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Study on the path and carrier selection in China’s multimodaltransport - taking southwestern China to Yangtze River Delta as an example

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Study on the path and carrier selection in China's Multimodaltransport---Taking southwestern China to Yangtze River Delta as an example

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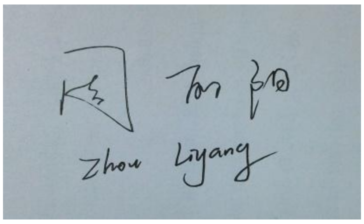

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Abstract

Title of Research paper:**Study on the path and carrierselection inChina's Multimodaltransport---Taking southwestern China to Yangtze River Delta as an example**

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Nowadays, the Ministry of Transportation and the State of Development and Reform Commission of China have paid high attention on the multimodal transport development. It is of great importance to choose proper path and carrier in multimodal transport. This thesis will focus on the routes from southwestern China to Yangtze River Delta and find out the most suitable alternative from the standpoint of multimodal transport operators.

In this dissertation, it will first analyze the development of international transportation as well as the current situation of China's multimodal transport to find out certain problems of that in China. And the comparison between different transport modes will be discussed. Secondly, this dissertation will use some mathematical models to analyze the path selection of China's multimodal transport. The AHP model will be used to determine the best alternative of the path transport cargoes from southwestern China to Yangtze River Delta. In this sector, various criteria affecting path selection in multimodal transport will be discussed. And both quantitative method and qualitative method will be adopted in the path selection modal. Thirdly, tendering and bidding process will be implemented in the multimodal transport carrier selection. From the multimodal transport operators' standpoint, incomplete information impact will be considered. Finally, this paper will analyze the results of the model and reach a conclusion. And this dissertation will give some suggestions on how to develop China's multimodal transport based on the findings.

It is found in this dissertation that AHP model can help multimodal transport operators better select multimodal transport path. In the path selection part, rail-water transport

is the best alternative of transporting goods with low value and low urgency. Thus rail-water transport is suggested to be strove to develop in China's multimodal transport. In carrier selection part, the tendering and bidding process can contribute to multimodal transport operators in choosing actual carriers under incomplete information.
Key words: multimodal transport, path selection, carrier selection, AHP, tendering and bidding

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Charpter 1 INTRODUCTION

1.1Research background

Over the past decades, the world has witnessed significant development in global economic integration. A new economic era is driving more countries toward trade liberalization and globalization. Multimodal transport has emerged with the massive growth of containerization. Multimodal transport is the integrated transportation by combining at least two modes of transport, including sea, rail, air, etc. The operator of multimodal transport issues the bill of lading during the entire process and the carriers will arrange the transportation of their parts. Under multimodal transport, all necessary ingredients in each mode of transport will integrate into one, including charging, consigning, insurance and customs clearance, etc. In another word, the whole transport process can be covered with only one document. Nowadays, shipowners and carriers prefer to multimodal transport since it gathers the advantages in fragmented transportations. The advantages of multimodal transport are prominent. The combination of various means (air, sea, rail, etc.) of transport can minimize the logistic costs of the company. And this kind of mode can ensure all cargoes are available to access to remote areas over the world. Besides, multimodal transport will improve the efficiency since it can save much delivery time to a large degree. In terms of these advantages, multimodal transport has been well developed in western countries. However, its development has been restricted due to reasons in different aspects like incomplete infrastructure. Fortunately, with the existing strategy of “the Silk Road Economic Belt and the 21st Century Maritime Silk Road” (B&R), China’s multimodal transport will usher in a significant opportunity in the next few decades.

As the intensive and efficient mode of transportation, multimodal transport began around 1960. With the development of technology of containers, multimodal transport experienced a rapid development after 1980. Since 1980s, most western developed countries strove to develop multimodal transport with various policies and regulations support. Multimodal transport has been the leading strategy of the transport system optimization, especially in 21st century. Nowadays, developed countries have formed the multimodal transport system with various forms, advanced technologies, complete standard system and reliable policy, etc. And the proportion of multimodal transport is still growing.

However, China’s multimodal transport is still at its primary stage with low coverage, low specialization and organization level. Besides, it also faces some obstacles from techniques, regulation, and policy, etc. In order to improve the integrated transportation system in China, the State Development and Reform Commission published an announcement of the demonstration project on the development of multimodal transport in 12th of July, 2015. This demonstration project places great importance on the multimodal transport development with the purpose to optimize the transport structure, improve the transport efficiency, reduce the transport cost and enhance the transport ability. One of the purposes of this project is to perform 15 multimodal transport project constructions to form leading multimodal transport hub station, organization mode, information system and multimodal carrier. Therefore, the first and foremost thing is to tackle the technical issues with scientific approaches. Multimodal transport path and carrier have great impact on the transport costs, time as well as the service level. Thereby the path and carrier should be selected scientifically and effectively.

Recently, the first 16 multimodal transport demonstration projects have been published. The 16 projects are listed as follows: 1. Piggyback transport ‘road-rail transport demonstration project; 2. “Eastern coast-Beijing, Tianjin-northwest” corridor of container sea-rail transport demonstration project in Hebei province; 3. Dalian Northeast Asia International Shipping Center: “Asia Pacific-Northeast” corridor container sea-rail-road transport demonstration project; 4. “Southeast coast-Yingkou-Europe” corridor container road-rail-water transport demonstration project in Liaoning; 5. New Eurasian Continental Bridge container multimodal transport demonstration project in Jiangsu Province; 6. “Ningbo-Zhoushan port-Zhejiang,Jiangxi,Hunan(Chongqing, Sichuan)” container sea-rail-road transport demonstration project; 7. “Belt and Road” cross-border container sea-rail-road transport demonstration project; 8. Zhengzhou-Europe international freight trains sea-rail-road transport demonstration project in Henan Province; 9. Container rail-water transport demonstration project in Wuhan—-promoting “the belt and road, the Yangtze River economic belt” strategy; 10.Sinotrans (Guangdong) "ASEAN-Guangdong-Europe" road-rail-sea-river intermodal transport demonstration project; 11. Road-rail transport demonstration project of cold chain logistic corridor running through the Eurasia; 12. Chongqing-Xinjiang-Europe multimodal transport demonstration project in Chongqing; 13. International railway port container rail-road-water multimodal transport demonstration project in Chengdu, Sichuan Province; 14. “Kunming - Southeast Asia, the Yangtze River economic belt and the northern Gulf of Guangxi” container sea-rail-road transport demonstration project in Yunnan Province; 15. South Asia international freight trains road-rail intermodal transport demonstration project in Lanzhou; 16. Xinjiang Production and Construction Corps: Silk Road international multimodal transport demonstration project.Chongqing which is in southwest of China has been included in these projects.Based on the researches in southwestern China, it is found that its multimodal transport level is relatively backward although it has the advantage of water transportation. Chongqing is the logistic center of southwestern China. Thereby the study on the route from southwest of China to Yangtze River Delta will make contributions to the multimodal transport development.

1.2Objective of the study

First of all, this dissertation is aimed at finding out problems in China’s multimodal transport through comparing with international multimodal transport. Second, the objective of the thesis is to select the most appropriate path and carrier in multimodal transport focusing on the example of the route from Chengdu, Guiyang to Shanghai through Chongqing. Third, this thesis is with the purpose of drawing experience from the example and applying it to the suggestions on China’s multimodal transport development.

1.3Methodology

Since selecting the path in multimodal transport is a multiple-objective decision problem, the AHP model will be used to determine the best alternative. The tendering and bidding process will be used in the carrier selection. In the discussion, different criteria of both path and carrier selection will be decided respectively. And questionnaires will be sent to related experts, professors and enterprises staff to decide the weight and score of each criterion.

Chapter 2 LITERATURE REVIEW

2.1 Introduction

The multimodal transport course can be divided into cooperating type and connecting type. In china, course of connecting type is widely adopted by multimodal transport carriers. The process of this type of multimodal transport can be classified into two parts, the through carriage and the actual transport organization. The through carriage is accomplished by multimodal transport operators. It mainly includes the organization and completion of the business affairs and cohesive services that it is related to. The actual transport process is completed by segmental carriers of different transport modes which are involved in certain multimodal transport. Its transport course belongs to the internal technic, business and organization process of each transport mode. As is mentioned in the previous chapter, with the prominent advantages, China has placed great importance on the development of the multimodal transport. In the multimodal transport demonstration projects, the path and carrier selection are considered as crucial issues since it is related to both technical and economic aspects. Path selection means a lot in reducing the logistic costs and minimizing delivery time under multimodal transport. Carrier selection decides whether the entire transportation process can be completed safely and efficiently. Generally speaking, quick delivery time and low logistic costs are needed in multimodal transport. However, fast delivery will lead to high cost. On the other hand, low cost will affect the service level. Proper path and carrier selection is quite crucial to balance the economic influence and the service quality.

The literature of this issue had been divided in four parts in this review. The first part is current research situation and existing problem of path and carriers in China's multimodal transport. The second part is the brief introduction of AHP model. The third part is literature related to path selection in China's multimodal transport. The fourth part is literature about carrier selection in China's multimodal transport.

2.2 Research situation

2.2.1 Situation

Although multimodal transport has gained great popularity in western countries, China is at the primary stage, trying to find the efficient way to boost multimodal transport. Proper path selection, transport program and selection of carriers are beneficial to the development of multimodal transport. And in recent years, there are many related researched on the path and carrier problem in multimodal transport. Jing Li, Yue Fang Yang, Huan Liu (2013) studied on the optimization multimodal transport path based on the improved genetic algorithm to transport scheme. Lu xin (2012) figured out the transport time and costs of shortest path using the algorithm of Kshortestpaths. And he found out the optimal solution of multimodal transport programme. Yang juhua and Zhu changfeng (2013) built the multimodal transport network with the purpose of minimum transport costs and maximum volume. Dijkstra algorithm was used in their articles to solve the problem. Englundh (2015) talked about the carrier liability in multimodal transport. He pointed out the basis of liability of multimodal carrier is difficult and this will give the transaction a negative effect.

Dong fang (2010) found the optimal solution of carrier selection in multimodal transport using mixed set programming. Transport costs, service quality, creditability and information capability are considered to measure the selection of carriers.

2.2.2 Existing problems

Researches related to the path and carriers in multimodal transport have obtained certain achievements, but some problems are still remained to be improved. In the existing researches, most both path and carrier selection will affect the transport costs, transport time and service quality. That is why the carrier needs to be chosen scientifically in one specific multimodal transport path. And a complete model needs to be developed.

2.3 AHP model

AHP (Analytic Hierarchy Process) is first put forward by Professor T.L.Satty in 1970s. It is a decision making method of making quantitative analysis on qualitative problems. It can divide various factors in complex problems into hierarchies. And it can combine suggestions from experts and objective judgements from analysts. The factors are in pair wise comparison. This model is often used in multi-objective, multi-factor, multi-hierarchy problems which are relatively complex.

The basic thought of AHP model is to classify all the factors in the research problem according to different hierarchies through analyzing various factors contained in the complex problem and their relationships. After marking the relationship between those factors in upper and lower levels, the multi-hierarchy structure can be built. The pairwise comparison matrices will be built based on the determined weight of each criterion. The score of each alternativewill be further determined, and so will the overall score (Mohammed, 2002). This will provide quantitative basis for decision-making problems.

2.4 Related researches

2.4.1 Path selection in China's multimodal transport

The proper path selection is the guarantee of the efficient operation of container multimodal transport.

Daniel Delling (2009) studied the optimal combined transport mode in a large-scale transport network. After setting the transport mode in some specific road sections and nodes, those in other road sections are properly allocated. With the method of access of nodes, he calculated the distance to the accessing node in each transport mode and limited the search to a smaller network without searching the road network. He finally found the shortest path and the transport modes it takes. His experience proved that the speed of this kind of method is 5 times quicker than that of Dijkstra.

Li Lei (2009) applied AHP model in his paper to take uncertain factors into consideration during the process of path selection. He chose the path of transporting a TEU container from Zheng Zhou to Rotterdam as the research subject. 5 paths are chosen to be valued. After analyzing the results of the modal, he found that the path from Zheng Zhou to Qing Dao port and then to Rotterdam is the best alternative. That is to say, Qingdao port is the most suitable transshipment port.

