, accounting for 82.6% of the ordered capacity, of which 126 ships of 10,000 TEU and above were ordered, for 1.823 million TEU, the capacity accounted for 55%. Ships on order are mostly delivered within three years. At this time, the proportion of medium and large ships in the cold chain container fleet will further increase, of which the proportion of the total container space of ships of 10,000 TEU and above will increase from 18% to 23.7% (as shown in Table 2).

Table 2. The details of the world's cold chain container ship orders.

Number of Shipping Containers (TEU)	Total		2010		2015		2020	
	NS	TTU	NS	TTU	NS	TTU	NS	TTU
<1000	5	0.4	1	0.1	3	0.2	1	0.1
1000~2000	86	12.8	10	1.7	30	4.3	46	6.8
2000~3000	81	19.2	3	0.7	35	8.2	43	10.4
3000~5000	26	10.5	8	3.3	14	5.6	4	1.5
5000~8000	27	14.9	4	2.0	16	9.3	7	3.5
8000~10,000	101	91.7	8	7.3	67	60.5	26	23.9
10,000~12,000	26	26.8	0	0	10	10.2	16	16.6
12,000+	100	155.5	4	6.2	47	77.2	49	62.2
total	452	331.7	38	21.3	222	175.5	192	125

NS = number of ships; TTU = ten thousand/TEU.

3. The Development of Cold Chain Shipping and Logistics in the Yangtze River under the Background of Carbon Neutrality

Cold chain logistics generally refers to the fact that refrigerated and frozen products are always at a specified low temperature environment in all links from production, storage, transportation, and sales to consumption. It is a system engineering issue to ensure the product quality and reduce product loss. Some scholars have put forward many definitions according to different understandings, and here are a few of them. Combined with some of the existing mature definitions, this study defined the cold chain Yangtze River shipping logistics as follows: Products that require a certain temperature (generally around 0 °C or below) and are in the process of production, storage, transportation, distribution, and sales. A special form of shipping logistics in the Yangtze River that is suitable for low temperature environments would thereby reduce the corrosion and ensure the product quality [22]. For more intelligent manufacturing and intelligent control technology aspects of cold chain container and low carbon management and control, perhaps we can refer to the innovative ideas in these studies [23–27]. In these studies, X. Xiao et al., introduced an automated control method that allowed them to reorient the part during the build using a five-axis machine and machine learning. The reorientations still allow the part to be built using traditional planar deposition but without the use of supports. They developed a quantitative model within a process network and achieved a constant quality level by controlling the process parameter set [28].

The cold chain Yangtze River shipping logistics generally includes four temperature ranges: refrigeration, ice temperature, freezing, and ultra-freezing. The cold chain products stored in different temperature zones are quite different. The common products that require the support of cold chain Yangtze River shipping and logistics include fresh products, processed foods, and pharmaceutical products [29,30].

The temperature requirements for biological products in pharmaceutical products are in the range of [2 °C, 8 °C], and the temperature of some frozen medicines is in the range of [−10 °C, −25 °C] for food at different cold chain temperatures, and is supported by a special pharmaceutical cold chain Yangtze River shipping logistics system. According to the scope of this study, only the types of foods under different cold chain temperatures are listed here, and the details are shown in Table 3.

Table 3. The food subdivisions under different cold chain temperatures.

Product Category	Refrigerated [0 °C~7 °C]	Ice Temperature [−2 °C~2 °C]	Freeze [<−15 °C]	Ultra-Freezing [<−50 °C]
Fruit	Bulk fruits such as apples	Tropical, imported and other niche fruits	—	—
Vegetable	Most vegetables	Tropical vegetables	—	—
Aquatic products	Chilled	Fresh fish, shellfish, etc.	Frozen aquatic products	Sashimi, etc.
Meat products	Frozen meat	Livestock, poultry, processed meat	Frozen Meat	—
Dairy products	Fresh milk	Pasteurized milk, yogurt	Ice Cream, Cheese, etc.	—
Frozen food	—	—	Frozen Dumplings, Pastries, etc.	—

Cold chain Yangtze River shipping logistics is an important branch of modern Yangtze River shipping logistics. Its particularity is obviously different from that of normal temperature Yangtze River shipping logistics as it has high requirements for temperature and humidity. Changes in storage conditions often lead to product deterioration. Therefore, cold chain Yangtze River shipping logistics is more sensitive to transportation and distribution time, and the timeliness is very obvious. Customers often put forward higher requirements for the receipt time window. These characteristics are quite different from the normal temperature Yangtze River shipping and logistics. The specific differences between the cold chain Yangtze River shipping logistics and the normal temperature Yangtze River shipping logistics are shown in Table 4.

Table 4. A comparison of the difference between the cold chain Yangtze River shipping logistics and the normal temperature Yangtze River shipping logistics.

Correlation Variable	Cold Chain Yangtze River Shipping Logistics	Normal Temperature Yangtze River Shipping and Logistics
Timeliness	high	not obvious
Yangtze River Shipping Vessels and Equipment	Cold chain cold chain container ship with advanced equipment	Ordinary cargo ships, equipment requirements are not high
Operation management	Complex and systematic	Relatively simple
cost	Very high	Relatively low
Storage conditions	Strict	Simple
Shipping network	Immature	Mature
Service provider	Few, high requirements	Many, relatively low requirements
Industry Standard	Inadequate and lack of regulation	Relatively perfect

The operation process of cold chain Yangtze River shipping logistics includes origin collection and post-production processing (pre-cooling), origin collection (preliminary processing), refrigerated transportation, low-temperature storage, sales location processing and distribution, retail sales, and other links. This process is generally applicable to the production, harvesting, transportation, and sales of fruits and vegetables, meat products, aquatic products, dairy products, flowers, etc., and even biological preparations, special drugs, etc. The cold chain Yangtze River shipping logistics operation process is shown in Figure 4.

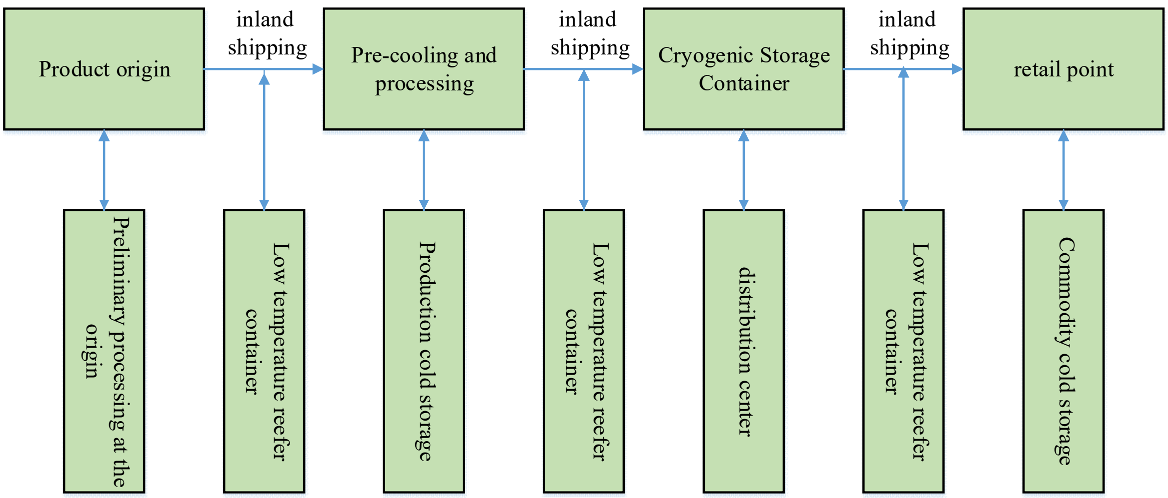

Figure 4. The cold chain Yangtze River shipping logistics operation process.

4. Calculation of the Fuel and Carbon Emissions of Shipping Vessels in the Yangtze River

The measurement of carbon emissions mainly includes three scales: macro, meso, and micro. Carbon emissions at the macroscale are mostly used for global forecasts, carbon cycle studies, and emissions estimation; the carbon emissions at the mesoscale focuses on the establishment, and research of the carbon emission model comes from the perspective of urban development; and the micro-scale includes the establishment of carbon emission systems such as households and enterprises, the determination of methods, and the study of ecological mechanisms. The calculation of carbon emissions in the optimization of the shipping cold chain distribution path in the Yangtze River is a typical micro-observation calculation. At present, academic circles have calculated the fuel consumption of ships in the Yangtze River first, and then converted it into carbon emissions through the conversion coefficient of fuel and carbon emissions. Six main calculation methods or models for the calculation of fuel and carbon emissions were investigated in this study. A comparison of the common smart optimization algorithms is shown in Table 5.

Table 5. A comparison of the common smart optimization algorithms.

