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Research on the Issues of Resource Allocation Efficiency of Multimodal Transport in Yangtze River Economic Zone

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Abstract: Yangtze River Economic Zone shoulder strategic missions of regional economic development as well as eco-civilization improvement. There for its multi-modal transportation system should be stressed in terms of high efficiency operation. High lighted by the first theorem of welfare economics, the paper works out the technical model of efficient allocation of multimodal transport resources in the Yangtze River Economic Zone by applying the transportation optimization method. As the findings of the paper, there are at least 6 categories of the resolutions in improving the transport efficiency, namely reducing the institution cost, improving the transportation demand, reducing the freight rate, shortening the transfer time, shortening the transit time, breaking the bottleneck of transportation between the two dams. The results of the research are respected to reduce the negative impact of the unfavorable shipping conditions as well as the blocks of river dams on the smooth operation of multimodal transport turnover in the region.

1. Introduction

The collecting and distributing system between Yangshan Terminal and the hinter land completely relies on the Donghai Bridge. Given about ten thousands of container truck traffic volume daily, it has restricted the efficiency of Yangshan Terminal's transport operations. With the development of the Yangtze River Economic Zone (shortened as "the YREZ"), the operation quantities of collecting and distributing in Yangshan Terminal will continue to increase. Therefore, to break the bottleneck constraints of ferry push, it is necessary to employ the Yangtze River golden waterway to carry out water-water transfer, and then to cover the central and western urban agglomerations of the YREZ via railways or highways, which will not only improve the efficiency of the transport network, but also reduce pollution and transport costs, so as to effectively promote the circulation of goods.

On September 25, 2014, the State Council issued the *Comprehensive Multi-dimensional Transportation Corridor Plan for the Yangtze River Economic Zone (2014-2020)*. The Plan made a layout for how to completely construct the YREZ crossing the whole nation and connecting the river and the sea, which is of convenience and efficiency. It also put forward the task of "vigorously developing multimodal transport". On September 19, 2016, the State Council issued the *Outline for the Development Plan of the Yangtze River Economic Zone*. The Outline proposed the development pattern of "one axis, two wings, three poles, and multiple points." Among them, "three poles" refers that three urban agglomerations—the Yangtze River Delta urban agglomeration, the mid-Yangtze River urban agglomeration and Chengdu-Chongqing urban agglomeration—is tend to serve as the main body and play an influential role in promoting economy, which will create three major growth poles of the YREZ. Relying on the Shanghai Free Trade Zone, the Hubei Free Trade Zone, the



Sichuan Free Trade Zone and the Chongqing Free Trade Zone and serving as the regional commodity circulation hubs, the three major growth poles will strengthen the linkages between their respective urban agglomerations and the international market. For the solution of how the three growth poles, with four free trade zones being as the commodity circulation hubs, will transfer commodity along “one axis” and effectively promote the development of two wings and the economic exchanges in multiple points, the *Outline* proposes the task of “building an integrated multi-dimensional transportation corridor”, so as to achieve a new pattern of opening up to the outside world with the integration of land and sea. In order to implement the *Outline*, on December 7, 2016, the National Development and Reform Commission together with the Ministry of Transport and the China Railway Corporation promulgated the *Multi-modal transport construction and implementation plan of ports along the Yangtze River Economic Zone under ‘Thirteenth Five-Year Plan’*(2016), which provides guiding suggestions for the general requirements, main tasks, and safeguard measures of multimodal transport. In the framework of the above guidelines and policies, this paper will study how to efficiently allocate multimodal transport resources from both sides of supply and demand according to regional conditions and future regional economic development patterns, so as to enable commodity to circulate freely in the multimodal transport corridor of the YREZ.

Throughout the world, countries and regions that close to the sea or rivers have the most developed trade and the fastest wealth growing (Lewis, 2010) [1], which shows the role of trade in regional economic development. However, distance and transport costs are negatively related to trade flow (Venables, 1996) [2]. Therefore, convenient multimodal transport can not only compensate for the negative effect of distance on trade flows, but also weaken the restriction of distance and transport caused by transport costs. This will open up a bigger market, deepen and develop the process of labor division. Moreover, transport costs and economy of scale will have an impact on modern industrial agglomeration and trade (Krugman, 1991)[3]. Therefore, convenient and low-cost transport can promote the commodity to circulation in a larger space and achieve an efficient allocation of resources.

The YREZ and the coastal belt together constitute the “T”-type macro-strategy for China’s territorial development and economic layout strategy (Lu Dadao, 1987) [4]. Due to the differences of natural conditions in the YREZ, the industrial spatial layout, from west to east, presents a sequence of resources-intensive industries, labor-intensive industries, capital-intensive industries, and technology-intensive industries. Since trade and industrial division and cooperation can all promote the coordinated development of urban agglomerations (Qin Chenglin, Zhou Jiao, 2010)[5], interregional trade, by enhancing economic interaction among regions, will form an associated interaction in economic development (Li Xinan, 2013) [6]. Interregional trade is still constrained by institutional mechanisms in different degrees (Pi Jiancai, 2008) [7], forming a division of administrative economy, so infrastructure investment is usually bounded by administrative regions as well. Nonetheless, as long as the urban transport networks are connected together, a comprehensive transport platform can be formed (Hao Shouyi, An Husen, 2015) [8] to promote commodity circulation and industrial division and cooperation among urban agglomerations. Based on the development strategy of “grasping for protection and refusing large-scale development”, the YREZ should strengthen trade and logistics cooperation to achieve effective integration of resources and promote coordinated development of regions. Therefore, the joint establishment of the Yangtze River transport system that covers the whole basin with overall linkage, and the promotion of the exchange and cooperation between the ports and logistics enterprises along the river through various forms of equity participation, mergers and alliances, will form an efficient, convenient and standardized Yangtze River basin logistics circle, and expand the economic exchanges between the middle and upper regions and international markets (Zeng Gang, 2014) [9].