Liu Yuan (2014) combined the quantitative and qualitative method to study the path selection of multimodal transport. EAHP modal is used in his paper to analyze various factors which affect the path selection. He believed the path selection is the key issue related to transport expenses and time. And such ideas can also be found in the article written by Xie Fang, Zhang Nan, and Ji Shouwen (2006).Ma Caiwen (2006) mentioned in her article that one of the efficient ways to make sure the operator can control transportation information in different segment under multimodal transport is to build the service network of container transportation enterprises. The multi-agent technology is used in his article to implement scientific path selection.

Shang Lingyun (2009) introduced the container multimodal transport corridors in Chongqing and analyzed the flow direction of cargos in Chongqing. She also made precise prediction to the container quantity using grey GM (1, 1). With AHP modal and vague comprehensive evaluation, she built the evaluation system on the container multimodal transport exporting corridor and made comprehensive evaluation on 8 exporting routes. In addition, the optimal multimodal transport path was selected. Based on the results, she analyzed the existing problems of each path and made proper suggestions to support the further development of each corridor.

Han Zengxia (2011) built the optimal modal with a time constraint based on the consideration of transport path and transport mode. The modal is aimed at minimizing the total cost of multimodal transport. And she transformed it into a shortest path modal with a time constraint and gave the solution to the modal. Besides, she took a container multimodal transport as an example to analyze the effect of container transit time on transport path and transport mode. Her results could help container multimodal transport operators and cargo owners make better decisions.

2.4.2 Carrier selection in China's multimodal transport

There are often alternative carriers in the same transport fragment, thus the multimodal transport operator have to choose the separate carrier in a scientific way to make sure the transportation can be completed safely and efficiently.

Wang Lisha (2011) proved in her paper that the analytic hierarchy process is an efficient way to solve carrier selection problem. She built the evaluating indicator system of the separate carrier in container multimodal transport and built the pairwise comparison matrices to estimate their weight. Four criteria are chosen to be valued and weighed in her article.

Qu Jianglei (2015) also made some research on the choice of fragmented carrier under multimodal transport. Based on the requirement of transportation, he used FAHP model to analyze the carrier selection. And transportation cost, transportation time as well as transportation are considered to be the factors which are needed to be valued.

Liotta (2014) mentioned that the operator and carrier in multimodal transport can contribute to define sustainable operations in both economic and environmental aspects. The cooperative decision-making setting and integrated optimal simulation approach was proposed in his article. And he concluded that service level improvements and transport cost reduction can be achieved through collaboration based on shared modal capacity between carriers.

Liu Guangche (2006) adopted the agent technology in the selection of carriers in various sections of the entire multimodal transport process. The carrier can be selected scientifically with the negotiation of multi-agents. He built the Java-based agent framework and designed the sub-carrier selection system according to the multi-agent model. Besides, he developed the prototype system of choosing various carriers in different segments of the multimodal transport.

Liu Jian (2015) analyzed the sub-carrier selection problem of multimodal transport based on two-stage theory. The game theory and decision theory are involved in his comprehensive evaluation modal. The risk attitude factors and the influence of incomplete information are considered in the initial stage of choosing qualified carriers. The sealed-bid mechanism and cost consideration are used in the final decision of selecting multimodal transport carriers.

2.5 Summary

In this chapter, it studies the situation of existing researches on path selection and carrier selection. The definition and application of AHP modal is mentioned to serve for the understanding of model used in later chapters. Besides, researches on the related topic are listed to provide an overall review on the topic.

All in all, the research on the selection of the path and carrier in China’s multimodal transport still has room to explore deeply. And researches on China’s multimodal transport still have a long way to go.

Chapter 3 ANALYSIS OF MULTIMODAL TRANSPORT

Transport mode is the indispensable part when talking about multimodal transport. Thereby characteristics of different transport modes will be mentioned first. In this chapter, the current situation and existing problems of China's multimodal transport will be discussed through the comparison with occident multimodal transport.

3.1 Comparison between different transport modes

As previously stated, multimodal transport is the carriage of cargos by at least two modes of transport under the multimodal transport. It interconnects different transport modes of transport-land, sea, air into one complete process. Multimodal transport is the complementary and coordination between different transport modes. The diversification of transport needs and the limitation of different transport modes are driving the different transport modes toward a shared market. Each transport mode occupies a certain share in the existing multimodal transport market. The differences of economic and technical effect among various transport modes make it an inevitable situation that any transport mode will have the advantages in certain aspects while having drawbacks when providing transport services. When a single transport means cannot gain satisfaction in all aspects, the combined service which can better to meet the transport requirements will emerge. Nowadays, economic globalization is calling for increasingly pressing needs on high transport speed, high quality and high efficiency. The container multimodal transport is deriving from these requirements. As is stated before, container is the embodiment of multimodal transport. Container multimodal transport system can enhance the aggregation of social economy and benefits of economies of scale. It also strengthens the link between the economic system and its subsystems. Container multimodal transport, which is based on system integration and supply chain and the collection system of modern information technology, is the development patterns and trend of modern logistic. Thus the diversity of transport modes is a necessity in developing multimodal transport.

However, if any of the transport modes is backward or any insufficient and unreliable link between different modes happens, the multimodal transport development can be hindered. Therefore, it becomes crucial for multimodal transport operators to choose proper transport modes during the whole multimodal transport. In the next few sections, the analysis of different transport modes will be covered to make it easier for multimodal transport operators to choose transport modes.

A. Railway transport

Rail transport has massive transit capacity with low transport costs. A freight train is capable of carrying 3000-5000 tons of goods which are much more than air transport and highway transport. Transport cost of railway transport is slightly higher than that of inland waterway and sea transportation, but is much lower than highway transport and air transport. In America, railway transport cost is 1/7 of highway transport and 1/18 of air transport respectively (Moccia, 2011). Besides, it can guarantee the continuous transportation due to its fixed track which is seldom affected by weather. The transport speed is around 80-120 km/h which is significantly higher than sea transport. In terms of the environment effect, the pollution ratio of railway transport is 3.9% which is 1/3 of air transport (10.9%) and 1/20 of highway transport (79.9%) (Wang Jinhua, 2010). The pollution mainly comes from burning of fossil fuel which can generate electricity. Although its environmental effect is inferior to that of sea transport, the pollution can is easy for integrated processing which may turn waste into energy.

However, railway transport also has its drawbacks. The transport time is often fixed and is lack of elasticity. That is to say, it can hardly meet the urgent requirements of clients. Apart from this, huge investments are needed in the railway infrastructure construction. And the maintenance and operation costs are considerable. The noise which may affect residents nearby cannot be neglected.

B. Road transport

Road transport can provide flexible and diversified services. It is widely used in door-to door service of high value and small volume cargos. The economic radium is within 200 km (Wang Jinhua, 2010). One distinct advantage of road transport can be its transport speed which is exceeded only by air transport. The speed can be several times higher than that of railway, waterway transportation. Road transport can choose different driving routes due to its flexibility. The transport time can also be arranged according to specific needs. In addition, road transport can realize “door to door” transportation without too much transshipment.

On the other hand, road transport has limitation in transport capacity owing to the volume of trucks. Thus it cannot transport large quantity of various goods and bulky cargos. Besides, compared to other transports modes, it has higher transport costs and larger energy consumption. The environment pollution caused by road transport is more serious than other transport modes.

Based on its characteristics, road transport is recommended to bare medium- and short-distance transportation. It can serve as the complementary and convergence of other transport modes likes sea transport and air transport. It is widely acknowledged that some transit commission cannot complete by certain transport mode like sea transport for some areas vessels cannot reached to. Under this circumstance, road transport can serve as the beginning and end section in the whole multimodal transport process. It is suitable for the container extraction and transportation in short distance. In view of the service level, inland transport service means a lot to shippers. The reliability of inland transport system may decide the efficiency of global trade. Most logistic enterprises who care more about time and services will place great importance on road transport.

C. Waterway transport

Waterway transport is compose of two parts—inland waterway transport and sea transport. Vessels, channels, ports and berth and so on are necessary components in waterway transport. Compared with railway transport and road transport, waterway transport has the distinctive advantage on transport price. The price of waterway transport accounts for 70-80% of railway transport and 50% of road transport respectively (Beresford, 2011). And the longer the transport distance is, the more obvious its price advantage will be. River and sea have offered waterway transport the natural channels. Thus the investments on the route construction are relatively low.

The investments per kilometer on the channel are estimated to be 1/5~1/10 of road transport route. According to the research, the average construction expenses of inland channel are 1/10 of highway construction and 1/100of railway construction costs. The inland waterway transport cost is around 1/5 of railway transport and 1/35 of railway transport. Another advantage can be its huge transport capacity. The capacity of the inland vessel is 3-5 times larger than that of a freight train (Cui Ligang, 2009).

The characteristic of vessels decide the slow transport speed of waterway transport. The speed of waterway transport is much lower than that of road and air transport. The volatility of waterway transport is high. The reasons can be attributed to the effects of weather and seasons. And it can also be limited by natural channels. The shipping and handling process can often be interrupted by bad weather condition. Thereby, the delivery time can be affected to large extent. And safety issues are often considered by multimodal transport operators not only because of the weather risk, but also the high percentage of current funds for the large cargo volume carried.

D. Air transport

Air transport is the existing fastest transport mode with the coordination of airplanes, airports and navigation equipment, etc. Currently, the speed of air transport can reach to more than 1000 km/h.During the fight process, it can hardly be affected by obstacles on the ground. Thus the straight flight line can be ensured. This is also the reason of high speed of air transport. And areas that other transport modes cannot reach to can be realized. In terms of the infrastructure, the cost is much lower than railway construction. ￥500 million and 10,000 hectares land are needed in developing a 1000 km civil flight path while 2 billion and 45,000 hectares are required in developing same length of railway path (Kazan,2013).

However, the transport cost of air transport is the highest among these transport modes. The fuel consumption of air transport is extremely high. It is estimated that fuel consumption/km of airplanes is 10 times more than that of trucks and 6.6 times than trains. That is why air transport will cause serious environment problems including air pollution and noise pollution. And air transport can easily be affected by certain weather condition. In addition, the transport capacity of air pollution is small.

Thus its transport cost/ton-km is high, which is 7 times higher than road transport, 18.6 times than railway transport and 146 times than waterway transport (Cui Ligang, 2009).

For the purpose of clearance, the comparison of economic and technical characteristics will be shown in table 3-1. The characteristic of infrastructure construction investments will be transformed into scores which can be easily measured. The higher score interprets the larger investments.

Table 3-1: Characteristics of different modes of transport

Transport modes	Infrastructure Construction investments	Transport capacity	Transport cost	speed	continuity	flexibility
Road	3	small	high	high	best	best
Waterway	1	largest	lowest	lowest	poorest	poorest
Railway	4	large	low	relatively low	good	relatively poor
Air	2	smallest	highest	highest	poor	good

(Source: *Asian Journal of Shipping & Logistics*)

Based on the discussions above, multimodal transport operators can choose their preferable transport modes in the selected routes. However, as is mentioned previously, 1 TEU cargoes will be transported in the following discussion and air transport is not suitable for transporting containers. Hence only road, water and rail transport will be considered when multimodal transport operators choose the transport paths.