Algorithm Type	Advantage	Shortcoming	Scope of Application
Genetic Algorithm	Good adaptability, strong robustness, less time-consuming, and various coding methods	The operation efficiency is not high, and it is easy to mature prematurely	Suitable for NP problems in complex optimization and combinatorial optimization
Tabu Search Algorithm	Suitable for local search, fast solution	High requirements for the initial solution, algorithm search is a single operation	Suitable for large scale problems
Simulated Annealing Algorithm	The calculation process is easy to understand, general, and stable in performance, and the global optimal solution can be searched	Slow convergence, performance is related to the initial value, and is greatly affected by parameters	Suitable for complex nonlinear optimization problems
Ant Colony Algorithm	It has an information feedback mechanism, strong global optimization ability, does not depend on the initial solution, and is easy to implement	Large amount of calculation, difficult to detach from local area, less pheromone in the early stage, and low efficiency	Optimal Combinatorial Problems for Multi-objective Functions
Particle Swarm Algorithm	The algorithm is easy to implement, stable in performance, high in precision and fast in convergence	It is difficult to escape from the local optimal solution region, and theoretical research needs to be further	Suitable for solving complex function optimization problems

The commonly used calculation methods for the fuel and carbon emissions of ships in the Yangtze River are as follows:

(1) Model 1: The calculation method for the carbon emissions of ships on the Yangtze River

This was proposed by the European Commission at the 22nd Conference (Methodologies for estimating air pollutant emissions from transport) report, which covered the calculation methods of the carbon emissions for different types of vehicles across transport modes such as road, rail, water, and air.

Among them, the carbon emission model of shipping and logistics carriers in the Yangtze River, which takes cold chain container ships as the research object, is widely used.

In this study, we point out the calculation formula for the carbon emissions of the cold chain container ship, which is described in Equation (1):

$$\varepsilon_{i,j,t} = \lambda_{i,j,t} + \xi LF_{i,t},\ i,j,t \in N \quad (1)$$

Here, $\varepsilon_{i,j,t}$ is the pollutants and carbon estimating emission of ships; $E_{i,j,t}$ is the estimating emissions for air pollutants except black carbon; $LF_{i,t}$ is the estimating emissions of black carbon; λ and ξ are the dimensionless coefficients.

(i) Estimating the emissions of all pollutants except for black carbon

Emissions from ships come from the main engines (MEs), auxiliary engines (AEs), and boilers (BOs). In the following equations, the MEs' power demand is a function of the installed MEs' power and the MEs' load factor; the AE and BO power demand depends on the ship class and capacity bin and the phase in which the ship is operating (e.g., cruise, maneuver, anchor, or berth). The AE and BO power demand assumptions were the same as those in the Third IMO GHG Study 2014 [31]. Emissions for all of the air pollutants except for BC were estimated according to Equation (2):

$$E_{i,j} = \sum_{t=0}^{t=n}\left(\left(\alpha n P_{ME_i} \times LF_{i,t} \times EF_{ME_{j,k,l,m}} + \beta D_{AE_{p,i,t}} \times EF_{AE_{j,k,l,m}} + \gamma D_{BO_{p,i,t}} \times EF_{BO_{j,m,l,m}}\right) \times 1\ h\right) \quad (2)$$

where:

i = ship;
j = pollutant;
t = time (operating hour, h);
k = engine type;
l = engine tier;
m = fuel type;
p = phase (cruise, maneuvering, anchor, berth);
l = fuel type;
E_{ij} = emissions (g) for ship i and pollutant j;
P_{ME_i} = main engine power (kW) for ship i;
$LF_{i,t}$ = main engine load factor for ship i at time t, defined by the equation below
$EF_{ME_{j,k,l,m}}$ = main engine emission factor (g/kWh) for pollutant j, engine type k, engine tier l, and fuel type m;
$D_{AE_{p,i,t}}$ = auxiliary engine power demand (kW) in phase p for ship i at time t;
$EF_{AE_{j,k,l,m}}$ = auxiliary engine emission factor (g/kWh) for pollutant j, engine type k, engine tier l, and fuel type m;
$D_{Bo_{p,i,t}}$ = boiler power demand (kW) in phase p for ship i at time t;
$EF_{BO_{j,k,l,m}}$ = boiler emission factor (g/kWh) for pollutant j and fuel type m;
α, β, and γ are the dimensionless coefficients.

Load factor (LF) is a function of the speed-over-ground (SOG), at time t, modified by a speed adjustment factor that corrects for underestimating the SOG for interpolated automatic identification system (AIS) signals, a hull fouling factor that accounts for an increase in the hydrodynamic resistance due to hull fouling as the ship ages and as biofouling builds up between drydock, a weather factor that accounts for the increased main engine power demand when the ship encounters bad weather, and a draught adjustment factor that reduces the load factor when the ship is lightly loaded.

The equation for calculating the ME LF for a ship at any given time is as follows:

$$LF_{i,t} = \left(\frac{SOG_t \times OGF_{i,t}}{V_{max}}\right)^3 \times HFF_i \times W_t \times DAF_i \quad (3)$$

where:

i = ship;

t = time (operating hour, h);
$LF_{i,t}$ = main engine load factor for ship i at time t;
SOG_t = vessel speed over ground at time t;
$SAF_{i,t}$ = speed adjustment factor for ship i at time t;
V_{max} = maximum ship speed;
HFF_i = hull fouling factor for ship i;
W_t = weather factor at time t;
DAF_i = draught adjustment factor for ship i.

There are some instances where the ship's speed over ground is greater than its maximum design speed. In these instances, SOG is replaced with the ship's average SOG for that phase and the load factor is recalculated. In the case of an invalid average SOG phase value of a ship, the average SOG for similar ship type, capacity bin, and phase is used. The load factor is then recalculated with the replaced SOG. If, after applying the ratios' speed adjustment factors (SAFs), the LF exceeds 1 and the LF is assumed to be 0.98 because ships do not typically operate above 98% of the maximum continuous rating (MCR).

(ii) Estimating emissions of black carbon (BC)

BC emissions are estimated as a function of the main engine type, main fuel type, and main engine load according to Equation (4):

$$BC_i = \sum_{t=0}^{t=n} \left(\left(\alpha FC_{i,t,ME} \times EF_{ME_{k,m,n}} + \beta D_{AE_{p,i,t}} \times EF_{AE_{k,m}} + \gamma D_{BO_{p,i,t}} \times EF_{BO_m} \right) \times 1\text{ h} \right) \quad (4)$$

where:

i = ship;
t = time (operating hour, h);
k = engine type;
m = fuel type;
n = main engine load factor;
p = phase (cruise, maneuvering, anchor, berth);
BC_i = black carbon emissions (g) for ship i;
$FC_{i,t,ME}$ = main engine fuel consumption (kg) for ship i at time t, equivalent to the quotient of the main engine's CO_2 emissions and the CO_2 intensity for the ship's main fuel type m;
$EF_{ME_{k,m,n}}$ = main engine black carbon emission factor (g/kg fuel), which is a function of engine type k, fuel type m, and main engine load factor n;
$D_{AE_{p,i,t}}$ = auxiliary engine power demand (kW) in phase p for ship i at time t;
$EF_{AE_{k,m}}$ = auxiliary engine black carbon emission factor (g/kWh) for engine type k and main fuel type m;
$D_{Bo_{p,i,t}}$ = boiler power demand (kW) in phase p for ship i at time t;
EF_{BO_m} = boiler emission factor (g/kWh) for pollutant j and fuel type m;
α, β, and γ are the dimensionless coefficients.

Emissions of all pollutants were calculated on a ship-by-ship basis and aggregated to the ship class level.

(2) Model 2: Deadweight model

This model involves few parameters and explains the relationship between fuel consumption, deadweight, and CO_2 emissions from ships in the Yangtze River. The model is derived from the regression analysis of the transportation distance and energy consumption of shipping ships in the Yangtze River. It can be found that the fuel consumption and the cargo ship capacity are linearly related w_0, the maximum cargo ship capacity is Q, the load capacity is q, and the fuel consumption per unit voyage is described in Equation (5):

$$\rho(q) = a(w_0 + q) + b \quad (5)$$

Due to the fuel consumption at the no-load case, $\rho_0 = aw_0 + b$, when the ship is fully loaded it is $\rho_f = a(w_0 + Q) + b$, so one can obtain Equation (6):

$$a = \frac{\rho_f - \rho_0}{Q} \tag{6}$$

Therefore, the fuel consumption per unit distance $\rho(q)$ can be calculated according to Equation (7):

$$\rho(q) = \rho_0 + \frac{(\rho_f - \rho_0)}{Q} q \tag{7}$$

Then, the carbon dioxide emissions of ships in the Yangtze River shipping process are described in Equation (8):

$$E_c = e_0 d \left[\rho_0 + \frac{(\rho_f - \rho_0)}{Q} q \right] \tag{8}$$

where e_0 is the factor for converting a unit of fuel to carbon dioxide and d is the total distance traveled by the Yangtze River shipping vessels.

(3) Model 3: Immediate emission fuel consumption model

The immediate emission model was first proposed by Bowyer [32]. This model assumes that the acceleration and deceleration process of ships in the Yangtze River are completed within a unit of time, and the piecewise function can be used to calculate the energy consumption per unit time, as shown in Equation (9):

$$f_t = \begin{cases} \alpha, R_t \leq 0 \\ \alpha + \beta_1 R_t v + (\frac{\beta_2 M a^2 v}{1000}), R_t > 0 \end{cases} \tag{9}$$

where f_t is the fuel consumption per unit time; α is the fuel consumption under the no-load condition; R_t is the power of the Yangtze River ships, its value is related to factors such as the inland shipping resistance of shipping vessels in the Yangtze River and the air resistance of inland shipping. β_1 is the amount of fuel used per unit of energy; β_2 is the energy added per unit of energy; v is the sailing speed of the Yangtze River shipping vessels; M is the self-weight of the Yangtze River shipping vessels; a is the instantaneous acceleration of ships in Yangtze River shipping.