In summary, the development of multimodal transport can effectively integrate the resources of the YREZ, promote commodity circulation, and coordinate regional development. This paper will employ the combination of transport optimization and the first theorem of welfare economics to study the efficient allocation of multimodal transport resources, so as to achieve free circulation of commodity.

2. Regional Linkage Analysis of the YREZ

2.1 Regional Economic Linkage

Science and technology are decisive forces for economic growth. Therefore, the aggregation of free trade zones and the development of high-end industries are conducive to integration between powerful enterprises. Once have occupied the high ground of science and technology, they will lead the interior region to occupy a dominant position in global competition and wealth distribution. The YREZ has five free trade zones, of which:

Shanghai Free Trade Zone focuses on the development of producer services based on the free trade ports, i.e. five major industrial clusters of international trade, financial services, shipping services, professional services, and high-end manufacturing, and prioritize the aggregation of three major industries—the headquarters economy, the platform economy, and the “four new” economy[10, 11, 12].

Hubei Free Trade Zone, based on the resource advantages of the mid-Yangtze River urban agglomeration, such as the solidly founded technology-intensive and capital-intensive industries and the multi-dimensional transport advantage including railways, highways, aviation and the Yangtze River, has become the demonstration area of undertaking industry and agglomeration area of strategic emerging and high technology industries in the middle of the YREZ. Under these circumstances, Hubei Free Trade Zone is actively developing modern service industries, such as high-end manufacturing and service industries and finance service [13].

Chongqing Free Trade Zone, serving as the key junction of “the Belt and Road Initiative” and the YREZ and the important pivot for the Western Development, sets up an international logistics hub and seizes the port dominant position by taking advantage of river ports, railway ports, and airports to promote the new pattern of a gateway city in the western region. It has driven the deep implementation of the Western Development and actively developed high-end manufacturing and modern service industries such as trade, finance, and logistics [14].

Sichuan Free Trade Zone relies on Chengdu Airport, Railway Port and Luzhou Port. It is committed to construct the development and opening zone of western gateway cities, inland opening strategy supporting & leading area, international opening channel hub, inland opening economy new highland, and the coordinated opening zone of inland, coast, borders and rivers. Sichuan Free Trade Zone is actively developing high-end manufacturing and trade, finance, logistics and other modern service industries [15].

Chengdu-Chongqing urban agglomeration, with dual-core driving forces of Chengdu and Chongqing, focuses on the building of the main development axis of Chengdu-Chongqing, accelerates the development of two city belt—the Chengdu-Deyang-Mianyang-Leshan City Belt and the Yangtze Riverside City Belt; and promotes the development of three areas—South Sichuan area, Nanchong-Suining-Guang'an and Dazhou-Wanzhou town concentrated areas. These layouts improve the efficiency of space utilization and build up a spatial development pattern of “one-axis and two-belt, dual-core and three-area” [16].

Mid-Yangtze River urban agglomeration strengthens the status of the central cities—Wuhan, Changsha and Nanchang, improves element convergence, technological innovation and service functions, upgrades the level of modernization and internationalization, advances the cooperative work promotion system and the interest coordination mechanism, and leads the coordinated development of the Wuhan City Circle, Changsha-Zhuzhou-Xiangtan urban agglomerations, urban agglomerations surrounding Poyang Lake, so as to build a polycentric coordinated development pattern [17].

Due to the their respective conditions in the four free trade zones and their hinterland urban agglomerations, it is easier to distribute responsibilities and complement each other's advantages to jointly reach a manufacturing agglomeration eminence.

2.2 Regional Transport Linkage

(1) *Waterway Transport.* The Yangtze River golden waterway was cut into two sections by the Three Gorges Dam and the Gezhou Dam. Chongqing serves as the upstream shipping center in the upper section, Wuhan as the midstream and Nanjing as the downstream. The two dams and the water depth restrict the development of the container transport of the Yangtze River golden waterway. The parameters of the nodes and the waterway are shown in Table 1.

Table 1. Parameter list of the Yangtze River waterway[16,17,18,19,20,21,22]

Nodes and Waterway	Trunk Line	Branch Line
Chongqing Shipment Center	Cuntan Port is a the waterway-highway hub with professional ro-ro and container terminals; Guoyuan Port is a railway-waterway-highway hub with 16 5,000-ton berths; Chongqing Railway Container Center Station; establishment of multimodal transport supervision area at ports and central stations.	Branch lines like Wujiang River, Jialing River, Minjiang River, Qujiang River, Jinsha River, Fujiang River.
Waterway between Chongqing and Three Gorges Dam	With 3.5-4.5 meters deep channel, 3000 tons of ships can be circulated throughout the year and 5,000 tons of ships during the wet season in summer. The whole course is about 671 kilometers. With the speed of $\geq 20\text{km/h}$, the time for sailing is about 33 hours.	
The Three Gorges Dam and the Gezhou Dam	5,000-ton ships can go through the Three Gorges five-step ship lock for free. The time for lockage is about 4 hours. 3000-ton ship is navigable to the ship lift with the lockage time of 40 minutes. The waiting time will vary from 2-5 days. Gezhou Dam is accessible for 10,000-ton ships. The lockage time for large ship is about 1 hour and mid ship 0.5-0.7 hours. The distance between the two dams is 38 kilometers, and the navigation channel is about 4.5 meters deep. 3000-ton ships are accessible throughout the year.	
Waterway between Gezhou Dam and Wuhan	With 3.5-5meters deep channel, 3000 tons of ships can be circulated throughout the year and 5,000 tons of ships during the wet season in summer. The whole course is about 612 kilometers. With the speed of $\geq 20\text{km/h}$, the time for sailing is about 30 hours.	
Wuhan Shipping Center	Yangluo Port has two container ship berths, berthing 5,000-ton ordinary type (also 10,000-ton wide and shallow hull type) river-sea direct steamer; Wuhan Railway Container Center Station; establishment of multimodal transport supervision area at ports and central stations	The Hanjiang River, the Dongting Lake basin and the Poyang Lake basin constitute the waterway in the midstream of the Yangtze River, including high-grade waterways like the Hanjiang River, Jiangnan Canal, Xiangjiang River, Yuanshui River, Ganjiang River, and Xinjiang River, and otherwaterways like the Songzi River and Hudu River.
Waterway between Wuhan and Yangtze Estuary	With 4.5-6 meters deep channel between Wuhan and Nanjing, 10.5-meter deep channel between Nanjing and Nantong, 5000-ton ships can be circulated throughout the year. After dredged, the channel is about 12.5-meter deep, which is navigable for 10,000 ships. The whole course is about 1125 kilometers.	