3.2Occidentmultimodal transport

Multimodal transport has witnessed rapid development over the years and has formed its own distinct features. The following contents will analyze the features of its development.

a) The volume of multimodal transport in western countries has maintained a sustained and fast growth. And there is still spacious room for its development. In 2007, the total multimodal transport volume in Europe 96 billion ton-kilometers. And it is estimated that it will increase to 306 billion ton-kilometers till 2030. The volume in America has increased from 0.217 to 1.62 ton-kilometers during 1997-2011. This number is expected to reach to 3.575 tons in 2040, accounting for 12.5% of the total freight volume. The value of multimodal transport freight will reach to $ 1 trillion till that time, accounting for 25.3% of the total value of cargo transported. Besides, multimodal transport has obvious advantages in long-distance and high value added cargo transportation. Nowadays, most ports are devoting to developing sea-rail transportation. For instance, the collector-distributor volume of sea-rail transport in port of Bremen has increased from 35.9% to 45.7% during 5 years (http://www.moc.gov.cn).

b) Road-rail transport has been the main way of multimodal transport. The proportion of road-rail, road-water, and rail-water transport in America is 53%, 34%, 13% respectively. And the corresponding turnover is 57%, 29%, 14% respectively, which indicates that the COFC/TOFC is the main mode of multimodal transport. The situation is similar in Europe. For instance, the road-rail transport in German remains an annual growth of 7-8% in recent years (http://www.moc.gov.cn).The largest logistic enterprise, DB Schenker, has accomplished the “door to door” transportation of 400 million TEUS in 2011. Of the total volume, road-rail transport accounts for 66% while the sea-rail transport only accounts for 34%.

c) Drop-and-pull transport has become the basic link in multimodal transport. Since the Occident emphasize that the multimodal transport is the seamless transportation based on the standardize transport unit, the dumping trailor transportation is the basic requirement of the transshipment among different modes of transportation. More than 70% of the cargo volume in large logistic companies is completed through drop-and-pull transport.

d) The multimodal transport station and the collection and distribution system are well established. America not only has the developed transport infrastructure, but also has the sound multimodal collection and distribution system consists of dedicated line, hubs and terminal nodes. Taking Chicago as an example, as the most important multimodal transport hub as well as the center of cargo collection and distribution in America, Chicago gathers the rail line of 1448 km and 125 rail converging points (http://www.moc.gov.cn). It is also the largest inland cargo and air traffic center in America. Thanks to the unique traffic advantage, Chicago has developed 28 major multimodal transport hubs, which attract most logistic enterprises from all over the world.

The US Department of transportation has made comprehensive assessment on the national ports, airports, roads and rail hubs, etc. And it finally determines 517 multimodal logistic nodes(See table 3-2). To ensure the collection and distribution of these nodes, the government builds 1222 miles road special line for 616 nodes. For those nodes with large amount of cargo volume, several collection and distribution lines are ensured. For other nodes, they are ensured to connect with the road network seamlessly.

Table 3-2: The type and quantity of US multimodal transport nodes

Multimodal transport nodes	quantity	Distance of road line (mile)
Ports (Ocean and River)	253	532
Airports	99	221
Truck/Rail Terminals	203	354
Pipeline/Truck Terminals	61	115
Total	616	1222

(Source: document of China's multimodal transport demonstration projects)

e) The market system of multimodal transport is relatively perfect. Under the policy-oriented multimodal transport and deregulated transport market, America has formed market participants which can be adaptive and promotive in multimodal transport. There are around 45,000 multimodal transport enterprises which can sign ”Through Bill of Lading” and select high quality transport service and economical transport mode for customers. In terms of railway, America has formed 5 main railway freight enterprises, which are the pioneers and main carriers of American road-rail transport. In terms of road transport, it has experienced restructuring and formed several large enterprises with assets of thousands of trucks. The largest logistic company in the world, Federal Express, has developed service of TAT (truck-air-train). And it establishes 1200 service stations and 10 air transshipment center all over the world (http://www.moc.gov.cn).

f) Application of advanced technology. As multimodal transport is related to various transport modes and covers wide geographical scope, it becomes especially crucial to monitor information during the transportation. In most developed countries, advanced information network are available for multimodal transport services. For example, highway, railway and port have their own information network which can communicate with each other during the process of transportation. Containers are transported from Frankfurt to the railway transshipment station by truck. And then they are transported by train to port of Hamburg and are exported through sea transportation. Once the container is loaded on the truck, the port can monitor it through electronic information network and know when the containers will arrive at the port. Thus staff of the port can arrange the shipping. Another example is Canada's extensive use of computer technology and information sharing in all aspects of multimodal transport. This provides a favorable channel for multimodal transport. Main ports and stations in Canada widely adopt the technology of EDI and realize paper-free transmission which can significantly improve the transport efficiency. Some companies also introduced the GPS (global positioning system) to monitor cargos during the whole transportation process.

g) Flexible price of multimodal transport. Reasonable pricing of various transport modes can improve the efficient utilization of scarce resource like transport capacity. For instance, the Government of Canada prices based on the facilities marginal cost in order to encourage the efficient use of facilities and to prevent the waste of resource. This kind of pricing can enable different transport modes coordinate and cooperate with each other in whole transportation process. Governments in German and Netherland do not intervene the price of container multimodal transport. The decisive factors are the market demands and transport volume and so on. Railway transport can bargain on the container transportation price with consignment companies according to the container volume transported. And it has gained the market thanks to the flexibility. In view of the government, it only macro-controls the multimodal transport prices.

3.3 China's multimodal transport

3.3.1 Current situation

At present, China's multimodal transport has gained development and popularity to some extent except Tibet. It has formed a network combining four lines of Beijing-Guangzhou, Beijing-Shanghai, Longhai, and the Yangtze River with five parts of North, East, South, Southwest, and Northwest of China. The container multimodal transport has developed a lot. Shipping companies dealing with containers has reached to more than 150. And more than 40 ports have container handling operations. Cargo transfer mode can be door to door, door to port, and port to door, etc. And some other situations of China's multimodal transport can be found in the article written by Fan Runjie (2010). China has been developing the demonstration project on the development of multimodal transport. The first and foremost thing is to solve the path and carrier selection problem, which is also the technical issue.

3.3.2 Exisiting problems

Guo Qin (2010) has pointed out some existing problems in her article. There are many problems which impede China's multimodal transport from moving forward. The most important problem is the incomplete infrastructure. Containerization is most common form in multimodal transport. And this requires high quality of infrastructures. However, in most developing countries, including China, few funds are put into the construction of multimodal transport.Zhang AnFu (1994) discussed in his article that the backward information system and technology has always been a problem in China's multimodal transport. And the information cannot be transferred instantly between districts, departments, etc. Yang Leru (2010) also talked about the obstacles in his paper. There is no complete policy and regulation secure, especially when cargo lost and damage happens.

The inland waterways in China are still at the natural state and the high-level deep-water channel is only of little proportion. Most of the inland ports have poor handling equipment with low efficiency. Some seaports don't have enough water depth which may affect the berth capacity. They cannot adapt to the tendency of larger container vessels. For the railway, its density in China is 1/3 of that in America, 1/5 in Japan, and 1/3 in Russia(http://www.moc.gov.cn). Besides, the modern transport means is backward and the automatic operation management is still at its primary stage. In view of road transportation, the overall technology for highway is relatively low. And the traffic capacity is poor, so is the density of highway network. For air transport, the transport facilities in main airports are inadequate for both cargo and passenger transportation. The communication and navigation technology in air traffic control also lags behind.

Overall, the facilities and technologies of transport in China are relatively poor. Thereby, it cannot adapt to the sharp increase of transportation demands. What's more, the information system supporting multimodal transport service and management has not formed yet. This indicates that the efficiency and quality of multimodal transport service is still poor.

The multimodal transport system is not well coordinated. Different modes of transport are managed by different departments in China. There is no agent which can efficiently manage and coordinate the whole transport system. In addition, insufficiency still exists in the combination of different modes of transport. Nowadays, most of the containers are transported through sea-road transportation. However, unified multimodal transport operation network has not formed yet. Problems also exist in the combination of railway with sea and inland transport, including the incomplete collection and distribution system, poor handling equipment, lagging delivery of documents and information, etc.

3.4 Summary

In this chapter, different transport modes are compared firstly. This can provide multimodal transport operators with intuitive understanding when choosing transport modes in certain transport tasks. Secondly, the development and situation of multimodal transport in western countries are listed. From the current situation of China's multimodal transport, the existing problems are easily found. In the end of the dissertation, this thesis will offer some suggestions on China's multimodal transport in accordance with the existing problems.

Chapter4 PATH SELECTION

The selection of path and carrier of multimodal transport in this thesis is based on the standpoint of multimodal transport operators. During the process of multimodal transport, the operator is the core of the contract, in both internal and external relationship. He is in the hierarchy contract relationship with cargo owners and actual carriers. First, the multimodal transport operator has signed combined transport documents with cargo owners and complies with the obligation of the whole transportation according to the contract. Second, when the multimodal transport operator completes the whole multimodal transport with the help of carriers in several segments, he has constituted the contractual relationship with other related transport parties. Finally, there is no direct contractual relationship between cargo owners and actual carriers. After considering the actual carriers, multimodal transport operator will sign multimodal transport contract with cargo owners. For cargo owners, most of them only care about the transport time and transport costs since multimodal transport operator is the main body of the contract. However, from the viewpoint of multimodal transport operators, they have to take various criteria into consideration. The criteria will be discussed in the following section. In this chapter, 8 paths will be chosen as the objects. 4 are from Chengdu to Shanghai and 4 are from Guiyang to Shanghai.

4.1 Consideration of criteria in path selection

Generally, multimodal transport operators will take the following factors into consideration when making decisions on transportation.

1) Economic factors

- Transport cost

For multimodal transport operators, transport cost is actually the total expenses of transporting cargoes to the customers. They usually choose the means of transport which they can afford the expenses according to the price of transportation. Transport costs may decide the competitiveness of a multimodal transport company. Thereby, it is the decisive factor in multimodal transport. The freight can consist of transport costs, handling charges, waiting costs, and inventory costs if needed, etc.

- Transport time

For multimodal transport operators, the transport time have a lot of things to do with delivery time. Therefore, they have to choose proper transport means according to the date of delivery. For multimodal transport operators, not only the transport time in separate sections is included in total transport time, but also the transshipment time and necessary inventory time. For example, New Eurasian Continental Bridge is often considered as the fastest and cheapest transport corridor connecting Asian-Pacific region and Europe. The transport distance by sea is 19889 km from Lianyungang in China to Rotterdam while the land transportation distance is 10990 km(Fan Runjie, 2010). And the speed of train is much higher than that of vessel. Theoretically, transport time can be shortened through land transportation. However, calculating with the transport speed regulated by China's railway department, the time from Lianyungang to Alashankou is 18 days. And after leaving China, each country needs at least 2 days for customs clearance, inspections, etc. According to preliminary calculation, full container transportation by train needs more than 30 days from Lianyungang to Alashankou while 25 days are actually needed if transported by sea (Fan Runjie, 2010).

2) Technic factors

- Transport quality

Transport quality mainly refers to no cargo damage or lost. During the process of transportation, cargoes may be damaged more or less due to force majeure like bad weather and waves. High quality transport path can reduce the possibility of cargo damage or lost. Thus multimodal transport operators have to consider the quality of transportation when choosing path.

- Service level

Service level of multimodal transport route mainly includes condition of port facilities, service quality of ports and station, instance of transport information, etc. The longer cargos stay in ports, customs, and yard and so on, the higher transport expenses will be and the lower the competitiveness of multimodal transport enterprises will be. In modern society, the smooth flow of transport is of vital importance since it can guarantee operators to monitor the transport conditions of goods and to make quick responses to emergencies. That is why service level of transport route is necessary in the selection of path.

3) Social effect

- Resource utilization efficiency

Resource utilization efficiency requires taking full advantages of transport resources, including existing facilities and inland water channel.

- Environmental effect

During the process of transportation, the air, water, soil, animals and plants will be adversely affected, and other natural landscapes and historical sites will be destroyed to some extent. The multimodal transport operators tend to choose paths which will do little damage to the environment.