For Yangtze River shipping vessels over a period of time t_0, the total amount of carbon emissions over time is described in Equation (10):

$$F_t = \int_0^{t0} f_t dt \tag{10}$$

The real-time emission model includes the consideration of the deadweight, load capacity, and partial resistance of ships in the Yangtze River shipping, but due to its lack of consideration of the macro data, it is more suitable for the energy consumption of short-distance and small ships, and the impact on carbon emissions. The calculation is converted according to the carbon emission factor.

(4) Model 4: Comprehensive Model Carbon Emission Model (CMEM)

CMEM is a comprehensive model based on physical and chemical principles, which was proposed by Barth et al., It mainly considers the propeller engine load and pollutant emissions from a microscopic perspective. CMEM can be used for the measurement of carbon emissions from ships of various types and parameters in the Yangtze River, and can be efficiently combined with traffic models to provide more accurate carbon emission factor calculations.

The CMEM model is related to 47 parameters, generally covering two parameter blocks, and its calculation includes three calculation modules of the propeller engine power, rotational speed, and fuel consumption rate.

The power of the ships in the river shipping can be calculated by Equation (11):

$$p_{tract} = \frac{(Ma + Mg\sin\theta + 0.5C_d\rho Av^2 + MgC_r\cos\theta)v}{1000} \tag{11}$$

where M is the quality of shipping vessels in the Yangtze River; a is the acceleration; g is the gravitational acceleration; C_d is the air resistance coefficient; C_r is the resistance to inland shipping. The relationship between the power and propeller engine power is shown in Equation (12):

$$p = \frac{p_{tract}}{\eta_{tf}} + p_{acc} \tag{12}$$

In Equation (12), p is the output power of the propeller engine; η_{tf} is the efficiency of the propeller drive shafting of the Yangtze River shipping ship; p_{cc} indicates the additional power of the propeller engine.

The relationship between the speed of the propeller engine and the average speed of ships in the river is approximately Equation (13):

$$N = Sv\left[\frac{R(L)}{R(L_g)}\right] \tag{13}$$

where N is the propeller engine speed; S is the ratio of the speed of the Yangtze River shipping vessels and the speed of the propeller engine at high speed; *R(L)* is the propeller engine gear ratio; v is the sailing speed of the Yangtze River shipping vessels.

The fuel consumption efficiency is described in Equation (14):

$$FR = \frac{\phi}{44}(KNV + \frac{P}{\eta}) \tag{14}$$

In Equation (14), φ is the fuel air mass ratio; K is the propeller engine friction coefficient; V is the displacement of the propeller engine.

(5) Model 5: Four-stage fuel consumption model in motion state

This model is an extension of the real-time emission model by Bowyer et al., which includes four processes of propeller engine idling, constant speed, acceleration, and the deceleration of ships in Yangtze River shipping. At the same time, the initial speed, final speed, and the fuel-related parameters were considered, which greatly improved the accuracy of the calculation.

The total fuel consumption of propeller engine idling, constant speed, acceleration, and the deceleration of the Yangtze River shipping vessels as calculated as per Equation (15):

$$F_t = \int_0^{t1} F_a dt + \int_0^{t2} F_d dt + \int_0^{t3} F_c dt + \int_0^{t4} F_i dt \tag{15}$$

where F_a, F_d, F_c, F_t are the fuel consumption corresponding to the acceleration, deceleration, constant speed, and idling state, respectively. t_i*(I = 1, 2, 3, 4)* for the duration of each state. Considering that the calculation of the fuel consumption F in each state is relatively complicated and has little relevance to this study, no specific calculation was made in this study.

(6) Fuel model based on sailing speed

This model is an extended form of the immediate emission model and the four-stage model. The acceleration, deceleration, and the constant speed sailing of shipping vessels in the Yangtze River were comprehensively considered in the model, but the idling of the propeller engine was not considered, and the fuel consumption of different shipping conditions could be calculated. However, its calculation effect is more suitable for long-distance transportation and shorter-distance transportation, which is shown in Equation (16):

$$F_s = \max\left\{\alpha t_i + x_s\left(\frac{f_i}{v_r} + \gamma + Bv_r^2 + 0.0981 k_G \beta_1 M E_{k+} + 0.0981 k_G \beta_1 M \omega\right), \alpha t_s\right\} \quad (16)$$

In Equation (16), F_s is the fuel consumption; α is the fuel consumption per second; x_s is the total voyage of the voyage; f_i is the fuel consumption of the propeller engine under idling; v_r is the average speed; γ, B, and k_G are the functional parameters related to fuel; β_1 is the efficiency parameter related to the propeller engine; M is the empty weight; ω is the angular velocity when the propeller engine is operating; t_i and t_s are the time corresponding to the idling of the propeller engine and the total sailing time, respectively.

In addition to the above six calculation methods, other models include MOBILE, EMFAC, IVE, COPERT, and other relatively mature measurement models. These models are developed according to specific needs, and their application scope is mostly macro or meso. Due to differences in factors such as the conditions of the Yangtze River waterway, the use of these mature models in China is still limited. At present, Chinese scholars mainly use the mature models provided by developed countries as references, and actively localize some of these models based on the measured data and practical experience in China to provide a scientific basis for the calculation of pollutant emissions from ships in the Yangtze River [33].

The six currently used micro-observation calculation models were compared, as shown in Table 6.

Table 6. A comparison of the fuel and carbon emission calculation models for shipping vessels in the Yangtze River.

Model Category	Considerations	Features	limitation
Model 1	Ship gross weight, fuel type, speed, propeller engine temperature, fuel carbon emission factor	Average speed as variable based on actual data and experience	The parameters of the Yangtze River shipping vessels in the same weight range were selected as the same, which is quite different from the actual domestic situation
Model 2	Deadweight, average speed, self-weight of ships in the Yangtze River, shipping distance	Considering the effect of load capacity, there is less demand data	The idealization was obvious, the error was relatively large, and the influence of speed changes was not considered
Model 3	Ship weight, load capacity, propeller thrust, efficiency, partial resistance of Yangtze River Shipping	Ignoring the time of acceleration and deceleration, focusing on the micro angle, the calculation is more complicated	Did not use macro data, suitable for micro-scale and short-distance measurement
Model 4	Propeller engine parameters, average speed, acceleration, slope of the Yangtze River Channel, etc.	Working condition type, with many model parameters, strong openness and high simulation accuracy	High data requirements
Model 5	Gross weight, load capacity, speed, efficiency, partial resistance, shipping distance, idling time, grade of the Yangtze River waterway, etc.	Considering the state comprehensively, the prediction accuracy is high	Applicable to measurement in short-distance transportation
Model 6	The ship's own weight, load capacity, propeller thrust, efficiency, resistance, speed, efficiency, shipping distance, Yangtze River channel grade, etc.	Aggregate model, the prediction is relatively accurate, suitable for different traffic conditions	Model is complex, suitable for measurement in long-distance transportation

Studying the relationship between shipping logistics and inland river economy is particularly necessary for the development of Yangtze River shipping and the social and economic development of the inland. By understanding the status quo of the development of Yangtze River shipping and studying the impact of Yangtze River shipping on the economic development, we can clarify the status and role of Yangtze River shipping in the economic development of the inland, with the hope to better guide the practice, provide theoretical support, and promote the construction of China's inland shipping economic development.

5. Research on Yangtze River Shipping and Development Implementation Plan

A certain geographic space is a region that includes political regions, natural regions, and economic regions. This division is obviously political, natural, and economic. The 'region' in regional logistics is an economic region, but the current division of the regional economy is still based on traditional administrative divisions, which are generally based on administrative regions. Academic circles have not yet unified the definition of regional logistics. Early scholars defined regional logistics as follows: regional logistics is in a certain regional geographical environment, centered on large- and medium-sized cities, and goods inside and outside the region are received from the supply place by integrated multiple transportation methods and logistics nodes such as roads, railways, aviation, water transportation, and pipeline transportation, and carries out basic logistics activities such as transportation, storage, loading and handling, packaging, circulation processing, distribution, and information processing. This concept incorporates the basic concepts of logistics into regionality. The regional economy is an economic union formed according to the needs of the natural region, economic connection, and social development, and it is a spatial reflection of the specialized division of labor and the collaboration of social economic activities. With the rapid development of globalization and regional economic integration, economic alliances can and have formed between transnational countries and regions, and they all belong to the category of the regional economy [34].

There is a close relationship between regional logistics and regional economy. Regional logistics contributes to the flow of production factors in the region, adjusts the industrial structure in the region, and promotes the development of regional economy. The development of a regional economy will have higher requirements for regional logistics, which will drive the development of regional logistics. Here, we introduce the role of regional logistics on the regional economy and the role of a regional economy on regional logistics in two subsections:

(1) The role of regional logistics in promoting a regional economy

From the above regional economic theories, we can see that the realization of regional economic growth must be based on material and information exchanges within and between regions. The polarization effect, diffusion effect, and correlation effect in regional economic theory all need to be based on the flow of factors. The flow of elements requires a complete regional logistics as a support, so the development of regional logistics is the fundamental condition for realizing regional economic growth. Fundamentally speaking, regional logistics is the result of unbalanced development within and between regions. We will introduce the impact of regional logistics on the regional economy from three aspects: point, line, and surface: for one of the industries, its development will create direct economic income for the region itself. However, the indirect income brought about by regional logistics to the region is much higher than the direct income. The development of an industry will inevitably require the input of certain production factors. The most basic production factor, the development of regional logistics, will increase the regional employment opportunities. At the same time, logistics is a comprehensive industry. It will promote the development of related industries such as transportation and machinery manufacturing, and create economic income for the region. From an online perspective, regional logistics has played a very good role in connecting between regions and between regions within regions, promoting cooperation and exchange between regions and regions within regions, accelerating the flow of production factors, and improving the flow of production factors. Resource allocation efficiency and inter-regional cooperation can realize the sharing of resources and information, and large-scale and standardized logistics can also reduce the transaction costs between transaction entities. These greatly reduce the transaction costs; according to equilibrium theory, the gradient transition theory, and the growth pole theory, regional logistics is a necessary condition for realizing the diffusion effect, radiation effect, and polarization effect. Generally speaking, the development of regional logistics will eventually become networked and nationalized. The development of the IoT and the support of logistics-related technologies will inevitably promote the large-scale development of regional logistics. The realization of regional logistics is no longer a single online development; it can take a certain center on the line as the growth pole, exert diffusion and radiation effects, and finally realize the economic development of the whole region [35,36].