	With the speed of $\geq 20\text{km/h}$, the time for sailing is about 56 hours.	
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(2) *Railway Transport.* The YREZ has six of the country's 18 rail container center stations; they are Kunming, Chengdu, Chongqing, Wuhan, Ningbo, and Shanghai. These central stations are container rail way distributing centers and origin-and-terminal centers, which enable the rearrangement of trains. The accessibility of the regional railways at and above the county-level in the urban agglomeration centered on Wuhan, Chongqing, and Chengdu is respectively 100%, 80%, and 93.33%. These branch lines construct the central and western transport networks of the YREZ.

(3) *Highway Transport.* Shanghai-Chengdu Expressway and Shanghai-Chongqing Expressway are two expressways along the Yangtze River from east to west, directly or indirectly connecting the comprehensive transport hubs of Chengdu, Chongqing, Wuhan, and Shanghai, thus connecting road transport corridors of Shanghai Free Trade Zone, Hubei Free Trade Zone, Chongqing Free Trade Zone and Sichuan Free Trade Zone. The accessibility of the regional highways at or above the county-level in urban agglomerations centered on Wuhan, Chongqing and Chengdu are all 100%. These branch lines construct a network of highways for transport in the central and western regions of the YREZ.

2.3 The Optimal Physical Channel of Multimodal Transport

The YREZ owns the Shanghai International Shipping Center in the East China Sea, the Nanjing Regional Shipping Logistics Center in the downstream of Yangtze River, the Wuhan Shipping Center in the midstream, and the Chongqing Shipping Center in the upstream. The layouts include hub ports like Shanghai Terminal, Ningbo-ZhouShan Port, Nanjing Port, Wuhan Port, and Chongqing Port. Since east waterway of the Yangtze River of Nanjing Port is in good condition, it is accessible for 10,000-ton seagoing vessels. The water-water transport technology from Yangshan Terminal to Nanjing Port is technologically developed. Therefore, the multimodal transport studied in this paper will omit this section. The multimodal transport of YREZ studied in this paper is shown in the dashed box in Figure 1. It relies on the golden waterway of the Yangtze River and connects the urban agglomeration economic zones that centered on three shipping centers of Shanghai, Wuhan, and Chongqing to circulate commodity. The innovation highlands and business flow hubs that possess four free trade zones for increasing product added value and the urban agglomerations that own three shipping centers as their logistics hubs coordinate and cooperate with each other, so the high value-added products can pass through the multimodal transport channel to the Asia-Pacific market via the Marine Silk Road and to international markets as the BRICS Free Trade Area and the European Union via the Southwest International Grand Channel and the Silk Road, which strengthens the international cooperation.

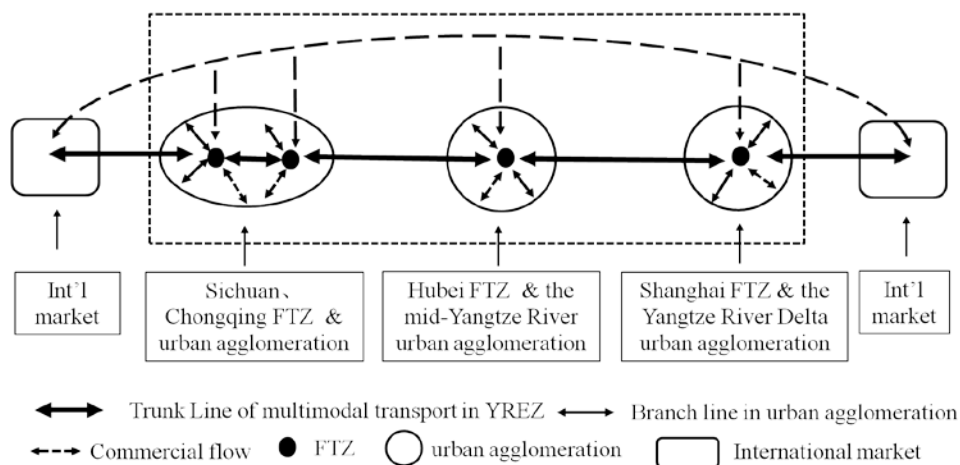


Figure 1. Multimodal transport channel in YREZ

The distances, transport times, and total freight rates for the three transport modes of waterways, railways, and highways in Chengdu, Chongqing, Wuhan, and Shanghai are shown in Table 2. The transport time in Table 2 refers to the contract transport time, which includes the time for the stockyard and the travel time.