Overall, the evaluation criterion with multi-hierarchy can be built. (SeeFig 4)

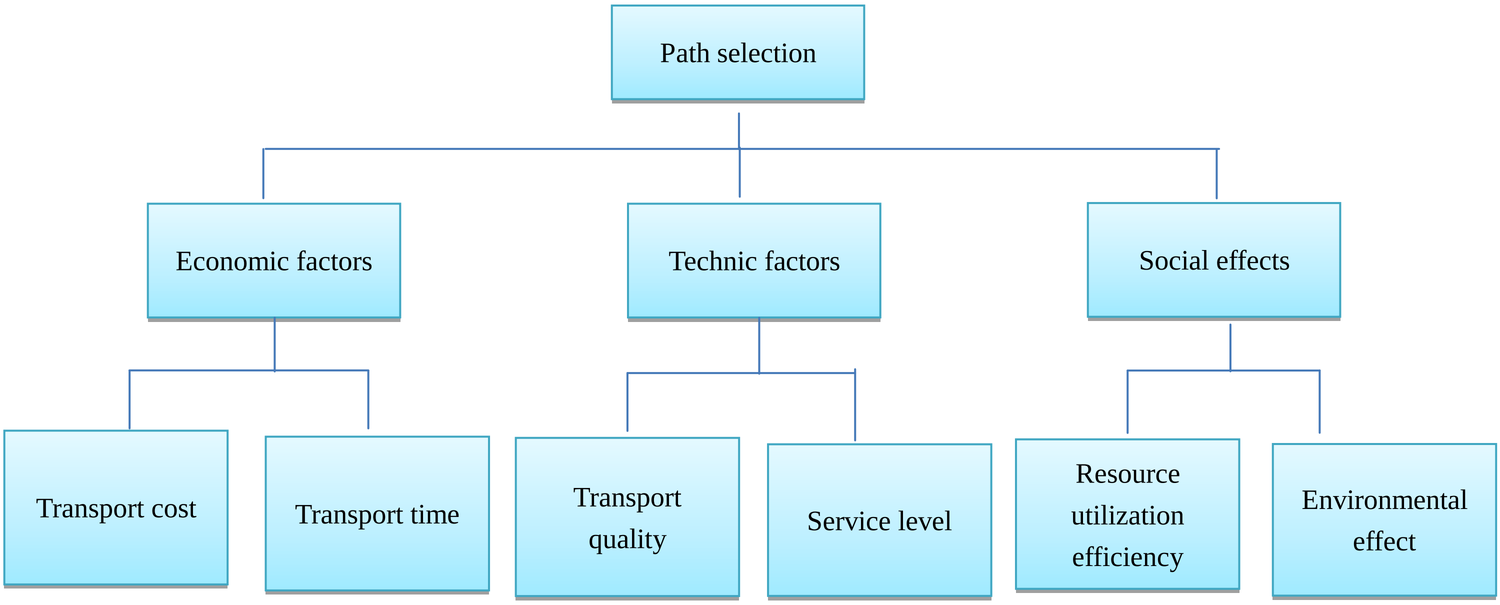


Figure 4: evaluation index of path selection of multimodal transport

(Source: self-presentation)

Path selection will be more simplified if only one criterion is considered. For example, a cargo owner who only cares about transport time will choose the fastest transport tool and the shortest transport path. However, in fact, this ideal situation can hardly exist. Multimodal transport operators have distinct advantages over cargo owners and actual carriers. Thanks to their previous relationship with cargo owners and shippers, multimodal transport operators have more abundant source of goods than a single cargo owner. And their service level is higher than that of sub-carriers. The multimodal transport operator is qualified to be engaged in the multimodal transport services. And they have sufficient capital to be involved. Besides, they can have special relationship with customs, hence more flexible in clearance. The factors considered above are all linked to each other and affect each other. Multimodal transport operators will consider their preference when making decisions. They will seek for the best on the factor which they regard as the most important and put less importance on those less important. However, if simply eliminating other factors, the results will be one-sided, which is not the proper path in multimodal transport. In view of the advantages of multimodal transport operators, the evaluation and selection of path and carrier will be affected.

4.2 Basic steps of AHP model

a) After determining the objectives of the decision making, classify the criterion which affect the objective and build a multi-hierarchy model.

b) Build Pairwise comparison matrix A to obtain the weight of each criterion. The entry in row i and column j of matrix A is labeled as a_{ij}. And this indicates the importance of the criteria. It is measured on an integer-value 1-6 scale which represents different importance that i is over j. The interpretation is shown as follows (table 4-1).

Table 4-1: interpretation of the value of importance

Value of a_{ij}	Interpretation
1	i is as important as j
3	i is slightly more important than j
5	i is strongly more important than j
7	i is very strongly more important than j
9	i is absolutely more important than j

(Source: decision-making techniques)

After building the matrices A, there is need to normalize it to get A* using the formula below.

$$a_{ij} *= \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

And weight for objective i has to be estimated using the following formula, as the average of the entries in row i of A*.

$$W_i = \frac{\sum_{j=1}^{n} a_{ij}}{n}$$

c) Check for consistency and correct the matrix if necessary.

First we have to compute AW ($AW=A^* W_i$). And then calculate $\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$. And constancy index(CI) needs to be computed. $CI=\frac{\lambda_{max}-n}{n-1}$.

The constancy index should be compared to the random index (RI) to see whether the consistency is satisfactory. (CR=CI/RI) The random index can be referred to in the following table4-2.

Table 4-2: Random index table

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

(Source: decision-making techniques)

When CR<0.1, it indicates that it passes the consistency checking.

d) Determine the scores of each alternative on each criterion and calculate the overall score for each alternative.

4.3 Background of routes studied

4.3.1 Reasons of the routes selected

On one hand, Chongqing is the important port in southwest of China and is also the biggest economic center of the upper reaches of Yangtze River. It is the integrated transport hub of eastern developed regions and western region with abundant resources. Connecting the west and east, as well as linking to the south and north, Chongqing has been the logistic center of southwestern region. It gathers the cargo volume in Sichuan, Yunnan, Shanxi, Guizhou province, etc. And as is shown in the following picture (Fig. 4-1), the cargoes mainly flow to the Yangtze River Delta region and then export to foreign countries. However, Yunnan is close to Guangxi, which means cargos in Yunnan will flow to Guangxi and then export due to the low transport cost in Guangxi. Therefore, in this thesis, the southwestern region mainly focuses on Chengdu and Guiyang.

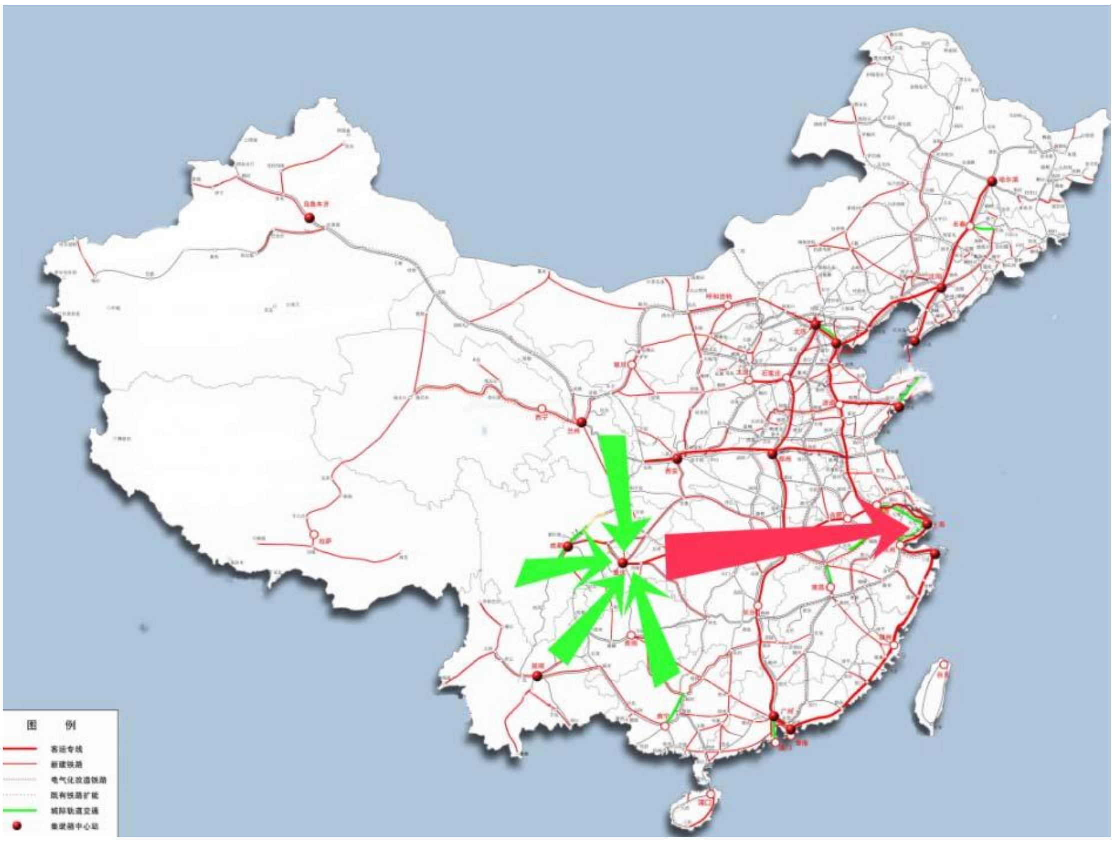


Figure 4-1: Cargo trend taking Chongqing as node by Yangtze River Delta corridor (Source: Chongqing transport ministry)

On the other hand, the Yangtze River Delta has formed integrated transport system with various transport means flourishing, including highway, railway, waterway, aviation, etc. (shown in Fig.4-2). The international shipping center which is bibcock with Shanghai has obtained certain achievement. And it promotes the international economic activities in Yangtze River region. And this dissertation will take Shanghai as export node to discuss the multimodal transport in China.

The cargoes will flow to Yangtze River Delta region from southwestern region and then export to Rotterdam. From Shanghai to Rotterdam, sea transport will be preferable. Thus in this thesis, the transportation from Shanghai to Rotterdam will not be considered because the criteria are the same for 8 paths (4 are from Chengdu to Shanghai and 4 are from Guiyang to Shanghai). That is why we only discuss the transport segment in China. The subject transported is a container of cargos (1 TEU). In this dissertation, 2 cases will be considered. One is transporting 1 TEU cargos with low value and low urgency and hence no special needs for the transport time. The other is transporting 1 TEU cargos with high value and high urgency. The cargo owner has special needs for the transport time. Thereby various routes can be considered as selected objectives.

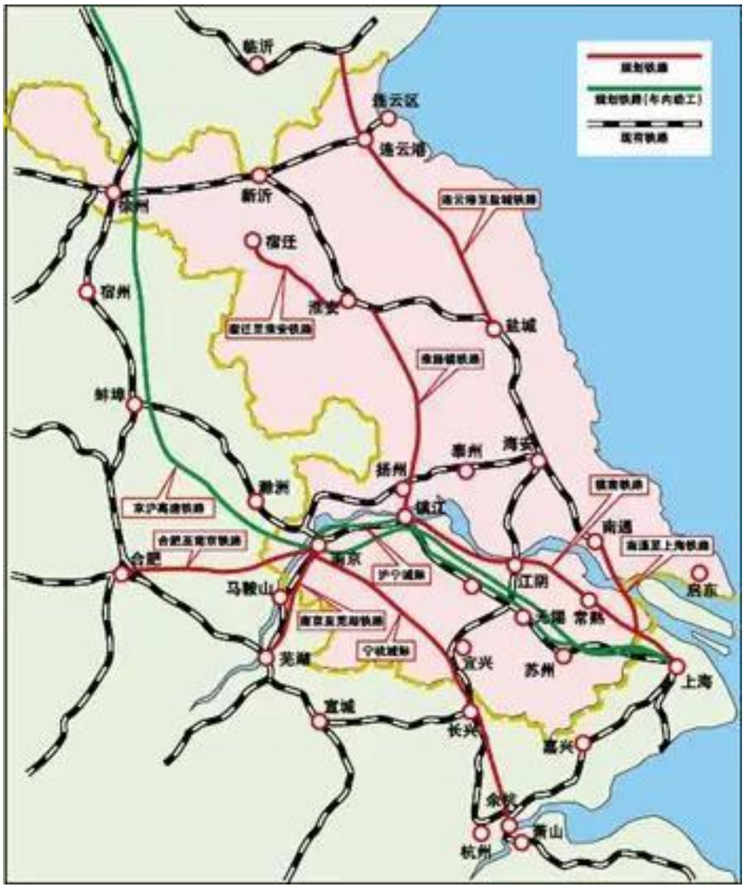


Figure 4-2: Transport network in Yangtze River Delta

(Source: transport plan in Yangtze River Delta)

4.3.2 Condition of transport modes in southwestern China

Chongqing is chosen as the node of multimodal transport routes in this thesis, thus the situation of transport means in Chongqing will be mainly introduced. Besides, air transportation will not be covered here.