(2) The pulling effect of regional economy on regional logistics

The development of any industry requires a certain economic foundation. The development of regional logistics must rely on a certain amount of funds, technology, talent, etc. to be able to develop, and the acquisition of these elements requires the support of the development of the regional economy. Therefore, the development of the regional economy is based on regional logistics to provide a material basis and create a good development space and platform. Through the study of regional economics and industrial economics and applying them to logistics, the influence of regional economy on regional logistics is mainly manifested as follows. First, the regional logistics industry, as a late-comer industry, is a product of regional economic development. The development of the regional economy requires the support of certain industries. Today, China's industrial structure is still that the primary and secondary industries are ahead of the tertiary industry. The development of the primary and secondary industries will create new and more efficient logistics demands. Generally speaking, for a port city, the regional economic center must be the regional commodity processing and trade center. The development of the primary and secondary industries has obvious advantages.

Regional logistics facilities are complete, human resources are abundant, and there is a large demand for centralized consumption, but there may be asymmetry with the surrounding areas. The development of surrounding areas lags behind. It is this asymmetric development that produces regional logistics. Regional logistics is realizing the balanced development of a regional economy through the polarization effect. Second, the continuous improvement in the level of regional economic development has brought forward the development of the animal flow. The more developed the regional economy, the more it can provide an excellent economic foundation and material and technical conditions for the development of regional logistics. The development level of the regional economy determines the development level of regional logistics. If the regional economy is underdeveloped because of the lack of the necessary economic foundation and material and technical conditions, the development of regional logistics will not have enough development motivation, and it will not be able to move to a higher level of development.

Among the five transportation modes of road, railway, aviation, waterways, and pipelines, water transportation occupies a certain advantage due to its low cost and large volume. It occupies an important position in the transportation system. Throughout international and domestic trade, water transportation is the first choice for bulk cargo transportation. Shipping is a form of water transportation, of course, it also has the advantages of low cost and a large volume of water transportation. At the same time, shipping is also one of the most energy-saving and relatively low-polluting modes of transportation. Today, in the construction of a 'resource-saving' and 'environmentally friendly' society, it will inevitably be favored by China. Shipping construction is the focus of national and regional construction. China has invested heavily in the construction of the Three Gorges Reservoir and has promoted the 'Yangtze River Golden Waterway

Construction' to a strategic position. It has also actively provided various support and formulated preferential policies for the development of shipping logistics.

(3) Advantages of shipping logistics

Shipping logistics is a mode of transportation, and this mode of transportation is cheap, will reduce the cost of transportation in the inland, promote trade between and within regions, and accelerate the flow of factors within the region. Here, we can obtain a large number of coastal cities, where it can be seen from the cities along the river that their economic exchanges and international trade are more frequent than that inland, and the economic development level of these cities is generally higher.

(4) Shipping logistics and trade

As above-mentioned, the development of the inland river economy mainly relies on international trade to create an international exchange income. Of course, shipping logistics has become the first choice for international trade, especially for the advancement of economic globalization and regional integration. The development of regional economy has an impact on shipping logistics. According to the statistics, world trade is completed by sea transportation, and China's inland waterway occupies a relatively high proportion of the entire transportation system. Through trade, the opening degree of cities in the inland can be increased. Shipping logistics and international trade complement each other. The growth of trade drives the prosperity of shipping logistics, and the development of shipping logistics in turn promotes the growth of trade.

(5) The port effect of shipping logistics

The port is the basic element of shipping logistics. The functions and advantages of shipping logistics are largely realized by ports. The port effect is not only the increase in the income of a single port brought by shipping logistics, but the multiplying 'numerical effect' also includes the promotion of economic development and urbanization in coastal areas along the Yangtze River. In addition, ports use spatial diffusion effects to produce economic radiation and industrial gradient transfer in the surrounding areas, and ultimately drive the economic development of the entire inland river. Economically developed countries are generally supported by well-known international trading ports and cities. The development of ports is advanced, and the level of economic development in the cities where they are located is very high. The economic development of the three major coastal economic zones in China: the Yangtze River Delta Economic Zone, the Pearl River Delta Economic Zone, and the Huanquan Sea Economic Zone rely to a large extent on the development of port cities. The economic development level of the cities where each port is located is in a leading position in China. For example, Shanghai Port in the Yangtze River Delta, Guangzhou Port in the Pearl River Delta, and Tianjin Port in the Chaohai Economic Zone, rely on port cities to take the lead in their development.

(6) Distribution and structure of shipping logistics and inland river industry

Shipping logistics promotes the rapid circulation of production factors between and within inland rivers, realizes the optimal allocation of resources, is prone to produce industrial cluster effects, and promotes industrial upgrading through the correlation effects. The best goal of industrial upgrading is that the tertiary industry accounts for a higher proportion. The secondary industry is higher than the primary industry. Shipping logistics provides important support for the development of the primary and secondary industries in the inland. The primary and secondary industries have developed well, and the industry linkage effects should be used to promote the development of the tertiary industry. According to the theory of gradient transition, the downstream area first realizes industrial upgrading, gradually moves upstream, and finally realizes the industrial upgrading of the entire inland river. In addition, the development of shipping logistics will promote the development of shipbuilding, port services and other related industries, increase the employment opportunities, and have a positive effect on population migration.

6. Qualitative Analysis of Yangtze River Shipping and Inland River Economy

The influence of Yangtze River shipping on the distribution of productivity in the inland is as follows:

(1) Impact on industrial layout

According to regional economic theory and the relationship between regional logistics and the regional economy, regional logistics has an important impact on the allocation of regional resources and the flow of factors, which will inevitably affect the distribution of the industrial layout. An important task of rationally arranging productivity is to choose a location with convenient transportation based on the natural and economic conditions of oneself, giving play to comparative advantages, develop one's own superior industries, and finally form an industrial cluster effect. The improvement in traffic conditions has strengthened the interrelationship between the regions and better exerted the effect of industrial relevance. The distribution of industries is less and less restricted by geographical location. With certain transportation conditions, various industries will be distributed in a reasonable area. The Yangtze River Economic Belt has become one of China's industrial intensive belts. According to the natural geographical conditions and resources in the region, three economic circles have been formed—the Yangtze River Delta economic circle, Wuhan City Circle, and Chengdu–Chongqing economic circle—which are distributed in the lower, middle, and upper reaches of the Yangtze River, respectively. There are significant differences in the industrial composition of the three economic circles, namely, the level of economic development, which are shown in Table 7.

Table 7. The distribution of indicators in the upper, middle, and lower reaches of the Yangtze River.

	Major Provinces	Population, Land, GDP	Pillar Industry
Upstream	Chongqing, Sichuan, Yunnan	25%, 38%, 15%	Metallurgy, petrochemical, tourism
Midstream	Hubei, Hunan, Jiangxi	47%, 47%, 33%	Agriculture, steel, electricity, automobiles
Downstream	Shanghai, Jiangsu, Anhui	28%, 15%, 50%	Electronics, clothing, products

The natural resource environment and social environment of these three regions are different, so they form three industrial clusters with their own characteristics. First of all, the downstream Yangtze River Delta Economic Circle, in terms of GDP, accounts for the highest proportion in China. The industrial development characteristics of this area are as follows:

(i) Traditional light and heavy industries such as chemical fiber, textile, steel, and other industries are gradually retreating in the core area of the 'Yangtze River Delta', taking a secondary position and beginning to spread to surrounding areas;
(ii) The core city (Shanghai) vigorously promotes high-tech industries, and industries such as electronic communications, biomedicine, and new materials will become important domestic bases and leap to the leading position in China;
(iii) Further development in international trade is booming, and the export-oriented economy is developing rapidly.

Secondly, the Wuhan urban economic circle in the central development region is a strategic study that has been included by the state in recent years following the implementation of the central rise strategy. Wuhan occupies a leading position in the central region and plays a central role in the construction of the Wuhan economic circle. Manufacturing advantages have made 'Made in Wuhan' famous throughout China. In recent years, modern manufacturing has begun to shift from the world to China. Wuhan is striving to build five major industrial bases: an optoelectronic information industry base, a modern manufacturing base focusing on ship manufacturing, steel manufacturing, and new material industry bases, and bioengineering, and it is believed that Wuhan will become a national modern manufacturing base with its own characteristics such as a new pharmaceutical industry base and an environmental protection industry base, and Wuhan's industrial development level as a whole has entered the ranks of advanced cities in China.

Finally, the upstream economic circle, the implementation of the western development strategy and the smooth completion of the Three Gorges Project have all provided new opportunities for the economic development of the region. The strategic positioning of the Chengdu–Chongqing Economic Zone is the growth pole or economic highland of the western development and includes the equipment manufacturing industry, automobile and motorcycle vehicle and parts production research and development, aerospace research and development and manufacturing, the biopharmaceutical industry, national civil aviation industry, etc. The eight pillar industries are actively supported and developed by the state.