Table 2. Parameter List of Main Transport Section

Transport Segment	Parameters	Waterway 20ft Box	Waterway 40ftBox	Railway 20ftBox	Railway 40ftBox	Highway 20ft Box	Highway 40ft Box
Chengdu To Shanghai	Section	—	—	2255	2255	1935.5	1935.5
	Time	—	—	10	10	3	3
	Rates	—	—	7522.3	11306	24000	24000
Chongqing to Shanghai	Section	2466	2466	2082	2082	1685.2	1685.2
	Time	20	20	9	9	3	3
	Rates	6000	7500	6635.6	10182.6	24000	24000
Wuhan to Shanghai	Section	1125	1125	1098	1098	850	850
	Time	7	7	5	5	2	2
	Rates	5000	6800	3906	6075.1	12800	15000
Chengdu to Chongqing	Section	—	—	333	333	313	313
	Time	—	—	3	3	1	1
	Rates	—	—	2793.7	3977.5	4200	4500
Chengdu to Wuhan	Section	—	—	1306	1306	1150	1150
	Time	—	—	6	6	2	2
	Rates	—	—	4966.6	7353.5	18000	19500
Chongqing To Wuhan	Section	1321	1321	1163	1163	880	880
	Time	14	14	5	5	2	2
	Rates	1600	2650	4086	6241.7	14000	15500

Notes: 1. Source of data: The railway transport data are taken from freight rates of the official website of Rail Freight (www.95306.cn) on August 1, 2017. The highway and waterway transport freight data are taken from the freight rates of Shanghai Outward Transport on 3 August 2017.

2. The total freight rate includes the yard service fee and transfer fee.

Unit: Section: km; Transport time: day; Freight rates: RMB/container.

After analyzing the data in Table 2, the following conclusions have been drawn:

- (1) The freight rates ratios of 40ft containers and 20ft containers are about 1.3 for water transport, 1.5 for railway transport, and about 1.0 for road transport;
- (2) In the same transport section, the longest is waterway Section, followed by the railway, and the shortest is the highway;
- (3) From Shanghai to Wuhan, the waterway freight rates is slightly higher than the railway freight, and much lower than the highway freight, that is only about 45% of its;
- (4) From Wuhan to Chongqing, due to the longer period of dam turning, the low freight rates advantages of waterway transport are counteracted;
- (5) From Chengdu to Chongqing, the freight rates and transport time for road transport and rail transport are similar, but the road transport is more flexible; and due to the wide variation of channel conditions between Luzhou Port and Chongqing Port, waterway transport is restricted.
- (6) Due to the time cost of dam-turning and the restriction on economies of scale caused by waterway transport, the Yangtze River waterway freight rates does not conform to the general rules for

waterway freight rates, that is not to conform to rule of "the cost of water transport is only 1/4 of the railway and 1/5 of the highway."

According to the data in Table 2, the principle of the two transport optimization models of the shortest route and the maximum traffic flow is integrated to construct a transport optimization model. As shown in Formula 1, the optimal physical channel for multimodal transport is calculated.

$$\begin{cases} \text{Min}C = \sum C_i \\ \text{Min}T = \sum T_i \end{cases} \quad (1)$$

After the calculation, the following conclusions are drawn:

(1) Among the five modes of transport from the Chongqing to Shanghai, the multimodal transport of railway-waterway from Chongqing to Shanghai via Wuhan is the optimal mode. However, the freight rates and transport time is 1.3 times that of the whole journey by railway transport. The multimodal transport is not as advantageous as the whole journey by railway transport.

(2) Among the six modes of transport from Chengdu to Shanghai, the multimodal transport of railway-waterway from Chengdu to Shanghai via Wuhan is the optimal mode. However, the freight rates and transport time is 1.3 times that of the whole journey by railway transport. The multimodal transport is not as advantageous as the whole journey by railway transport either.

(3) Railway transport excelling these two types of multimodal transports is because it avoids the constraints of the two dams, but the railway transport capacity has reached saturation.

Therefore, it is necessary to explore the potential of the golden waterway of the Yangtze River, strengthen the construction of waterway transport from Shanghai to Wuhan, and shift the railway transport capacity in Shanghai-Wuhan section to Wuhan-Chongqing and Wuhan-Chengdu sections. Meanwhile, efficient allocation of transport supply and demand resources can further reduce the shipping freight rates and shorten the shipping time, which will improve the efficiency of multimodal transport in the YREZ under the conditions of breaking the bottleneck of the two dams.

3. Model of Allocating Resource Efficiently of Multimodal Transport

According to the theory of the equilibrium process of transport supply and demand, institutional costs can be reduced and convenience and enthusiasm of investment in the transport and manufacturing industry can be promoted through institutional reforms such as investment environment optimizing, integration of regional customs clearance, and regional coordinated development planning to level the playing field for transport and optimize the interaction between freight rates and trading volumes (as shown in Figure 2), reaching the transport equilibrium of supply and demand (Q_E, P_E) (as shown in Figure 3).

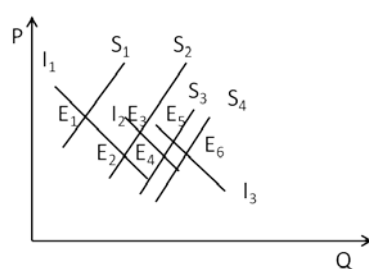


Figure 2. Equilibrium process of free competitive market in transport

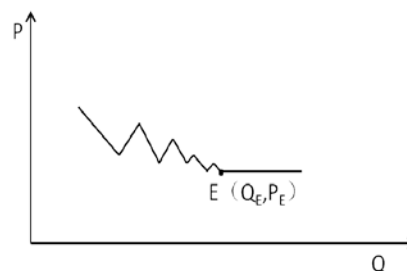


Figure 3. Equalization point locus

According to the First Theorem of Welfare Economics, the allocation of transport resources reaches Pareto Optimalit when the multimodal transport reaches a competitive equilibrium. Therefore, the technical model for achieving dynamic equilibrium and resource efficient allocation is shown in Figure 4.