1) Water transport

- The Yangtze River is the only waterway transport corridor throughout the eastern, central and southern China. (See Fig. 4-3) It is also the bond which links southwestern regions to central eastern areas. And it serves as the important basis of economic development and opening up in Chongqing. Due to the geographic advantage and abundant traffic resources, Chongqing has experienced vigorous development in waterway transport.

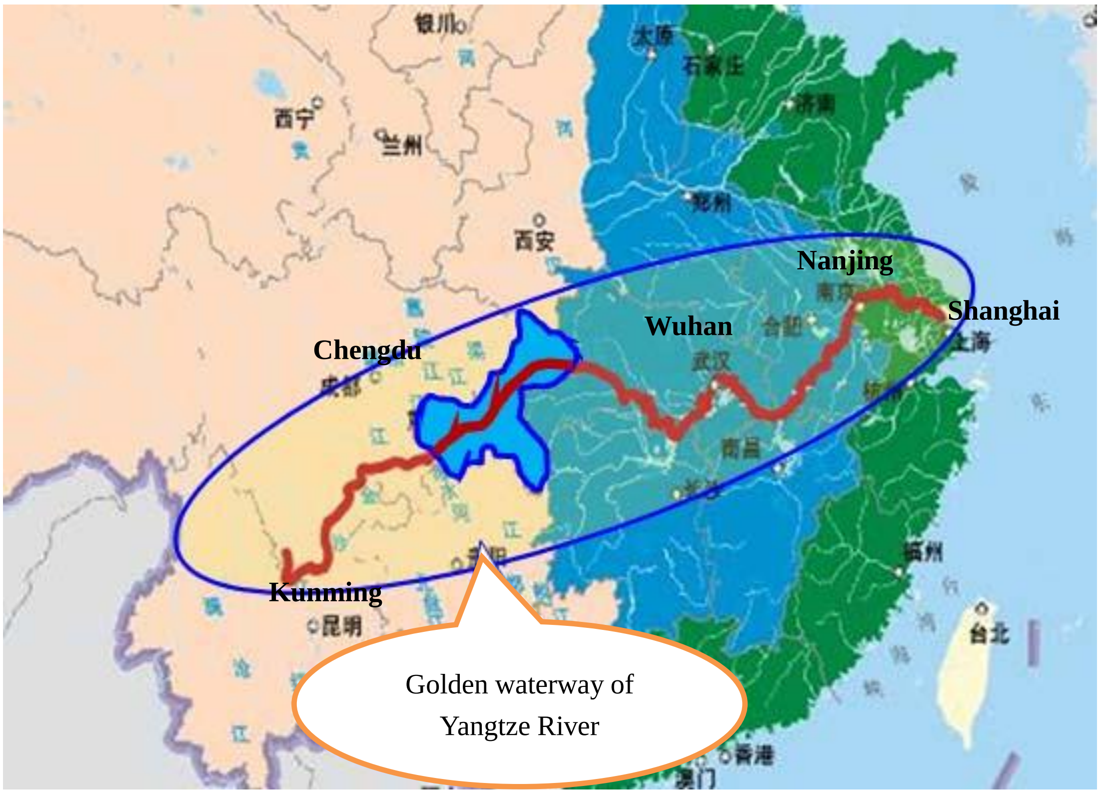


Figure 4-3: Golden waterway of Yangtze River

(Source: Thoughts of developing multimodal transport in China. *Logistic Engineer and Management*)

The city of Chongqing is built by the water, thus it has the superior advantage of developing water transportation. The leaf vein-like channel system consists of the Yangtze River, Wujiang River and other high-level channels runs throughout 70% of the city. It stands as the bridge between the east and the west and plays an important role in the comprehensive transport system in southwestern region. In the western development and economic construction of upper reach of the Yangtze River, Chongqing has contributed a lot. In addition, Chongqing is one of the main shipping hub ports in the country as well as the biggest port city of the upper reaches of the Yangtze River. It is regarded as the significant transport hub and foreign trade port of multimodal transport and land-sea transshipment in southwest of China.

- Condition of inland waterway

Till now, Chongqing has 136 channels including the Yangtze River, the Jialing River, the Wujiang, etc. with a total mileage of more than 4337 kilometers which covers more than 70% of the city's districts and counties. During the period flood, the Yangtze River can bare the passage of 4000-ton vessels. It can bare the pass of 2000-ton vessels in dry season. Since 2010, Chongqing has built the channel system of “one trunk and two branches”, which indicates that the Yangtze River is the main channel while the Jialing River and Wujiang are the branches. (See Fig. 4-4) what’s more, the grade of waterway channel has been improved. According to the statistic, the mileage of primary channel has reached to 527 km (Ma Haifeng, 2015).

Figure 4-4: Inland waterway of Chongqing

(Source: International Journal of Operations & Logistics Management)

- Port construction

Harbors of Chongqing are made of 3 hinge ports including main city, Wanzhou and Fuling, 5 key ports including Jiangjin, Yongchuan, Hechuan, Fengjie and Wulong, 12 county-level ports. (Shown in Fig. 4-5) The annual cargo throughput can reach to 64.34 million tons. To meet the needs of economic development in Chongqing, the specialized transport system of containers, bulk cargos, ro-ro transport, etc. is built.

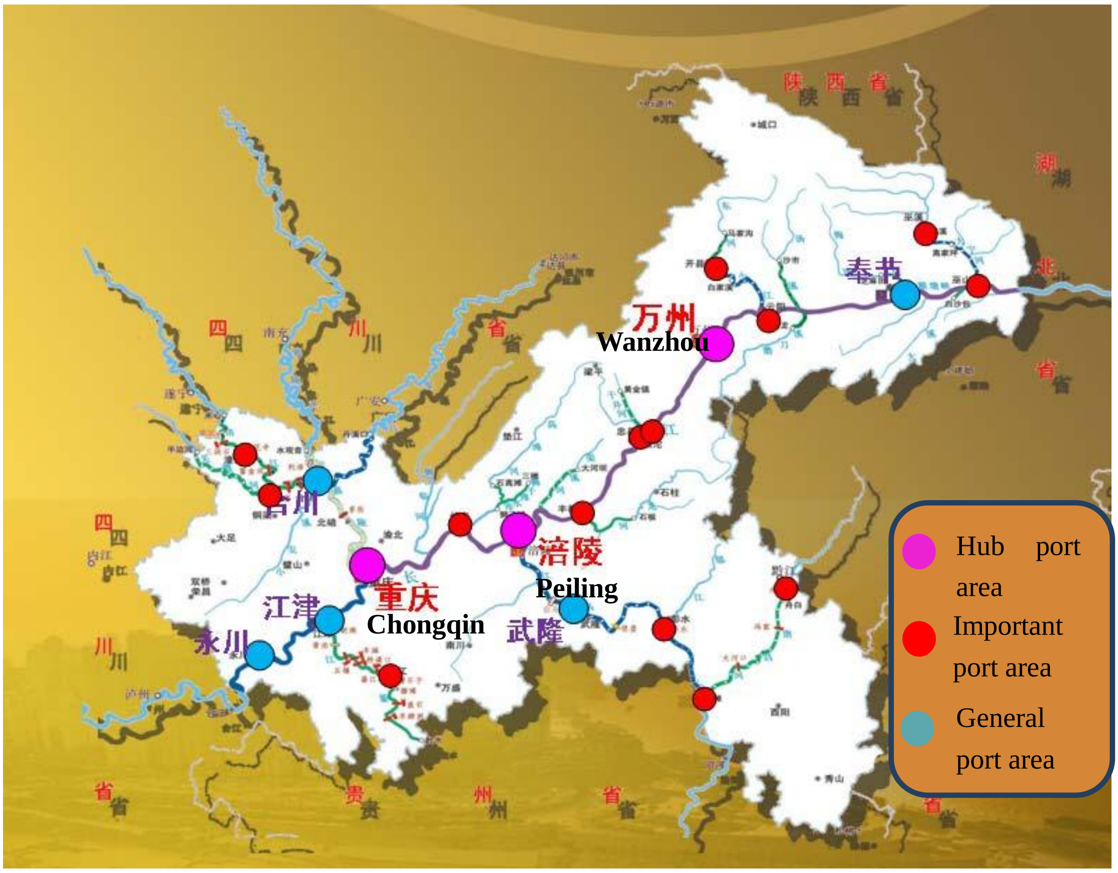


Figure4-5: Inland ports distribution in Chongqing

(Source: International Journal of Operations & Logistics Management)

2) Highway transport situation

- Chongqing has constructed 2000 km highway with the density of 2.4 km/100 km2, ranking the first in cities of China. In 2015, the highway mileage has reached to 3200 km which is in tandem with density of road transportation in European countries. It takes only 4 hours to the peripheral areas and 8 hours to coastal areas. (Shown in Fig.4-6) It is estimated that “two ring eight short” highway transport system will be completely built before 2020. And the highway mileage is expected to reach to 3600 km in 2030.It can link to Chengdu-Chongqing Economic Zone in communication, the Yangtze River Delta, the Pearl River Delta, Southeast Asia and other regions.

Figure 4-6: Distance from Chongqing to peripheral cities

(Source: Chongqing Transport Ministry)

- Container freight station of road transportation in Chongqing has lagged behind for years. There is even no container freight station in real sense in Chongqing. Most of the transshipments of containers in highway transportation are accomplished in the existing road freight station. There are 11 road freight stations in the city. And one of these is primary station.

3) Railway transport situation

- Chongqing is an important railway hub in southwest of China, with total railway mileage of 1257km and operational capacity of 7,500 tons. There isone hub

(Chongqing hub), six trunks (Chengdu-Chongqing, Chongqing-Guizhou, Hunan-Chongqing, Dawan, Suining-Chongqing, and Chongqing-Huaihua line) and two branches (Sanwan, Wannan line) in Chongqing.

According to the new positioning of building the fifth railway hub in China, Chongqing has formed intensive railway network. It has made the plan of "one hub, thirteen trunk lines, and three branch lines" with total mileage of 2144 km (see Fig. 4-7)

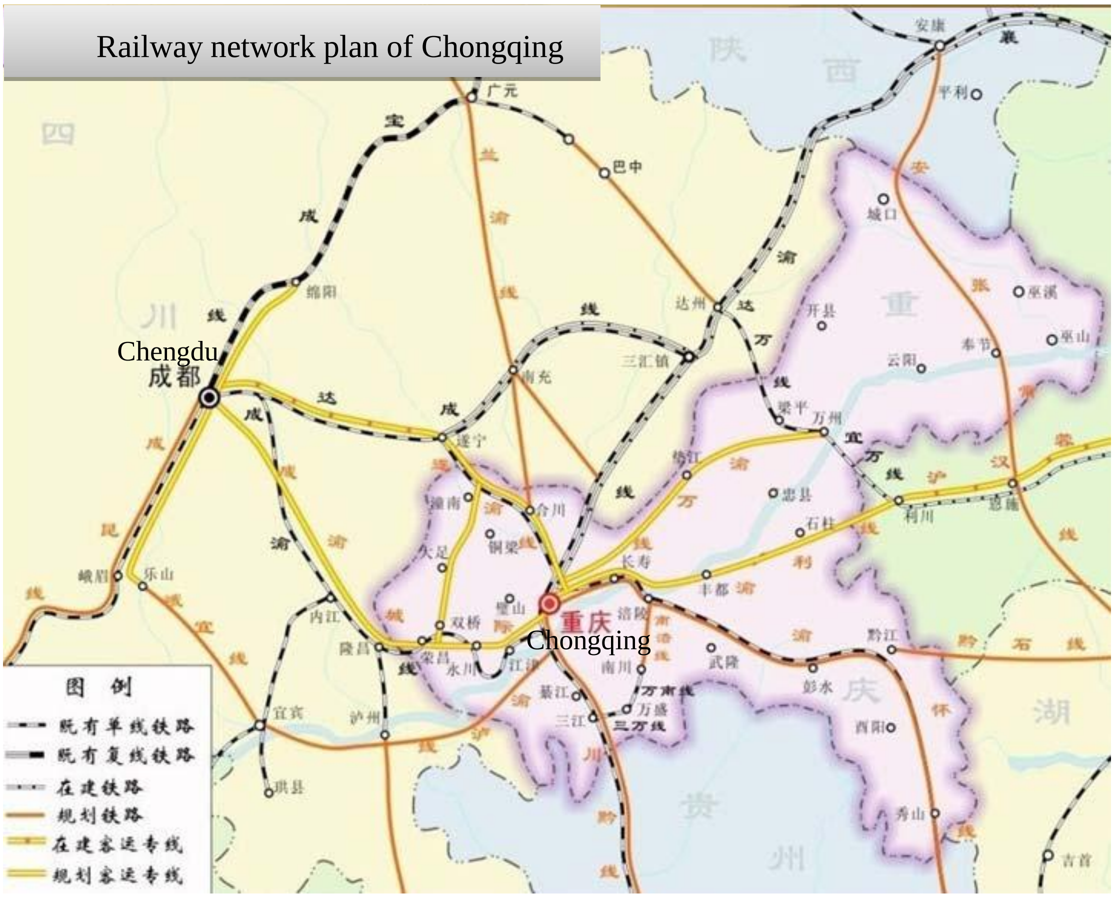


Figure 4-7: Railway network plan of Chongqing

(Source: Chongqing Transport Ministry)

- At present, there are 5 railway stations in Chongqing, including Chongqing station, east Chongqing station, south Chongqing station, west Chongqing station, and north Chongqing station. However, Chongqing station and north Chongqing station has not realized the diversion of cargos and passengers. Thereby the efficiency of the two stations is much lower than others.