These three economic circles influence each other and develop together. In order to realize the economic development of the entire inland river, Yangtze River shipping will surely play the role of economic link, leading the development of the eastern region first, and then driving the development of the western region, from east to west, so the economic radiation effect of the inland Yangtze River drives the development of the national economy.

With the advancement in economic globalization, economic cooperation and cargo shipping between regions have become more frequent, and trade has played an increasingly important role in regional economic development. Trade includes two aspects of domestic and international trade. Compared to domestic trade, the development of international trade can better represent the degree of openness of a city and the direction of economic development, and it has a deeper significance for the driving effect of the economy. Yangtze River shipping provides convenient conditions for domestic and international trade within the inland. In particular, the Yangtze River Delta region, Shanghai, and Jiangsu Province rely on ports to actively develop export trade and rapid economic development. Both Chongqing Port and Shanghai Port are large ports in the inland Yangtze River, which have played an important role in driving the local economy.

Yangtze River shipping has also had an important impact on the urbanization of the inland. The improvement in traffic conditions will inevitably speed up the process of urbanization, and China has relied on river transportation to develop cities since ancient times. The Yellow River in the north and the Yangtze River in the south have two major water systems that have made important contributions to the transportation industry, population flow, and urban agglomeration throughout China. It seems an inevitable choice to build cities along the river and develop along the river. Throughout China, many large- and medium-sized cities have developed by relying on local convenient transportation conditions, so they are called 'Cities Drawn by Ships' and 'Water Capitals'. The development of shipping on the Yangtze River is of great significance to the improvement in inland river traffic. The low cost of shipping has promoted the circulation of essential factors between cities in the inland river and produced a strong cluster effect. The cooperation between cities can help big cities stand out; under the leading role of big cities, at the same time, the complementary cooperation of small cities or towns will inevitably increase the level of urbanization. According to the statistics, more than 60% of large and medium cities in China are concentrated in the inland Yangtze River.

The IoT is the Internet-like connection between objects. The IoT is mainly based on Internet technology, and the foundation of the progress of the IoT is the development of the Internet. On the basis of the continuous development of the Internet, advanced science and technology such as artificial intelligence are combined with the Internet to strengthen and refine the functions of the Internet, and then combine the needs of the users to produce the IoT. The IoT mainly refers to the connection between objects. Generally, global positioning systems and sensing devices are used to enable information interaction between objects and objects to ensure that these objects can be perceived in specific locations, and then the Internet will bring these objects into the category of one's own contact, and then realize the purpose of object monitoring through the corresponding positioning function.

Shipping logistics containers are an important method for economic and trade exchanges. In order to ensure the safety and smooth running of shipping logistics, relevant departments and enterprises are constantly developing and improving the status of shipping logistics containers, but there are still some in actual work. Therefore, it is necessary to further adopt corresponding countermeasures, do a good job, and improve the monitoring of containers and internal cargo to eliminate some hidden safety hazards in shipping logistics. The current development of the IoT has reached a certain stage, and the application of the IoT in the monitoring of containers and cargo has a certain feasibility. At present, relevant IoT service platforms have emerged and gradually improved. Shipping companies have also developed and applied corresponding service platforms according to the user needs and their own business characteristics. The data of the entire process of container logistics can be entered into the service platform, and the corresponding sensing equipment can be equipped to realize the real-time transmission and sharing of container logistics data. Shipping companies, ports, agents, and cargo owners can use the IoT service platform to pay attention to the status of the cargo and the specific location at any time, which not only improves the transparency and safety of container logistics, but also increases mutual trust. Through interconnection, the IoT, and sharing, the development of container shipping logistics will be further promoted. At present, the construction of container terminals is constantly developing, and fully automated container terminals have also begun to operate. The application of IoT technology and its combination with other advanced technologies can effectively promote the improvement in the quality of container terminals. With the continuous development of communication networks, the IoT is applied to port logistics, and the sharing of port data and information is realized with the help of the IoT. Through the positioning technology and identification technology in the IoT technology to build a logistics monitoring system that meets the specific development status of the port and the needs of other related parties, real-time monitoring and data collection of the port will effectively improve the safety of port logistics and the effect of data sharing. Therefore, relevant personnel should continuously optimize information technology, improve the efficiency of logistics, and promote the development of port logistics, so that the entire logistics industry can be safer, and the logistics management system will be more detailed. With the attention of China and the efforts of a large number of scientific research personnel and logistics staff, China has made certain breakthroughs in container monitoring Radio frequency identification (RFID) technology, and this technology has been at the forefront of China's shipping and ports. The further development of logistics will have a significant impact. Therefore, in the current port construction and transformation process, advanced RFID technology and other information technologies can be fully applied to improve the efficiency of various port tasks and create good conditions and foundations for the comprehensive application and development of the IoT. The application of the IoT can establish a connection between things and enable staff to use the IoT to monitor objects. At present, China's international trade industry continues to develop. Shipping logistics and ports occupy an important position in the international trade industry. The application of the IoT to shipping logistics and ports can effectively promote the improvement in related work efficiency. Corresponding cargo shipping owners can use the IoT to monitor their goods in real-time, thereby increasing the acceptance of cargo owners. The application of the IoT is also helpful for the collection and processing of the various data and information of shipping logistics and ports, and promotes the level of information processing in the shipping logistics and port industry, so that the corresponding staff can understand the shipping information in a more timely and comprehensive manner. At present, China's container monitoring technology has developed to a certain extent, which is helpful in the monitoring of containers and cargo shipping in China's ports. At the same time, it can also reduce the occurrence of various problems and better guarantee the safety of China's port transportation as well as promote the high-quality development of the IoT economy in the hinterland regions [25,26,37].

7. Qualitative Analysis Theory of Correlation

7.1. Explanation of Correlation Theory

Shipping is one of the main transportation modes and occupies an important position in the transportation system. At present, there are few and immature theories on the relationship between shipping logistics and the inland river economy, but the studies on the relationship between transportation and the economy are relatively mature, which can be used as the qualitative analysis theory of shipping and the inland river economy. Regarding the research on the relationship between transportation and the national economy, China's representative views include: 'alternative push–pull relationship theory'. This view holds that the relationship between transportation and social economy is a push–pull relationship. Transportation follows the development of social economy whereas development constantly puts forward new requirements for transportation, in the initial stage, these requirements can be met by the transformation of the original transportation system. At this time, the role of the transportation industry in economic development is often relatively hidden, passively supporting economic growth; if the development of the transportation industry keeps up with the pace of economic development, it is difficult for us to find the role of the transportation industry, and it is often overlooked; if the development of the transportation industry lags behind the pace of economic development, it will play its role in a negative way to hinder economic development. At this stage, economic development has to drive the transportation industry to adopt the 'interaction theory'. Economic development is inextricably linked. On one hand, various economic regions are linked together through transportation, which is the link to realizing economic cooperation among various regions. It determines the number, speed, and flow of the transportation links between economic regions, promotes the rational allocation of resources, and has a positive impact on the economic development, social prosperity, and progress of various economic regions. On the other hand, different economic development levels require different economic structures to adapt to them to ensure smooth economic development. Changes in the economic structure require the reconfiguration of production factors, leading to the flow of production factors within a certain space. The flow of production factors causes changes in the transportation demand and promotes the development of transportation [27,28].

Nonlinear relationships between two variables can be expressed by the correlation coefficient in Equation (17):

$$\rho_{xy} = \frac{Cov(r_x\ , r_y)}{\sigma_x \sigma_y} \tag{17}$$

In the 'External effect theory', the external effect refers to some economic activities having a certain impact on others, but they do not pay any costs or receive any rewards. External effects are divided into positive effects and negative effects.

The beneficiary does not have to pay any costs, and the negative effect means that the victim does not receive any compensation. There may be such externalities between transportation and social economy.

7.2. Explanation of Transportation Theory

The theory believes that transportation and industrialization are interdependent. Industrialization cannot be separated from transportation, and transportation is produced and developed along with industrialization. Transportation is the most important basic industry and basic condition on which economic development depends. Specifically, transportation is manifested in the following aspects: early means of transportation are replaced by mechanically powered means of transportation, humans gradually overcome the limitations of the natural geographical environment on the spatial displacement of people and goods, and the transportation capacity expands rapidly; transportation objects change from the original agricultural products and handicraft products into mineral energy, raw materials, and the finished products and semi-finished products required by large-scale industries. Production factors begin to gather in specific areas, production areas and sales areas are separated, and the economic relationship between goods begins to emerge; thus the relationship between people and goods are part of economic life. The total amount of spatial displacement has increased, the mobility of resources has been strengthened, and the scale of displacement has become larger and larger, resulting in a higher transportation demand. The number and scale of China's investment in the transportation industry are increasing day by day, and the transportation industry has gradually taken a place in the national economy. The transportation industry is the basic condition for economic development. It is not difficult to find that the economic development level of regions with a developed transportation industry or convenient transportation is generally very high. This difference will lead to greater and more investment in the transportation industry by China, thus promoting the development of other industries such as steel and machinery manufacturing. The whole transportation is divided into three stages: pre-transport, transportation and post-transport. The transportation stage includes two stages: preliminary transportation and perfect transportation. Industrialization has gradually developed in the two stages of 'preliminary transportation' and 'perfect transportation'. With the rise in post-industrial economy, informatization has increasingly highlighted its importance and gradually replaced transportation, and the trend of 'post-transportation' has appeared. The picture is a schematic diagram of the transportation stage, which reflects the corresponding relationship between transportation and industrialization. We used the total freight volume to represent the development trend of transportation. The growth rate slowed down during the transportation phase, and slowly declined in the post-transportation phase [30,31].