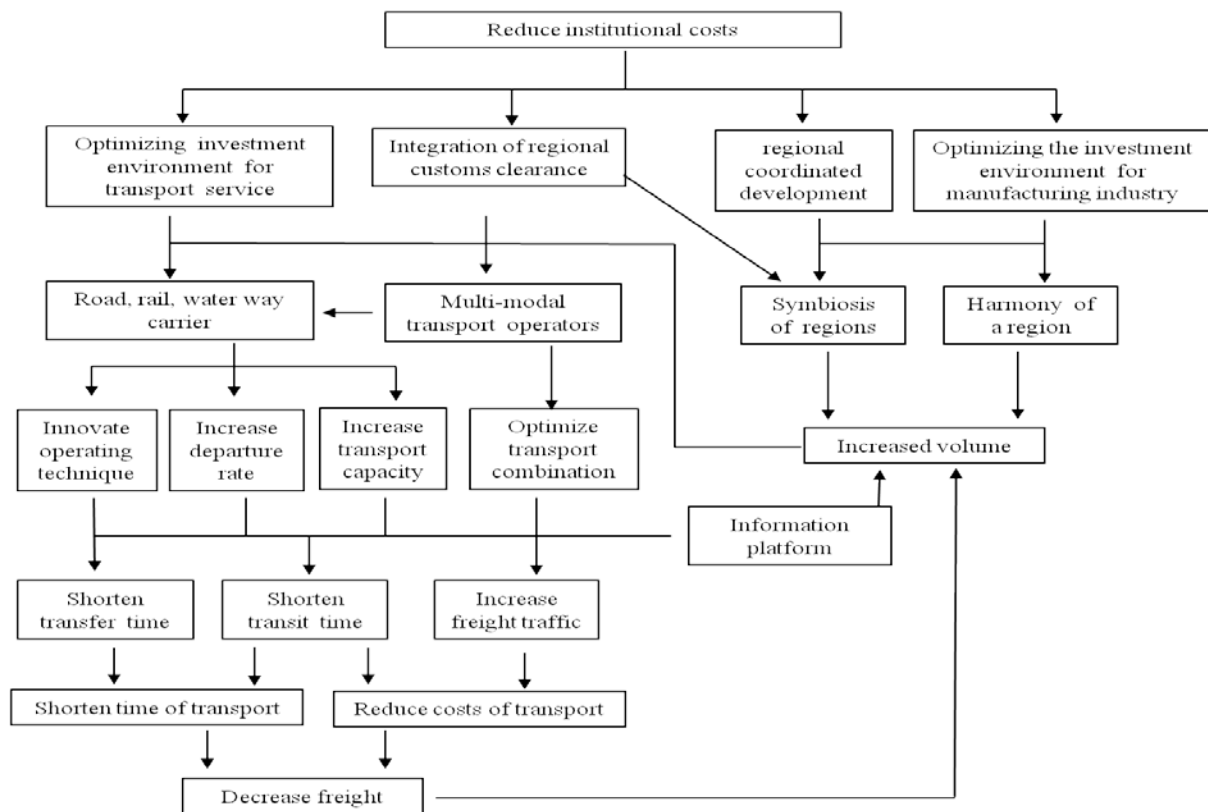


Figure4. Model of allocating resource efficiently of multimodal transport in YREZ

4. Approach of Allocating Resource Efficiently of Multimodal Transport

According to the conclusion of analysis in part 2.3, “The development of multimodal transport requires further reduced freight rate of Yangtze River shipping and shortened time of shipping transport”, we can see that the supply of multimodal transport capacity in the YREZ is insufficient. In combination with the regional attributes of the YREZ and the efficient allocation of multimodal transport resources as shown in Figure 4, the effective allocation of multimodal transport resources in the YREZ is as follows:

4.1 To strengthen regional collaborative development and optimize corporate investment environment based on lowering institutional costs.

(1) Promote regional collaborative development. The reform of the YREZ to reduce institutional costs is mainly reflected in the dissolution of the administrative economy and the strengthening of regional collaborative development, such as the *Outline of the Yangtze River Economic Zone Development Plan*, the integration of regional customs clearance, the planning of a world-class manufacturing cluster base, the construction of free trade zone and other institutional innovations. These reforms that reduce institutional costs have optimized the manufacturing investment environment. Among these reforms, regional economic integration has promoted the efficient integration of resources and industrial specialization and cooperation; the Free Trade Zone has led regional innovation and strengthened the spatial effects of the hinterland region and the international market.

(2) Optimize investment environment. The reform of the YREZ to reduce institutional costs is also reflected in the planning and construction of three-dimensional traffic corridors, such as the *Yangtze River Economic Zone Integrated Three-Dimensional Corridor Planning (2014-2020)* and the *Multimodal transport construction and implementation plan of ports along the Yangtze River Economic Zone under ‘Thirteenth Five-Year Plan’(2016)*. These reforms have optimized the investment

environment for transport industry and improved the conditions for the investment facilitation of carriers and multimodal transport operators.

(3) *Promote market competition order.* The competent authorities further introduced relevant policies based on market demand to maintain the free, healthy and fair competition in the transport market.

The above institutional innovations have built manufacturing and transport operating platforms and optimized the investment environment for enterprises. When selecting an investment position, an enterprise can not only seek quality resources that can be integrated in the supply chain, but also avoid the risk of duplicate construction investment, thereby further reducing the institutional cost.

4.2 To Improve the Resource Allocation of Transport Demand Based on Geographical Advantages

(1) *Promote regional division and cooperation.* The “single window” of international trade in the Shanghai Free Trade Zone gradually covers physical trade and service trade. By integrating with the “one-window” standard specification at the national level, it can promote the cross-regional customs clearance business of the YREZ, and strengthen data convergence and coordinated supervision. The supervision and cooperation between the Shanghai Free Trade Zone and the YREZ along the Yangtze River and the ports along the “One Zone and One Road” will form a central hub of the Asia-Pacific supply chain connecting domestic and international key ports. Therefore, the Hubei, Chongqing and Sichuan Free Trade Zones and the Shanghai Free Trade Zone form an integrated innovative powerhouse and export-oriented economic zone which connects domestic and foreign key ports following Asia-Pacific supply chain in the east and connects the Free Trade Zones of BRICS and EU market in the west, driving demand for export-oriented transport of urban agglomerations.