- The operational ability is crucial for container freight station. It can be measured by yard capacity, operation lines, gantry crane and forklift capacity. The container freight station capacity of Chongqing is shown in the following table 4-3.

Table 4-3: container freight station capacity of Chongqing

Stations	Handing equipment			
	Yard capacity(TEU)	Operation line	Gantry cranes	forklift
East Chongqing station	700-800	3	3（50T，36T，32T）	14
South Chongqing station	200-300	1	2（36T，32T）	6

(Source: Chongqing railway service)

4.3.3 Basis of cost calculation

Container is the basic carrier of multimodal transport. Thus this thesis will talk about transporting a container (1 TEU) from Chengdu, Guiyang to Shanghai taking Chongqing as node. The costs involved in this thesis are mainly based on "Regulations of the People's Republic of China on Price Control", "Provisional Regulations of Rate Control of Motor Transportation", "Notice of the Ministry of Development and Reform Commission on the Adjustment of the Price of Railway Transport", "Charging Methods of Domestic Waterway Container port".

1) Road transport expenses often include three parts: transport costs between place of departure and destination, highway toll and intra-urban transport costs. According to the researches, the total cost of transporting a container by highway

is around $0.903/km.[1]

2) According to the <Notice of Price Adjustment of Railway Transport> published by Ministry of Development and Reform Commission and Ministry of Railways, the total expense of transporting a container is about $0.609/km.[2]

3) Road-water transport costs contain the highway transport costs, the transshipment fees and the water transport costs. Highway transport costs will follow that in item (1). Handling costs and intra-port transport costs are included in the transshipment costs which are around $94.94/TEU[3] according to the researches. Besides, the transport cost from Chongqing to Shanghai by water is $210.98/TEU.[4]

4) Rail-water transport costs consist of the railway transport costs, the transshipment expenses and the water transport costs. Railway transport costs will follow that in item (2). Based on the investigation information, the transshipment fee is around $99.46/TEU.[5]

4.4 Main paths selected

Since the water transport system is not well developed in Chengdu and Guiyang, this thesis will consider railway and highway as main transport means from Chengdu and Guiyang to Chongqing or Shanghai. In addition, the cargo will be transported from Chengdu and Guiyang to Shanghai and then be exported to Rotterdam. The transport segment from Shanghai to Rotterdam is the same in different routes, thus in the analysis we will only talk about the multimodal transport in China.

✧ Chengdu to Shanghai

Path 1: Chengdu----Shanghai(transported by highway)

[1] Provisional Regulations of Rate Control of Motor Transportation
[2] Notice of Price Adjustment of Railway Transport
[3] Regulations of the People's Republic of China on Price Control
[4] Charging Methods of Domestic Waterway Container port
[5] Regulations of the People's Republic of China on Price Control

- Transport time: The time from Chengdu to Shanghai had been shortened to large extent since the Shanghai-Chongqing Expressway was opened to traffic. The cargos can be transported through Chongqing-Chengdu Expressway and Shanghai-Chongqing Expressway. (see Fig. 4-8) The total distance of this route is 2018 km. And the whole transportation takes around 3 days.
- Transport costs: The whole transportation goes through several provinces and the charges in different provinces are diversified. As is mentioned before, the average costs of transporting a container is $0.903/km. The total transport cost is 2018*0.903=$1822.25.

Figure 4-8: selected highway route from Chengdu to Shanghai

(Source: google map)

Path 2: Chengdu----Shanghai (transported by railway)

- Transport time: According to the Transportation Committee, the establishment of Huhanrong high-speed railway (see Fig.4-9) can contribute to the cargo transportation along the way from Chengdu to Shanghai. The distance transported by railway is 2081 km. And the time of transporting in general freight trains is around 5 days.

- Transport costs: Based on the data in "Customer Service of China's Railway", the basic price of transporting a standard container is $0.304/km/TEU. The total expense is around $0.609/km/TEU including the handling fee and other costs. Thus the transport cost by railway is 2081*0.57=$1266.34.

Figure 4-9: Huhanrong high-speed railway

(Source: customer service of railway transport)

Path 3: Chengdu----Chongqing----Shanghai (highway from Chengdu to Chongqing, waterway from Chongqing to Shanghai)

- Transport time: The distance from Chengdu to Chongqing through Hurong Expressway is 340 km. The golden waterway of the Yangtze River is a good choice for the transportation from Chongqing to Shanghai and the transport distance is 2398 km. The total transport time needed is 7 days.
- Transport costs: This path is road-water combined transportation. Thereby transshipment fees are needed. According to the research, the transshipment cost is $94.67/TEU. The transport cost by highway from Chengdu to Chongqing is

0.903*340=$307.02. And that from Chongqing to Shanghai by waterway is 0.088*2398=$211.02. The total transport cost is $612.71.

Figure 4-10: Chengdu—Chongqing---Shanghai road-rail transport route

Path 4: Chengdu---Chongqing---Shanghai (railway from Chengdu to Chongqing, waterway from Chongqing to Shanghai)

- Transport time: The distance from Chengdu to Chongqing transported through Chengdu-Chongqing railway is 338 km. The segment from Chongqing to Shanghai through golden waterway of Yangtze River is also 2398 km. And the total time needed is 9 days.
- Transport cost: This path is rail-water combined transportation and the transshipment cost is $99.18/TEU. The transport cost by railway from Chengdu to Chongqing is 0.609*338=$205.84. As is mentioned before, transport cost from Chongqing to Shanghai by waterway $211.02. Thus the total transport cost is $516.04.

✧ Guiyang to Shanghai

Path A: Guiyang---Shanghai (transported by highway)

- Transport time: The selected path from Guiyang to Shanghai can go through Hangrui Expressway and Hurong Expressway. (See Fig. 4-11) The transport distance in this recommended path is 1871.1 km which needs 3 days to complete the transportation.

- Transport cost: Referring to related information, the cost of transporting 1 container from Guiyang to Shanghai by highway is $0.897/km/TEU. Thus the total cost is 0.897*1871.1=$1678.38.
-

Figure 4-11: selected highway route from Guiyang to Shanghai

(Source: google map)

Path B: Guiyang---Shanghai (transported by railway)

- Transport time: According to the survey, the distance transported by railway is 2054 km. And the time of transporting in general freight trains is around 4 days.
- Transport costs: As is mentioned before, the basic price of transporting a standard container by railway is $0.304/km/TEU. The total expense is around $0.518/km/TEU including the handling fee and other costs. Thus the transport cost by railway is 2081*0.518=$1063.97.

Figure 4-12: selected railway route from Guiyang to Shanghai

Path C: Guiyang----Chongqing----Shanghai (highway from Guiyang to Chongqing, waterway from Chongqing to Shanghai)

- Transport time: The distance from Chengdu to Chongqing through Qianyu Expressway is 392 km. The transport distance through the golden waterway of the Yangtze River is 2398 km. The total transport time needed is 7 days.
- Transport costs: This path is road-water combined transportation. According to the research, the transshipment fee is $94.67/TEU. The transport cost by highway from Guiyang to Chongqing is 0.901*392=$353.19. And that from Chongqing to Shanghai by waterway is 0.088*2398=$211.02. The total transport cost is $659.61.

Path D: Chengdu---Chongqing---Shanghai (railway from Chengdu to Chongqing, waterway from Chongqing to Shanghai)

- Transport time: Since Qianyu Railway is still under construction, the Chuanqian railway is recommended in the transportation. The distance from Guiyang to Chongqing by railway is around 345 km. The segment from Chongqing to Shanghai through golden waterway of Yangtze River is also 2398 km. And the total time needed is 9 days.

- Transport cost: This path is rail-water combined transportation and the transshipment cost is $99.18/TEU. The transport cost by railway from Guiyang to Chongqing is 0.591*338=$203.89. Transport cost from Chongqing to Shanghai by waterway is also $211.02. Thus the total transport cost is $514.09.

For the purpose of clearance, the transport time and transport costs of the selected paths are shown in the following table4-4.

Table 4-4: the total transport time and total freight of each path

From Chengdu to Shanghai

Selected paths	Transport time (day)	Transport costs ($/TEU)
Path 1	3	1822.25
Path 2	5	1266.34
Path 3	7	612.71
Path 4	9	516.04

（source: self-calculation）

From Guiyang to Shanghai

Selected paths	Transport time (day)	Transport costs ($/TEU)
Path A	3	1678.38
Path B	4	1063.97
Path C	7	659.61
Path D	9	514.09