7.3. Theory of Regression Analysis

Regression analysis is an important statistical inference method. In practical applications, regression analysis is the closest connection between mathematical statistics and real life problems, has the widest application range, and the most effective statistical analysis method. It is a powerful tool for analyzing data and seeking relationships between variables. Regression analysis has been applied to various fields such as biology, medicine, agriculture, forestry, economy, and management. We determined the explanatory variable and the explained variable for things that have a correlation, which is also called the dependent variable and the independent variable, respectively. The regression equation is used to illustrate the relationship between the dependent variable and the independent variable.

(1) The establishment of the model

In real life, it is often difficult to obtain all of the information of each unit of the whole. The data obtained are only a part of the whole, that is, sample data. Only a sample regression model can be established based on the sample data:

$$Y = \hat{\alpha} + \hat{\beta}X + \varepsilon \tag{18}$$

The least squares method can be used to find and establish the sample regression equation.

(2) Model test

(i) Economic test

According to the constant terms and coefficients of the sample regression equation, the economic meaning of the equation can be evaluated, that is, the economic test, to test whether the equation conforms to the economic theory.

(ii) Goodness of fit test

$$r^2 = \frac{ESS}{TSS} = 1 - \frac{RSS}{TSS} \tag{19}$$

where r^2 is called the coefficient of determination, $0 \le r^2 \le 1$, the closer the r^2, the better the linear effect.

(iii) Integrity test of the equation (F-test)

This refers to a statistical test to determine the linear relationship between the explained variable and the explanatory variable in the model, which is significantly established under a certain level of significance.

$$\mathrm{F} = \frac{r^2}{1 - r^2}(n - 2) \tag{20}$$

The larger the value of F, the greater the linear influence of X on Y, and vice versa, the smaller the value of F, the smaller the linear influence of X on Y. This is the linear relationship.

7.4. Grey Correlation Analysis

The gray correlation analysis method is a multi-factor statistical analysis method. This is based on the sample data of each factor and uses the gray correlation degree to describe the strength, size, and order of the relationship between the factors. The sample data reflect the changes of the two factors. The direction, size, and speed of the situation were basically the same. The correlation between them is the linear relationship.

(1) Standardization of indicators

Since the evaluation indicators usually have different dimensions and orders of magnitude, they cannot be directly compared. In order to ensure the reliability of the results, it is necessary to standardize the original indicators. Suppose the change interval of the first index is the minimum value of the Kth index among all of the evaluated objects, and the maximum value of the Kth index is among all the evaluated objects, then the original value becomes a dimensionless value, and the normalized raw data will become data greater than 0 and less than 1.

$$C_k^i = \frac{j_k^i - j_{k1}}{j_{k2} - j_k^i},\ i = 1, 2, \ldots m, k = 1, 2, \ldots n \tag{21}$$

(2) Calculate the correlation coefficient

According to the grey system theory, taking $\{C^*\} = \left[C_1^*, C_2^*, \ldots, C_n^*\right]$ as the reference sequence and $\{C\} = \left[C_1^i, C_2^i, \ldots, C_n^i\right]$ as the comparison sequence, the correlation analysis method was used to obtain the correlation coefficient between the *k*-th index of the *i*-th evaluated object and the *k*-th index optimal index, namely:

$$\varepsilon_i(k) = \frac{\min\limits_i \min\limits_k \left|C_k^* - C_k^i\right| + \rho \max\limits_i \max\limits_k \left|C_k^* - C_k^i\right|}{\left|C_k^* - C_k^i\right| + \rho \max\limits_i \max\limits_k \left|C_k^* - C_k^i\right|} \tag{22}$$

Here, $\rho \in 0, 1,$ when $\rho = 0.5$. The average value of the coefficients was obtained by the above formula, that is, the degree of relevance between the *i*-th index and the *n*-th index. The greater the value, the greater the degree of association we can obtain.

7.5. Multiplier Theory

The multiplier theory is an important theory in Western economics (the macro part). Because of its simplicity and intuitiveness, it is now used in many fields and is the most widely used in national economic research. It is well-known that investment, consumption, and exports are the troika driving the economy. The multiplier theory is often used in the analysis of investment effects, taxation, and the impact of consumption and exports on the national economy, that is, the degree of sensitivity of the economy to these factors, so the multiplier theory is also called the sensitivity analysis method. Its analysis has played an important role in guiding the government's macroeconomic decision-making. Its general interpretation is the percentage change of another variable caused by the percentage change of one variable, expressed by Equation (23):

$$K = \frac{\Delta Y}{\Delta I} \tag{23}$$

Known also as the investment multiplier formula, the increase in total income caused by the increase in investment also includes the indirect consumption increase (ΔC)) caused by this, that ism $\Delta Y = \Delta I + \Delta C$, and the size of the investment multiplier is closely related to the propensity to consume. The relationship between the two is expressed by the mathematical equation as follows:

$$K = \frac{\Delta Y}{\Delta I} = \frac{\Delta Y}{\Delta Y - \Delta C} = \frac{1}{1 - \frac{\Delta C}{\Delta Y}} \tag{24}$$

Among them, $\frac{\Delta C}{\Delta Y}$ is the marginal propensity to consume. It can be seen that the investment multiplier is directly proportional to the marginal propensity to consume.

7.6. Pie Chart of Shipping Vessels in Yangtze River Port

The pie chart mainly introduces the types and proportions of various ships in Shanghai Port, Nanjing Port, Wuhan Port, and Chongqing Port. It analyzed the proportion of ship types that arrive at the port within 30 days.

The pie chart of Shanghai Port is shown in Figure 2: Shanghai Port (Cargo—cargo ship; Tanker—oil tanker; High Speed Craft—high-speed ship; Search and Rescue—search and rescue ship; Pleasure Craft—cruise ship; Other—other ships; Unspecified—non-special boat; Navigation Aid—beacon; Fishing—fishing boat; Passenger—passenger boat; Special Craft—special boat; Tug—tugboat)

As can be seen from Figure 5, the vast majority of ships passing through Shanghai Port are cargo ships, and the others are a minority. It shows that the main business of Shanghai Port is mainly cargo transportation, other businesses are auxiliary businesses, and the transportation is also very developed. It is not difficult to see from the geographical location that Shanghai Port is located in the economic hinterland and that all goods need to pass through it. At the same time, it is also the center of China's international trade.

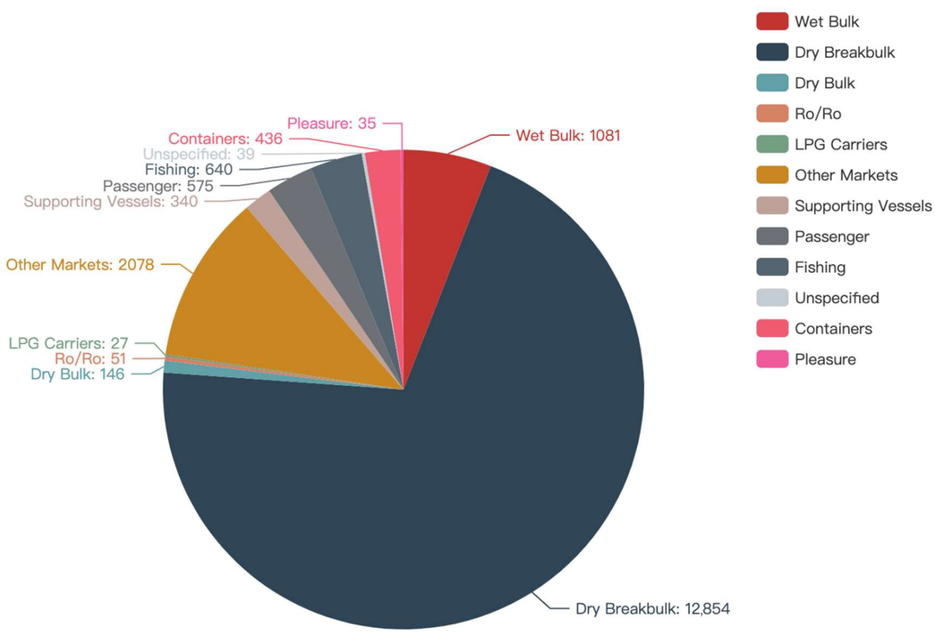

Figure 5. A pie chart of the ship types in Shanghai Port.

The pie chart of Nanjing Port is shown in Figure 6: Nanjing Port (Cargo—cargo ship; Tanker—oil tanker; High Speed Craft—high-speed ship; Search and Rescue—search and rescue ship; Pleasure Craft—cruise ship; Other—other ships; Unspecified—non-special boat; Navigation Aid—beacon; Fishing—fishing boat; Passenger—passenger boat; Special Craft—special boat; Tug: tugboat). From Figure 6, it can be seen that unlike Shanghai Port, most of Nanjing Port is in service to passenger ships. Cargo ships, passenger ships, fishing boats, and special ships all occupy a certain proportion in Nanjing Port, which means that the trade of goods through Nanjing Port is not so frequent. Some of the ships are functional ships, or fishermen who go out to sea to fish, and from the proportion of passenger ships, it can be seen that the tourism industry in Nanjing Port has developed to a certain extent.