Based on the carrying capacity of resources and environment, the Yangtze River Economic Zone Industrial Development Plan has subdivided the industry direction of more than 100 national, provincial-level development zones and industrial parks in 11 provinces and municipalities, and cultivated world-class manufacturing clusters at international advanced level in five fields. As a result, the division of labor within the industry and the product promotes regional division and cooperation, and progressively increase the demand for transport within the region.

(2) *Build information platform for multimodal transport to improve public service level.* The effect of information platform in improving the efficiency of supply and demand transactions and promoting complete competition at the market has been confirmed in e-commerce platforms such as Taobao.com and JD.com. The YREZ multimodal transport has introduced the “Internet Plus” technology to build an open information platform for multimodal transport, linking the capacity information resources (such as shipping schedule and freight tariff) of the railway 95306 platform, the port EDI center, China Changjiang National Shipping Group Co.Ltd (Changjiang Shipping Company), and multimodal transport operators. Transport capacity can be easily selected by the consignor according to transport time, freight, etc., and by breaking carriers' monopoly, free competition can also be facilitate the in the transport market due to the reduced freight tariff and thus the transport market can embark on the benign track of competition where supply and demand function well.

4.3 *Allocation and Optimization of Transport Resources Based on Reducing Freight Rates.* It is necessary to increase the transport demand based on the optimization of the investment environment for manufacturing and give investment subsidies for support based on the optimization the investment environment for transport industry, support transport companies in increasing their investment in capacity and promoting their enthusiasm for the industry to spur on the reduction of tariffs in transport market during the process of dynamic equilibrium.

(1) *Encourage practice of multimodal transport operators.* More qualified actual carriers should be encouraged to carry multimodal transport operations in the YREZ as multimodal transport operators and implement related policies. It is necessary to not only encourage ports, railway companies, and Changjiang Shipping Company to integrate advantageous resources in various forms such as equity

participation, mergers, alliances, joint ventures, and cooperation, and set up railway and waterway combined transport companies[25], but also to implement the policy that customs should cultivate non-publicly-owned carriers regarding to the qualifications in carrying international cargos on the Yangtze River and introduce more carriers to participate in the competition of the Yangtze River shipping.

The Ministry of Transport of the PRC cultivates non-vehicle carriers and NVOCCs regarding to the qualifications of getting engaged in multimodal transport operations in the YREZ, and issues multimodal transport operator licenses to operators that meet the qualification requirements. Non-vehicle multimodal transport operators can effectively collect transport resources and promote complete competition in the transport market.

In this way, with the good platform with an optimized investment environment, more multimodal transport operators, attracted by transport demand, have invested in multimodal transport operations. They capture opportunities to gain market profit with professional insights and help to promote transport supply. The large platform, under the environment of supervision on and service of multimodal transport, fosters more multimodal transport operators who operate legally and compete freely, soundly and fairly.

(2) Support investment in technological innovation of railway transport along the Yangtze River. The investment subsidies are provided for multimodal transport projects with equipment and technology innovation such as COFC, railway double-decker container transport, etc. [23].

(3) Support the investment of shipping companies in Yangzi River. Financing preferences or investment subsidies are provided for the investment in transport vehicles and infrastructure that meet the conditions of the fairway.

(4) Strengthen the trunk line capacity in the middle. The waterway freight from Shanghai to Wuhan, which is about 45% of the road freight, is slightly higher than the railway freight, far lower than the road freight. This shows that under the circumstance that the railway transport capacity is saturated, Changjiang Shipping Company obtained a certain degree of monopolistic profit due to the shortage of supply capacity. With the improvement on conditions of the waterway from Wuhan to Nanjing, the routes of “five scheduled (scheduled time, scheduled route, scheduled ship, scheduled cargo and scheduled harbor)” liner barges, non-“five scheduled” barges and “shuttle buses” on the lower reaches of the Yangtze River extended to the Wuhan Shipping Center, linking the highway transport of the middle reaches of the Yangtze River and railway transport of the urban agglomerations of Chengdu-Chongqing. This will not only help increase the capacity of multi-modal transport in the YREZ and reduce the water transport costs from Shanghai to Wuhan, but also increase the freight volume due to the increase of hinterland routes, which can further ease the problem of low average load rate caused by uneven distribution of containers to Yangshan Terminal.

(5) Develop branch line capacity. By promoting the drop and pull transport which is combining of tank semi-trailer or container semi-trailer and ferry as a public water transport, the inland waterway system in the transport network can be fully utilized in the terminals with limited container handling conditions to share the pressure of road transport and achieve Door service.

(6) Innovate container operations to reduce operating costs. The LCL (Less than Container load) service, which satisfies the transport needs of small batches of goods, is an important business in container transport. Usually, the cargos of 2 to 3 shippers are assembled in a 20-inch standard container. For each shipper, the freight (including crating charge and devanning charge) of the service is less than that of a 20-inch FCL (Full Container Load) service, but with the risk of cargo damage increased when unpacking the container, the yard operation time prolonged and early delivery pressure.

The application of 10-inch nested containers, 10-inch conjoined containers, and mother containers ingeniously compensates for the deficiencies of LCL services. For example, the shipper loads the cargo into a 10-inch nested container and delivers it to the carrier in the form of FCL but with freight

less than what should have paid in the form of LCL. Then the carrier can combine the 10-inch nested containers with a 20-inch or 40-inch frame container in the yard, with significant less operation costs and operation time than what a 20-inch LCL operation could have taken. Moreover, if we nest 10-inch nested containers together when shipping the empty containers, transport costs can be reduced.