（source: self-calculation）

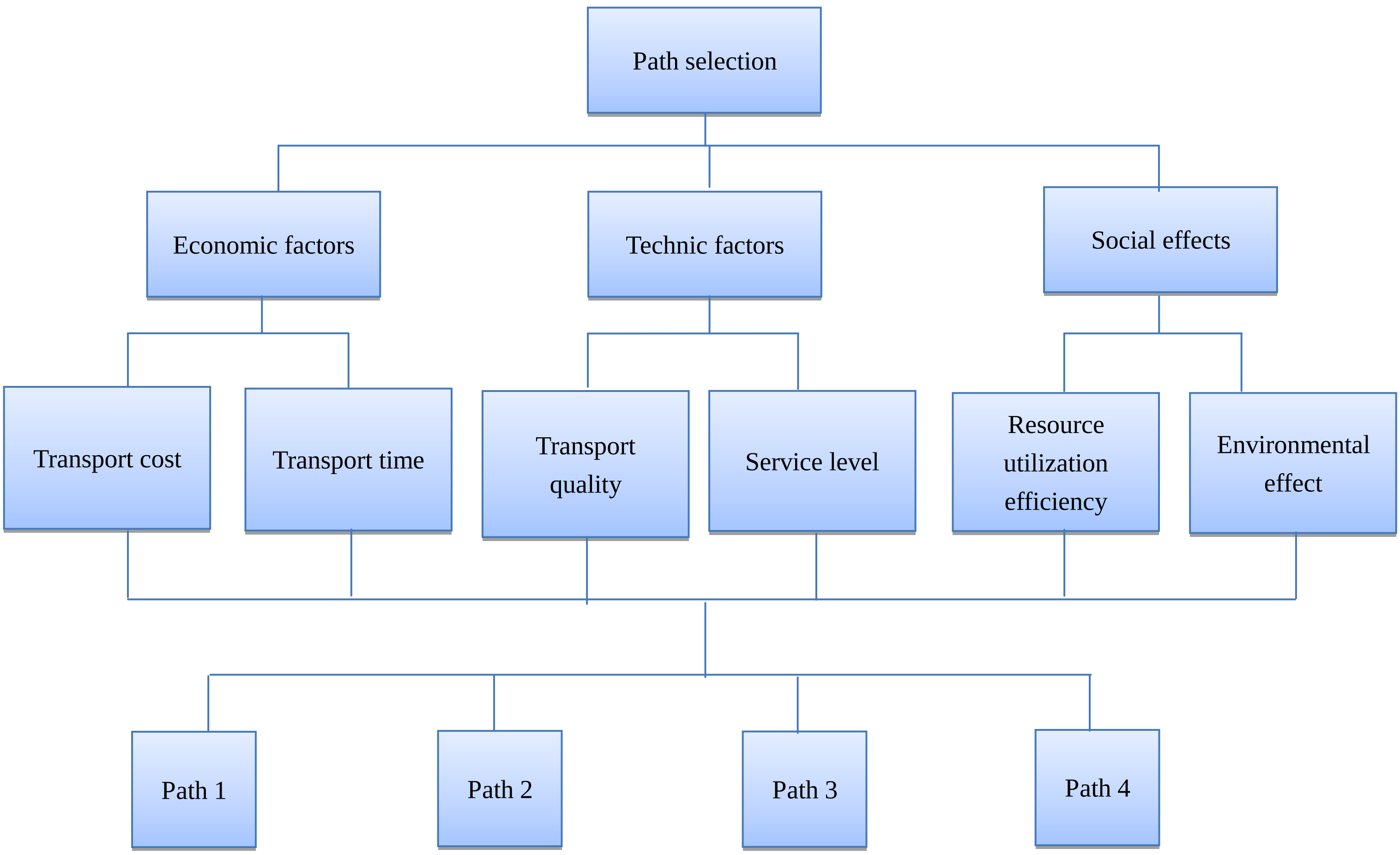
4.5 Procedure of the model

The model will be divided into 2 parts. One is the path selection from Chengdu to

Shanghai and the other is from Guiyang to Shanghai. The detailed procedure is shown as follows.

A. From Chengdu to Shanghai

a) Based on the analysis above, the AHP model of path selection of China's multimodal transport can now be built. The modal is shown in the following chart.



(Source: self-presentation)

b) In order to obtain the convincible results and build the scientific pairwise comparison matrix, questionnaires (See Appendix 1) are designed and sent to professors and experts as well as staff of some enterprisesin shipping and logistic field to get the weight of the criterion. Professors who help with the questionnaire are Daniel Moon, Malcom Willingale, Trevor Law, etc.

Case 1: The experts and professors are asked to give scores on the criteria based on the consideration of transporting 1TEU cargos with low value and low urgency. On account of the collection and classification, following matrix is obtained (Tab. 4-5).

Table 4-5: pairwise comparison matrix of path selection model

A=		transport cost	transport time	transport quality	service level	resource utilissation efficieny	environmental effect
	transport cost	1	4	5	4	6	6
	transport time	1/4	1	2	3	5	4
	transport quality	1/5	1/2	1	3	4	4
	service level	1/4	1/3	1/3	1	3	2
	resource utilissation efficieny	1/6	1/5	1/4	1/3	1	2
	environmental effect	1/6	1/4	1/4	1/2	1/2	1

(Source: self-calculation)

c) With the formula mentioned earlier, we can normalize the matrix above to yield a new matrix A* (tab. 4-6).

Table 4-6: normalized matrix of path selection model

		transport cost	transport time	transport quality	service level	resource utilissation efficieny	environmental effect
A*=	transport cost	0.491803279	0.636604775	0.566037736	0.338028169	0.307692308	0.315789474
	transport time	0.12295082	0.159151194	0.226415094	0.253521127	0.256410256	0.210526316
	transport quality	0.098360656	0.079575597	0.113207547	0.253521127	0.205128205	0.210526316
	service level	0.12295082	0.053050398	0.037735849	0.084507042	0.153846154	0.105263158
	resource utilissation efficieny	0.081967213	0.031830239	0.028301887	0.028169014	0.051282051	0.105263158
	environmental effect	0.081967213	0.039787798	0.028301887	0.042253521	0.025641026	0.052631579

(Source: self-calculation)

Using the average of the 6 entries, the weight of each criterion can be calculated with the known formula. The results which are shown in the following table (tab.4-7) can be easily obtained with formula in EXCEL.

Table 4-7: weight of each criterion

w(transport cost)	0.44265929
w(transport time)	0.204829134
w(transport quality)	0.160053241
w(service level)	0.092892237
w(resource utilizationefficiency)	0.054468927
w(environmental effect)	0.045097171

(Source: self-calculation)

d) In case of inconsistencies existing, we have to check for consistency of the pairwise comparison matrix. The formula "MMULT" in EXCEL can be used to calculate AW (shown in the following table4-8).

Table 4-8: average weight

AW=	3.031207567
	1.367010467
	1.027940767
	0.57878564
	0.330383033
	0.283774895

(Source: self-calculation)

The ratio of each element in AW to the corresponding weight in W and the average of these ratios have to be found to calculate the λ_{max}. And then the constancy index can be calculated. In this case, λ_{max} is 6.4221492. Thus CI is 0.08442984.

λmax=	6.4221492
CI=	0.08442984

Referring to the random index table, we can find that RI of 6 values is 1.24. Now the consistency ratio (CR) can be calculated which is 0.068088581. As previously mentioned, the degree of consistency is satisfactory when CR<0.1. Thereby, in this case, the matrix can pass the consistency checking.

e) Scores of each path on each criterion have to be determined to calculate the overall score. Since transport costs and transport time has been obtained through investigation and calculation while other criteria cannot be measured in figure, we combine quantitative method with qualitative method. In view of environment effect, it can be measure by emission of CO_2 and consumption of energy. With the increase of railway electrification rate and the application of LNG in vessels, zero emission can be realized in the future. But at present there is nothing can replace petroleum in highway transport. According: to the research, the emission per ton per km of highway, railway and waterway is 14.8： 1.2:1 respectively (see fig. 4-13).A vessel shipping 1000 tons cargos consumes 2 kg diesel per kilometer. The average energy consumption is 2.8 kg/thousand ton-kilometers. In railway and highway transport, the average energy consumption is 10 and 16 respectively.

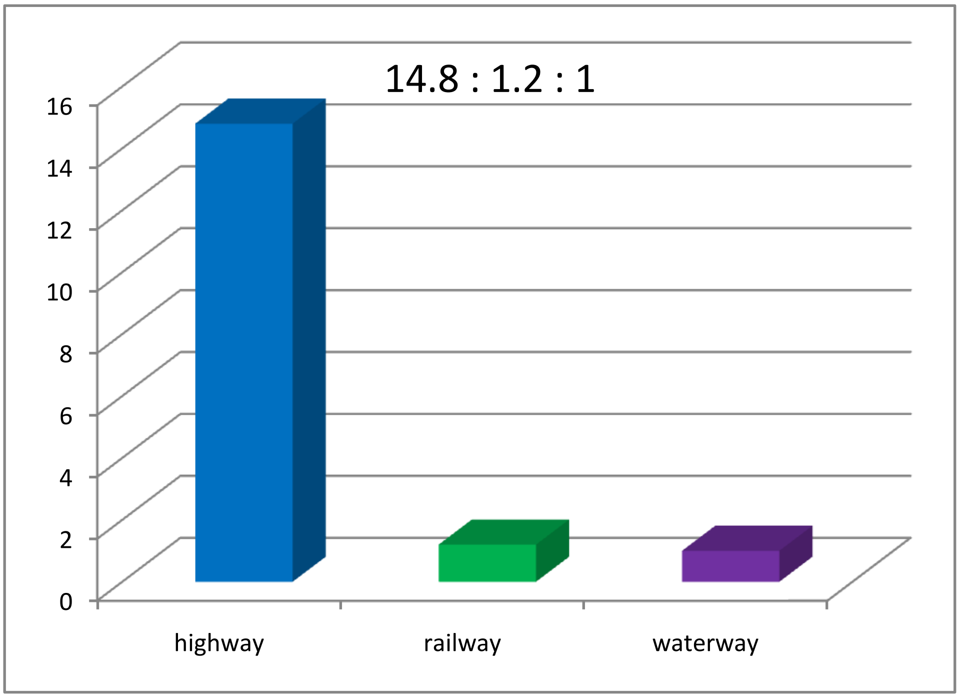


Figure 4-13: CO_2 emission ratio of three transport means

(Source: ministry of transport in China)

For the scores of each path, related professors and experts are asked to help in the form of questionnaires. Based on their opinions, the following tablecan be formed after being reorganized. For instance, it can be seen from this table (tab. 4-9) that path 1 meets the criterion of short transport time, but scores are worst on transport cost and environment effect.

Table 4-9: scores of each path on each criterion

	transport cost	transport time	transport quality	service level	resource utilization efficiency	environmental effect
path 1	1	5	2	4	2	1
path 2	3	2	4	3	2	2
path 3	4	2	4	2	3	4
path 4	5	1	5	2	4	4

(Source: average score of questionnaires from experts)

f) Now the overall scores of 4 routes of multimodal transport from Chengdu to Shanghai can be calculated. For each score, it is the weighted sum of the scores for that path. Similarly, the results (see table4-10) can be obtained through the formula “SUMPRODUCT” in EXCEL.

Table 4-10: the overall scores of each path of Chengdu to Shanghai

	score
path 1	2.312515416
path 2	2.855658009
path 3	3.350088331
path 4	3.802440654

(Source: self-calculation)

Case 2: Under the circumstance of transporting 1TEU cargos with high value and high urgency, those professors, experts and staff also give scores on the importance over two criteria. And a new matrix is obtained on the basis of collection and classification. (Tab. 4-11).

Table 4-11: pairwise comparison matrix of path selection model

A=		transport cost	transport time	transport quality	service level	resource utilization efficiency	environmental effect
	transport cost	1	1/4	2	3	4	3
	transport time	4	1	3	4	5	4
	transport quality	1/2	1/3	1	3	4	4
	service level	1/3	1/4	1/3	1	3	3
	resource utilization efficiency	1/4	1/5	1/4	1/3	1	2
	environmental effect	1/4	1/4	1/4	1/3	1/2	1

(Source: self-calculation)

With normalized matrix, the weight of each criterion in case 2 can be calculated. And the λ_{max} and CI (consistency index) can be calculated. The result of CI is 0.088078085. Consulting to the random index table, it can be find the RI of 6 values is 1.24. With the given formula,it can be easily obtained the consistency ratio which is 0.071030714. Since it is less than 0.1, it can pass the consistency check.