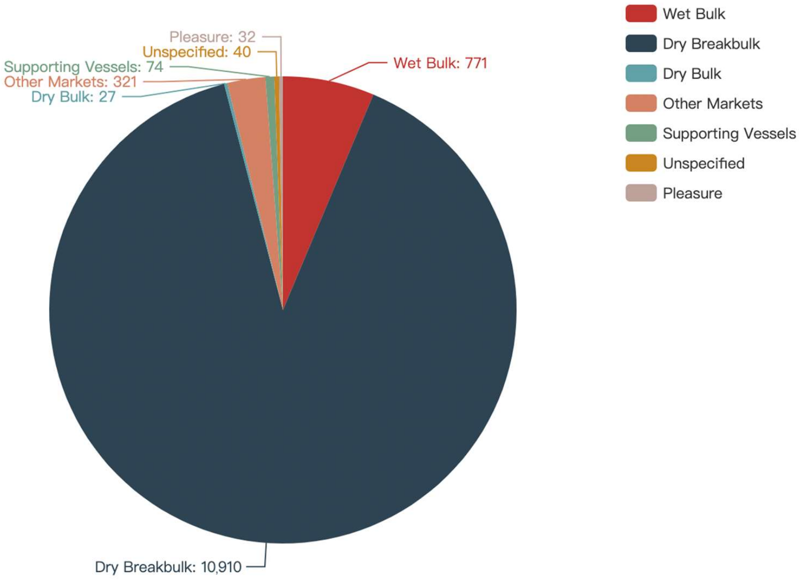

Figure 6. A pie chart of the ship types in Nanjing Port.

The pie chart of Wuhan Port is shown in Figure 7: Wuhan Port (Cargo—cargo ship; Tanker—oil tanker; High Speed Craft—high-speed ship; Search and Rescue—search and rescue ship; Pleasure Craft—cruise ship; Other—other ships; Unspecified—non-special boat; Navigation Aid—beacon; Fishing: fishing boat; Passenger—passenger boat; Special Craft—special boat; Tug: tugboat).

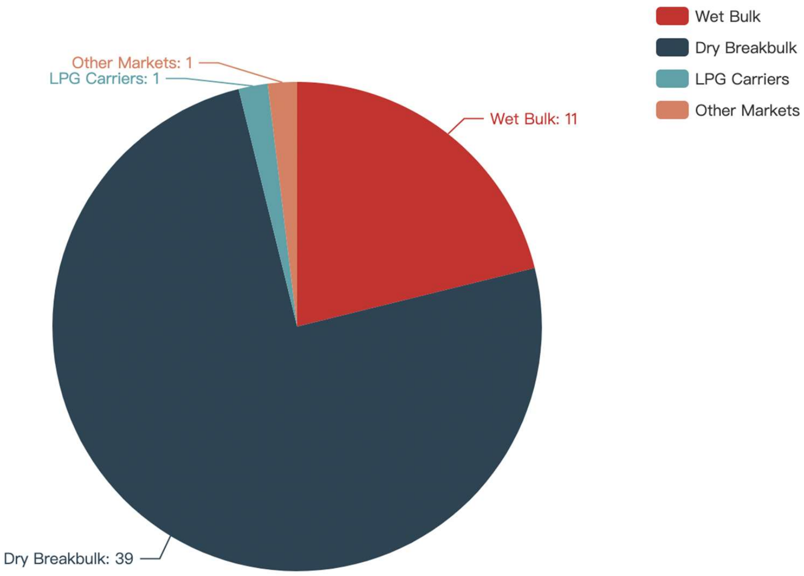

Figure 7. A pie chart of the ship types in Wuhan Port.

From Figure 7, it can be seen that the proportion of passenger ships in Wuhan Port accounted for almost half, which shows that the tourism industry in Wuhan Port is very developed, many ships transport passengers to various small islands to play, and Wuhan's economy is very developed, so there are not many fishing boats and cargo ships, which also accounted for a certain proportion.

The pie chart of Chongqing Port is shown in Figure 6: Chongqing Port (Cargo—cargo ship; Tanker—oil tanker; High Speed Craft—high-speed ship; Search and Rescue—search and rescue ship; Pleasure Craft—cruise ship; Other—other ships; Unspecified—non-special boat; Navigation Aid—beacon; Fishing—fishing boat; Passenger—passenger boat; Special Craft—special boat; Tug—tugboat).

From Figure 8, it can be seen that the proportion of cargo ships in Chongqing Port also accounted for almost 50%. The cargo trade of Chongqing Port is also very frequent. Chongqing Port also has a very good geographical location, and the flow of goods is very convenient. The economic hinterland passes through the port of Chongqing through many goods, providing abundant resources for the Yangtze River Delta.

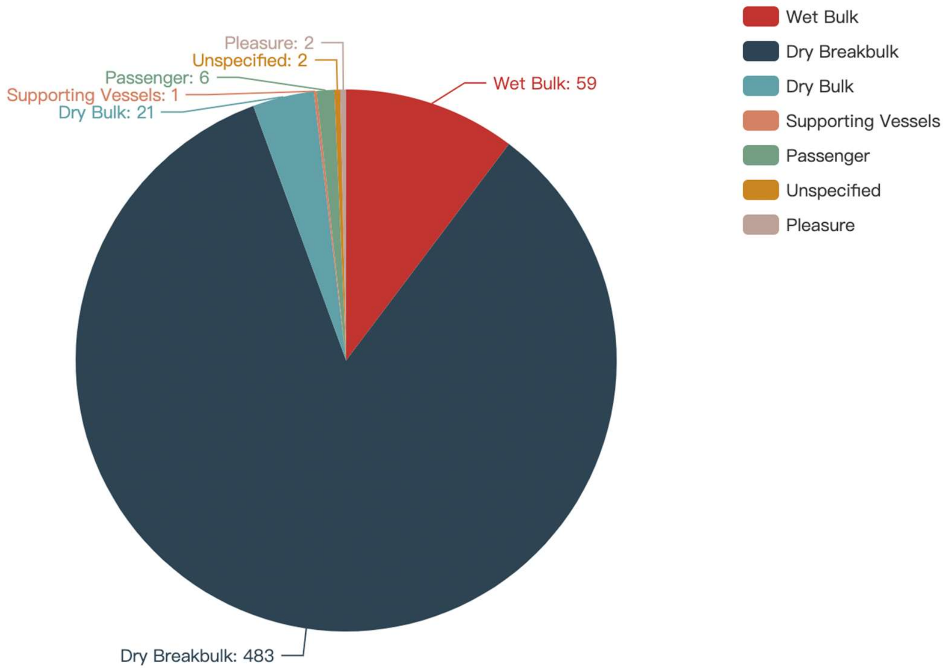

Figure 8. A pie chart of the ship types in Chongqing Port.

Generally speaking, there are many cargo ships and even cold chain container ships in Shanghai Port and Chongqing Port, and their ports are also large in scale. They are located in the economically developed Yangtze River Delta, which transports a large amount of resources to the inland. There are also many berthing points around them, and sea traffic is relatively developed; while Wuhan Port and Nanjing Port have cargo ships, they are more functional ships, and they tend to develop in other directions such as tourism and fishing. This is also related to their geographical location. Imported goods generally need to travel farther, so the cost will also increase.

7.7. Line Chart of Shipping Vessels in Yangtze River Port

The line chart mainly describes the arrival and departure of ships in Shanghai Port, Nanjing Port, Wuhan Port, and Chongqing Port for one day within a week. Figure 9 shows a line chart of the ship arrivals and departures at Shanghai Port for one day.

It can be seen from Figure 9 that the number of ships arriving and departing at each time point was roughly the same. From 2:00 AM to 3:00 AM in the morning, the departures and arrivals almost reached the minimum value, indicating that the port was in the low peak period of work at this time.

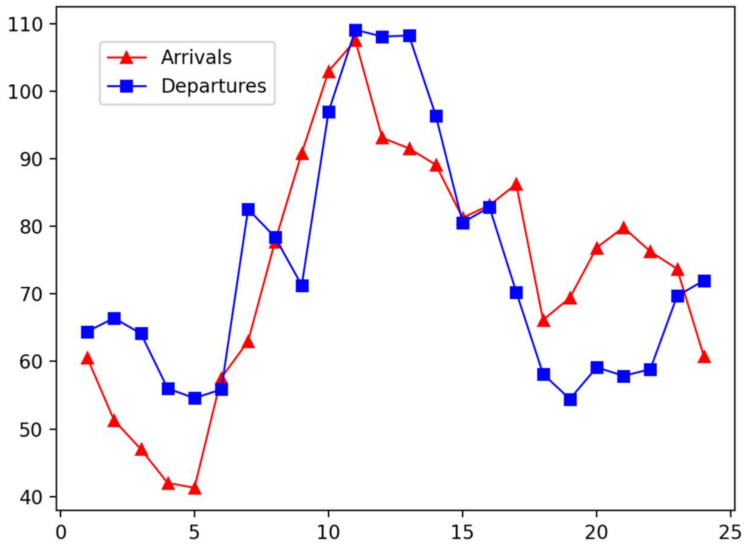

Figure 9. The line chart of the ship arrivals and departures at Shanghai Port for one day.

At 13:00 PM, almost all of them reached their peak, which was the peak working period; at 9:00 PM, the difference between the departures and arrivals reached the maximum. At this time, many ships arrived and berthed, but most ships did not travel at night.