Or the shipper loads the cargo into a 10-inch conjoined container and delivers it to the carrier in the form of FCL but with freight less than what should have paid in the form of LCL. Then the carrier can combine two 10-inch conjoined containers into a 20-inch container, with significant less operation costs and operation time than what a 20-inch LCL operation could have taken. When we recycle empty containers, two 10-inch conjoined containers can be connected tightly to make a 20-inch standard container, which can be used to transport all types of dry goods, improving the turnover rate of conjoined containers.

In addition to high assembling efficiency, 10-inch nested containers and conjoined containers, as independent strong assembly units, enjoy greater transfer efficiency and customs supervision efficiency than that of a 20-inch LCL, because they can be transferred and supervised by customs like FCL after the container door is hung with a container seal or a customs seal. In addition, these 10-inch containers have a rated load of 10 tons and a maximum total weight of 12 tons, so they can also be used in factories, yards, and docks that lack standard container handling equipment. In this way, it is also possible to fully integrate water and land transport capacity along the river branches to improve the operational efficiency of each link by means of container transport. It benefits shippers and helps tap more goods sources and capacity for the carrier, thus advancing multimodal transport industry in YREZ from the perspective of increasing transport demand and transport resources.

4.4 Transport Resources Optimization Based on Shortening Transfer Time

According to the analysis result of 3, if we choose the two optimal multimodal transport service routes, namely from Chengdu via Wuhan railway and shipping joint transport to Shanghai and from Chongqing via Wuhan railway and shipping joint transport to Shanghai, then according to the data in Table 2, the analyses of transport time distribution are shown in Table 3 and Table 4 respectively.

Table 3. Timing analyse of railway and shipping combined transport between Chengdu and Shanghai via Wuhan

Transport Segment	Section (km)	Transit Speed (km/h)	Transit Time (h)	Contract Transport Time (h)	Transfer Time(h)	Ratio of Transfer Time
Chengdu-Wuhan(1)	1306	60-80	20	144	122	84.7%
Wuhan-Shanghai (2)	1125	≥ 20	56	168	112	66.7%
(1)+(2)	2431	----	76	312	234	75%

Table 4. Timing analyse of railway and shipping combined transport between Chongqing and Shanghai via Wuhan

Transport Segment	Section (km)	Transit Speed (km/h)	Transit Time (h)	Contract Transport Time (h)	Transfer Time(h)	Ratio of Transfer Time
Chongqing-Wuhan(1)	1163	60-80	18	120	102	85%
Wuhan-Shanghai (2)	1125	≥ 20	56	168	112	66.7%
(1)+(2)	2288	----	74	288	214	74.3%

Calculation results in Table 3 and Table 4 show that the ratio of cargo transfer time is too large, indicating that there may be problems like insufficient transport capacity, delayed transport due to the pursuit of a full load rate, and poor transfer between different modes of transport. Based on these factors, there are five ways to reduce transfer time.

(1) *Encourage the practice of multimodal transport operators without vehicles.* First of all, we should encourage the practice of non-vehicle multimodal transport operators, because they share the characteristics of low fixed-cost investment and low cost recovery pressure. Non-vehicle multimodal transport operators have greater bargaining power than one single shipper because they have a greater amount of cargo. They can dismantle transport monopoly through integrating quality transport capacity flexibly, therefore promote the actual carrier's yard operation efficiency and transport operation quality, reducing the amounts of deliberate delayed transport, which damages the interests of shippers.

(2) *Optimize the connection between vehicles and ships.* The actual carrier can optimize the train diagram and ship schedule and facilitate the transit connection between upstream and downstream transport segments, thereby compressing the cargo transfer time in yard and improve their convenience advantage in the competition.

(3) *Optimize the distribution of railway transport capacity.* The ratio of stockpiling time for railway transport is greater than that of shipping, which indicates that the railway transport capacity is tight. Therefore, we can replace railway transport with shipping in Shanghai-Wuhan segment, and transfer the liberated railway transport capacity to Wuhan-Chong/Chengdu segment. This can optimize transport resources and effectively shorten the stockpiling time for railway transport.

(4) *Increase new shipping capacity.* With the development of YREZ, the degree of labor division and cooperation and the volume of transactions within the regions have gradually increased. However, the problem of shipping capacity supply shortage has become increasingly evident, especially as the country's investment in lanes and ports of multimodal transport has increased, and the market share of Yangtze River shipping has increased. Therefore, the Yangtze River shipping carrier should increase new shipping capacity based on market demand and shorten transfer time by increasing the shipping departure rate, thereby improving their capability advantage in the competition.

(5) *Innovate the comprehensive customs supervision mode in multimodal transport supervision area.* There are mainly two modes of transfer of container cargo in the multimodal transport supervision zone: transfer between two international transport segments and transfer between international transport segment and domestic one. The former's customs supervision mode, like port transfer supervision mode, generally declaration is applied by the manifest by a carrier; the latter is applied by customs clearance. Based on the integrated platform for customs clearance in YREZ, we should strengthen data connection and supervise data collaboratively, innovating cross-regional customs clearance services.

LCL service is also an important business in the supervision zone. The use of 10-inch nested containers and conjoined containers can improve the operating and supervision efficiency of LCL service, thus shortening the transfer time. Customs can use methods like inspection first to encourage and guide shippers to use such containers in LCL service.

4.5 Transport Resources Optimization Based on Shortening Driving Time

(1) *Invest in river-to-sea ship.* We should research, develop and invest in river-to-sea ship that can simultaneously adapt to the Yangtze River route and the Yangshan Terminal's offshore waterway, avoiding the transfer of goods in the upper and middle Yangtze River to Nanjing Port, Taicang Port or Waigaoqiao Terminal, thus reducing the time and operating costs caused by transit. At the same time,

according to design standards, the speed of this new type of ship is generally 20km/h, which is approximately twice the speed of the existing ships.