Figure 10 shows the line chart of the arrivals and departures of ships at Nanjing Port for one day. It can be seen from the figure that compared with Shanghai Port, the arrival and departure situation of Nanjing Port is somewhat disorganized. This is because the number of ships arriving and leaving is relatively small, and there is greater randomness, but it can also be seen that the big trend is that more ships arrive and depart during the day, while there were few cases where they departed at night.

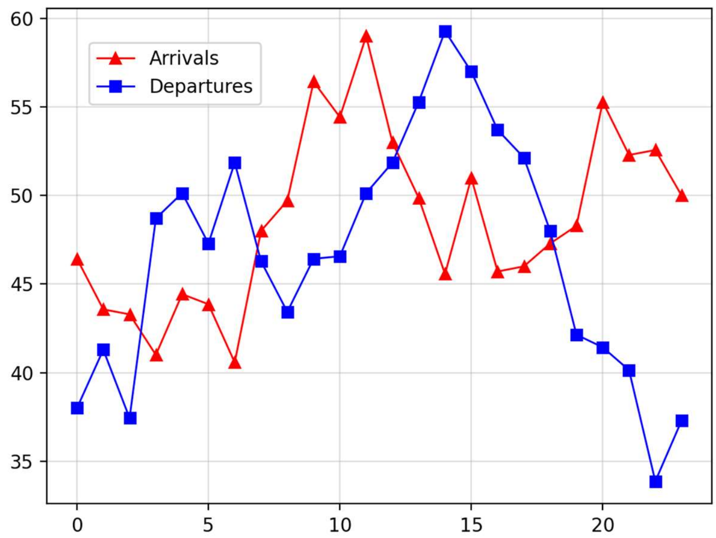

Figure 10. A line chart of the ship arrivals and departures at Nanjing Port for one day.

It can be seen from Figure 11 that the arrival and departure of ships in Wuhan had more obvious changes with time. The number of ships arriving and departing during the day was the largest, and the number was the smallest at night. The peaks were reached at 11:00 AM and 16:00 PM, and the cases were lowest at 4:00 AM.

Figure 12 shows the line chart of the ship arrivals and departures at Chongqing Port for one day. The peak and trough periods of the arrival and departure times at Chongqing Port and Shanghai Port were almost the same. These peaks and troughs appeared more extreme, with more ships arriving and departing during peak periods and fewer troughs.

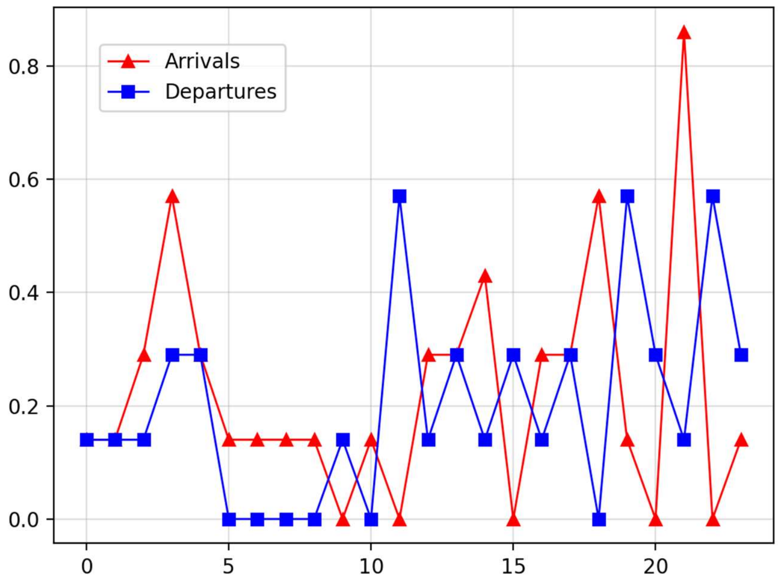

Figure 11. A line chart of the ship arrivals and departures at Wuhan Port for one day.

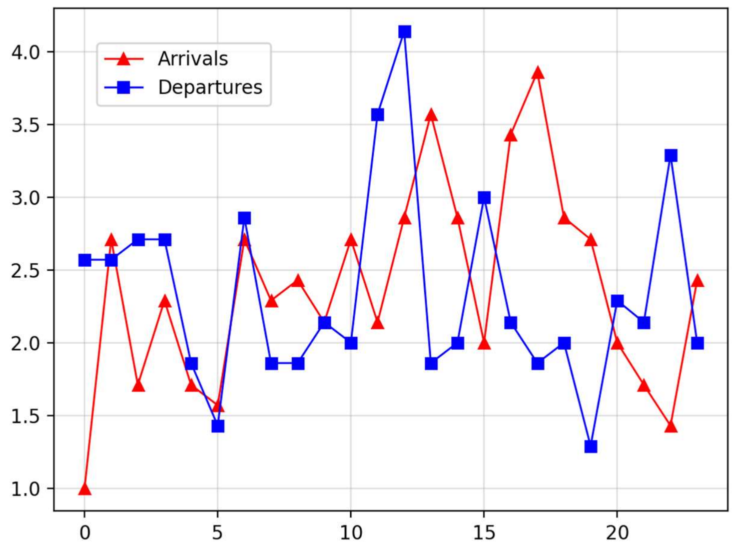

Figure 12. A line chart of the ship arrivals and departures at Chongqing Port for one day.

Generally speaking, the arrival and departure of ships were roughly equal at the same time point; the highest was from 10:00 AM to 16:00 PM, and the lowest was from 2:00 AM to 4:00 AM, which also reflects the peak and trough periods of port operation. It is recommended to avoid ports. During the peak period of work, one can choose a smooth period of work to arrive, so that one can save a lot of time regardless of the loading and unloading.

8. Conclusions

As we know, the contribution of the Yangtze River shipping to the inland economy is very obvious. Because of the differences in the natural geographical environment, social environment, and the contribution of various regions, the upstream regional economy is relatively mountainous and economic development depends on water transportation to a relatively high degree. The degree of dependence on water transport was weakened, but the economic output created by water transport was the highest because it is a link connecting the upstream and downstream. The economic development of downstream areas is relatively active, and there are many factors affecting economic development.

Moreover, the downstream areas are mainly export-oriented economies and are affected by financial changes. Due to the influence of many factors such as trade, shipping, etc., the dependence on inland waterway shipping is relatively low. Including shipping, water transportation in downstream areas should have the highest proportion across the entire transportation system. Based on the status quo of water transport development in the three regions and the status quo of industrial cities, we propose the following suggestions for shipping on the Yangtze River and the economic development of the inland:

(1) The national government continues to unswervingly promote the infrastructure construction of the Yangtze River Golden Waterway, strengthen the construction of the Yangtze River waterway, improve the navigability of the Yangtze River waterway, dredge and clean up the main and tributary streams of the Yangtze River, and integrate the upstream 'Chuanjiang Water Transport' with the downstream, the Han River, Xiang River, Gan River, etc., maximizing the utilization efficiency of the Yangtze River as well as strengthen port construction and enable the port to develop in the direction of mechanization and scale. At the same time, the important ports are managed in a unified manner, and the cooperation and exchanges between them are strengthened. The information and resources are achieved via sharing.

(2) To strengthen the information construction of Yangtze River shipping using technology and positioning systems to realize the Yangtze River shipping network, obtain intelligent, timely updated shipping information, anytime and anywhere to grasp the domestic and international shipping information, only in this way can we gradually drive Yangtze River shipping toward marketization and internationalization. To build a harmonious and safe Yangtze River, we will strengthen the support and guarantee system for shipping along the Yangtze River including modern water traffic supervision and security, prevention and control systems as well as ship systems and transportation systems along the main river.

(3) All regions should make rational use of Yangtze River shipping to develop the local economy according to regional conditions. The upstream areas are rich in mineral resources, are focused on the development of heavy and chemical industries, and at the same time, use abundant hydropower to generate electricity, strengthen the maintenance of the Three Gorges Reservoir, not only providing sufficient resources for the region. The electricity in the middle and lower reaches can also meet the power demand of the middle and lower reaches. The ecological environment of the upper reaches is good, and tourism or ecological agriculture should be actively developed; the topography of the middle reaches is flat, and on the basis of the development of agriculture (to meet the upstream or downstream regions and even the national demand for grain, oil, and other agricultural products), it should focus on the development of the manufacturing industry in the region, especially the automobile manufacturing industry, while slowly developing the tertiary industry, actively introducing technology and capital to downstream areas, and transitioning from labor-intensive industries to capital-technology-intensive industries. The rise in the central region is being realized; the downstream regions should make use of the port and coastal advantages of the region to vigorously develop export trade, vigorously support the development of microelectronics high-tech industries, and transport technologies and talent to the upstream regions. In short, the upper and lower reaches of the Yangtze River should strengthen cooperation and use the links of the Yangtze River Channel to promote each other and develop together, so that the Yangtze River Economic Belt will always be at the forefront of East Asian countries.

(4) Yangtze River shipping should strengthen the connection with other transportation networks, and establish a fast freight network system connected with the main highway freight hub and the main railway freight hub. It will strengthen cooperation with China's Pearl River and other water areas, realize the real integration of transportation, and greatly improve the transportation efficiency of the entire inland river and the whole of society. By strengthening the pollution control of the trunk and tributaries of the Yangtze River and dividing the water system, each province and city should govern the waters in the

area. The strict responsibility system of whoever pollutes bears responsibility. The Yangtze River Shipping achieves not only the greatest economic benefits, but also the best social ecology. The effect is to respond to the construction of China's 'resource-saving' and 'environmentally friendly' two-oriented society by building a socialist harmonious society.

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