(2) *Diverse multimodal transport services in the lower reaches of Yangtze River.* As the waterway conditions from Nanjing Port to the Yangtze River estuary are better, we should integrate existing seagoing ships to mainly share the river-to-sea multimodal transport service between Yangshan Terminal and the lower reaches of Yangtze River, thus reducing the berthing time of river-to-sea ship in the lower reaches of the Yangtze River.

4.6 Crack the Transport Bottleneck between the Two Dams

From the data in Table 2, we can calculate that the total shipping costs from Chongqing to Shanghai is 0.74 times that of Chongqing Railway to Shanghai, and it is 0.57 times that of Chongqing to Shanghai via Wuhan by joint railway and shipping. However, due to the long transport time, with 2.2 times and 1.67 times respectively, its competitiveness is constrained; similarly, according to data in Table 2, although the freight from Chongqing to Shanghai via Chongqing by joint railway and shipping or by joint road and shipping is 0.81 and 0.85 times respectively than that of Chengdu to Shanghai via Wuhan by joint railway and shipping, the transport time is 1.77 and 1.62 times respectively longer. The competitiveness is constrained as well. These data show that although the shipping costs from Wuhan to Chongqing is lower than that of railway transport; the time delay caused by passing the Two Dams has severely restricted the competitiveness of waterway transport.

Although the use of ship lifts to a certain extent has improved the conditions for passing dams, it is not possible to navigate ships of 5000-ton class. Besides, waiting for the ship lock costs 2-5 days. Although the expansion of the fifth-level ship locks is put on the agenda, it is difficult to work in the short run. Therefore, according to the data in Table 2, in the short term, the railway transport capacity from Chengdu and Chongqing to Wuhan can be used to compensate the navigation capacity between the Two Dams, diverting goods that are sensitive to time effects. The 880 kilometers from Chongqing to Wuhan and 1150 kilometers from Chengdu to Wuhan have exceeded the economic distance of road transport; therefore they can only be used as supplementary transport capacity when the railway transport capacity is insufficient.

5. Conclusion

Relying on the Yangtze River golden waterway to develop multimodal transport, we can effectively allocate the multimodal transport resources of the YREZ from six aspects under the conditions of dynamic equilibrium of supply and demand: lowering institutional costs, increasing transport demand, lowering freight rates, shortening transfer time, shortening transit time and breaking the transport bottleneck between the Two Dams. This paper has also put forward specific implementation measures, namely mobilizing advanced resources of the YREZ in terms of geographical advantages and institutional innovations and combined with transport technology innovation, improving the flow efficiency of the east-to-west international channel within the region and smoothing regional economic connection. The conclusion of the study will also help us overcome the adverse natural conditions such as water depth and constraints of the Two Dams of the Yangtze River Channel, thus ensuring a smooth multimodal transport.

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7. References

- [1] W. Arthur Lewis. The Theory of Economic Growth[M]. Zhou-Shiming. Beijing:The Commercial Press,2010:74.
- [2] Venables A. Equilibrium locations of vertically linked industries. International Economic Review, 1996,37(2):341-359.

- [3] Krugman P. Increasing returns and economic geography [J]. Journal of Political Economy, 1991, 99(3):483-499.
- [4] <https://baike.so.com/doc/5656929-5869580.html>
- [5] QIN Chenglin, ZHOU Jiao, Coordinated Development of Urban Agglomerations: Connotation, Conceptual Model and Realization Paths [J], Urban Studies, 2010(12): 7-12.
- [6] LI Xinan, Interregional mobility of factors of production and coordinated development of regional economy in China [J], Regional Economic Review, 2013(1): 129-134.
- [7] Pi Jianchai, Regional Market Integration under Interjurisdictional Competition in China: On the Role of the Central Government in Regional Market Integration [J], Economic Research Journal, 2008 (3):115-124.
- [8] Hao Shouyi, An Husen, Regional Economics (3rd Edition)[M], Beijing: Economic Science Press, 2015:P86.
- [9] Zeng Gang, Condition and Strategy for Coordinated Development of Yangtze Economic Zone [M], Beijing: Economic Science Press, 2014:P310.
- [10] Further Deepening the Reform and Opening Scheme of China (Shanghai) Pilot Free Trade Zone [EB/OL]. http://www.gov.cn/zhengce/content/2015-04/20/content_9631.htm
- [11] Deepening the Reform and Opening Scheme of China (Shanghai) Pilot Free Trade Zone in an All-round way [EB/OL]. http://www.gov.cn/zhengce/content/2017-03/31/content_5182392.htm
- [12] Shanghai Federation of Social Sciences, 150 Questions for China (Shanghai) Pilot Free Trade Zone [M], Shanghai: Truth and Wisdom Press, 2013.
- [13] General Scheme of China (Hubei) Pilot Free Trade Zone [EB/OL]. http://www.gov.cn/zhengce/content/2017-03/31/content_5182299.htm
- [14] General Scheme of China (Chongqing) Pilot Free Trade Zone [EB/OL]. http://www.gov.cn/zhengce/content/2017-03/31/content_5182300.htm
- [15] General Scheme of China (Sichuan) Pilot Free Trade Zone [EB/OL]. http://www.gov.cn/zhengce/content/2017-03/31/content_5182304.htm
- [16] Development Planning of Chengdu-Chongqing Urban Agglomeration(2016)
- [17] Development Planning of Urban Agglomeration in the Middle Reaches of the Yangtze River(2015)
- [18] Changjiang River Administration of Navigational Affairs, MOT. <https://www.cjhy.gov.cn/>
- [19] Three Gorges Navigation Authority, <https://www.sxthj.com.cn/>
- [20] Changjiang Waterway Bureau, <http://www.cjhdj.com.cn/>
- [21] <http://www.cjienc.com/>
- [22] Chongqing Shipping Bureau, <http://www.cqshipping.com/>
- [23] Multi-modal transport construction and implementation plan of ports along the Yangtze River Economic Zone under “Thirteenth Five-Year Plan”(2016)