In case 2, the scores of each path on each criterion are the same with those in case 1. Accordingly, the overall scores of 8 routes can be calculated. The results are shown in the following table. (Tab. 4-12)

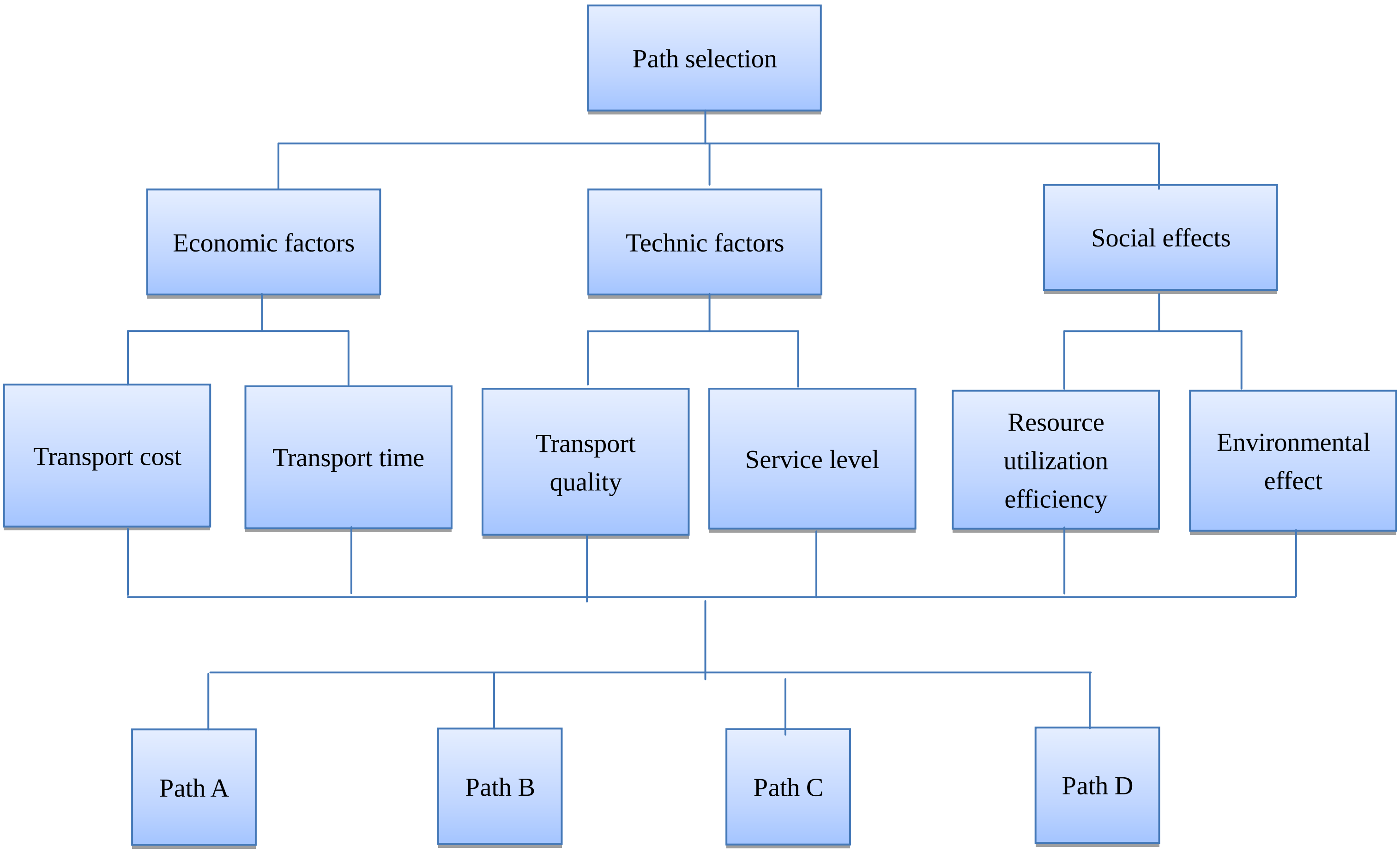
Table 4-12: the overall scores of each path of Chengdu to Shanghai

	score
path 1	3.147089719
path 2	2.675221904
path 3	2.933184844
path 4	2.984704972

(Source: self-calculation)

B. From Guiyang to Shanghai

Since the procedure of the path selection has been stated in detail, it will not be expounded step by step in this part. Based on the procedure above, the following model of path selection from Guiyang to Shanghai can be built



(Source: self-presentation)

With the previous analysis and relevant formula, the pairwise matrix in 2 cases (1 is transporting 1 TEU cargos with low value and low urgency and the other is with high value and high urgency) can be built. And the matrix is proved to pass the consistency check. The difference between the 2 path selection models is the score on each path. The scores of the 4 paths from Guiyang to Shanghai are listed as follows (Tab. 4-13).

Table 4-13: scores of each path on each criterion (Guiyang to Shanghai)

	transport cost	transport time	transport quality	service level	resource utilization efficiency	environmental effect
path A	1	4	2	4	2	1
path B	2	4	3	2;	2	3
path C	4	2	3	2	3	3
path D	5	1	4	2	4	4

(Source: average score of questionnaires from experts)

Now the overall scores of 4 routes of multimodal transport from Guiyang to Shanghaiin 2 cases can be calculated, shown in Tab. 4-14 and Tab. 4-15

CASE 1:

Table 4-14: the overall scores of each path from Guiyang to Shanghai

	score
path A	2.107686282
path B	2.614808681
path C	3.144937919
path D	3.642387413

(Source: self-calculation)

CASE 2:

Table 4-15: the overall scores of each path of Guiyang to Shanghai

	score
path 5	2.751685538
path 6	3.023107883
path 7	2.700885323
path 8	2.802657866

(Source: self-calculation)

4.6 Results and conclusion of path selection modal

In the path selection model from Chengdu to Shanghai, it can be seen from the above table that the score for path 4 is highest under the condition of transporting 1 TEU cargos with low value and low urgency, which means path 4 is the best alternative of multimodal transport path from Chengdu to Shanghai. The order of the 4 paths is: path 4, path 3, path 2, and path 1. It indicates that the rail-water combined transport path from Chengdu to Chongqing to Shanghai to Rotterdam is the best transport mode combination. In this case, the multimodal transport operator has no special needs for the transport time. Hence the multimodal transport operator prefers to minimize their costs as much as possible. Path 4 is transporting 1 TEU cargos from Chengdu to Chongqing by road transport and from Chongqing to Shanghai by railway and then from Shanghai to Rotterdam by sea. The cost advantage of path 4 is obvious based on the previous analysis. Thus the result can be regarded as a reasonable one. In case 2, the best alternative is path 1 (transporting 1 TEU cargos from Chengdu to Shanghai by road transport and from Shanghai to Rotterdam by sea). Under this circumstance, the value of goods is high and the multimodal transport operator has requirements in delivery time, hence both transport time and transport quality will be placed great importance. In path 1, the highway transport has distinct advantage in transport cost and superior advantage in safety issues.

In the model of path selection from Guiyang to Shanghai, it can be found that path D is the best alternative in case 1. It discloses that the best choice of transporting 1 TEU cargos from Chengdu to Shanghai is road transport from Chengdu to Chongqing and from Chongqing to Shanghai by railway and then from Shanghai to Rotterdam by sea. In case 2, path B is regarded as the best alternative, which means railway transport is the best transport mode of transporting high value and urgent cargos from Guiyang to Shanghai.

Since the sea transportation part is similar among the 8 paths, the analysis will focus on the domestic part. In path 1, the most obvious advantage can be the short transport time. Among the few transport means, highway transport is the fastest. However, this also leads to high transport costs. Besides, the environment effect of path 1 is more serious than that of other paths. The condition is similar in path A due to the same transport means they use. In path 2, transport cost can be its advantage while the transport time is longer than highway transport. Besides, the transport quality of path 2 is high. The railway transport is safe, near to the degree of safety in air transport. Path 3 is the combination of highway transport and waterway transport. Since highway transport has the highest transport costs and shortest transport time while waterway has the opposite situation, the road-water transport can have the medium transport time and costs. However, transshipment is necessary in this case, thus the service level is relatively lower. This situation is similar in path C. In path 4, the advantage can be the low transport costs. And it does less harm to the environment compared to other paths.

According to the calculation, the transport cost of transporting a container (1TEU) from cities around Chongqing to Shanghai by highway is the highest. Transport expense of railway transportation comes the second while that of rail-water combined transport is the most economical. The transport cost of rail-water transport only account for 20%-26% of that in highway transport and 40%-50% of that in railway transport. Besides, road-water transport is also relatively economical. Therefore, in view of the transport costs, the rail-water transport and road-water transport should be vigorously developed. In view of the transport time, rail-water transport and road-water transport need more time than other transport modes. Highway transport has the shortest transport time and has the advantage of flexibility. In this case, cargo owner has no special needs on the transport time. Thus rail-water combined and road-water transport are more preferable.

In this case, Chongqing is taken as the node of the multimodal transport. And as previously stated, Chongqing has joined the 16 multimodal transport demonstration projects while Shanghai is not in the list. Therefore, the path selection of Yangtze export corridor can contribute to the development of multimodal transport in Shanghai. It can be found that both cargo owners' preference and the actual condition of the routes will affect the choice of multimodal transport operators. This model can help operators to better select transport paths.

4.7 Summary

In this chapter, various criteria are considered from the standpoint of multimodal transport operators, namely, transport cost, transport time, transport quality, service quality, resource utilization efficiency and environment effect.The scores of the importance of these criteria are given by experts, professors and enterprises staff in the form of questionnaires. And the analysis of selected paths is provided. AHP model is used in this chapter to select path from Chengdu and Guiyang to Shanghai. 2 cases are discussed in this chapter. Of some paths, Chongqing is chosen as the node. The procedure of the path selection model is discussed in detail. Finally, results of the model and conclusion are drawn.

Chapter 5 CARRIER SELECTION

Carrier selection of China's multimodal transport is mostly based on experience, hence lack of scientific procedure. In this chapter, tendering and bidding process will be introduced. The criteria when multimodal transport operators select the actual carriers will be discussed. In this chapter, this thesis will give the tendering and bidding model design based on the criteria of transport time and transport cost.

5.1 Basic conception

In container multimodal transport, the operators can authorize the whole or part of the transportation tasks to the sub-carriers. In this thesis, the carrier mentioned represents the sub-carrier in each segment of the whole multimodal transport process. Under most circumstances, the multimodal transport operator concludes a contract with the shipper and signs combined transport documents. They have no transport tools and do not participate in the actual transportation process. They will sign transport contracts with carriers to complete the transportation.

The existing international rule of multimodal transport has generally defined the concept of multimodal transport operator. But the concept of actual sub-carrier has not been regulated. In view of China's legislation, Article 104 in <maritime law> makes a distinction between multimodal transport operator and carrier. <International Intermodal Transport Management Rule> in 1997 had explicitly regulated the concept of carrier in each segment of multimodal transport. On the concept of carrier, International Intermodal Transport Management Rule states that:

> No matter whether he and the multimodal transport operator is the same person, carrier is the one who signs segmental transport contract with the multimodal transport operator and bare the transportation in certain segment in the whole multimodal transport process.[6]

5.2 Consideration of criteria in carrier selection

When multimodal transport operators select the sub-carrier among several candidates, it's impossible for them to completely grasp information of the candidates. And the evaluator's attitude of taking risk can directly affect the information processing. Besides, game logic may exist during the entire process of selecting carriers due to the

[6]International Intermodal Transport Management Rule in 1997

incomplete information. The game not only takes place between operators and carriers, but among the candidates. Therefore, Game Theory can serve as the basis of the carrier selection modal.

There are various factors that may have an impact on the carrier selection. However, for different multimodal transport operators, they face different situations and have different requirements. Thus the criteria they take into consideration are different. However, most commonly, they will consider their own conditions, the requirements of the multimodal transport tasks as well as the characteristics and ability of the potential cooperated carriers, etc. In this section, 3 principles will be considered to measure the carrier selection.

- ✧ Capability. Multimodal transport has to make an evaluation on the carriers' capabilities. This may be involved in the transport ability, market position of segmental carriers. And the controlling ability of the logistic process and management ability can also be evaluation indicators for the multimodal transport operators. These criteria can not only reveal the transport ability of carriers and it future developing trend, but also its position in the cooperation with multimodal transport operators.
- ✧ Compatibility. It is mainly about whether the carriers can be compatible with sub-carriers in organizational culture and daily operational management. This may include the culture of enterprises, the financial standing, the institution and developing strategy. The compatibility between operator and carriers is the guarantee of their cooperation in the following transport process. And this can reduce the extra costs caused by the intermediate links of the transport chain.
- ✧ Commitment. When multimodal transport operator looks for the potential cooperated carriers, they have the expectation that carriers can have the same investment willing with them. Maximizing the profits is the ultimate of multimodal transport operator. Thus the carriers will be required to cooperate with operator to minimize the total costs involved in the transportation task. If the carriers are not willing to invest money, human resource, technics and equipment and so on to develop and operate the multimodal transport system, they may be

not regarded as the potential selection.

5.3 Tendering and bidding process

Based on the analysis above, the actual carriers can be regarded as the partner of multimodal transport operators. Thus the process of selecting carriers can be seen as the partner selection. This kind of selection process can be dealt with bidding theory. Therefore, this dissertation will build the carrier selection modal based on the tender and bidding process.

5.3.1 Basic concept of tendering and bidding

The so called tendering and bidding is a market transaction where the purchaser put forward the conditions and requirements of certain goods, projects or services and invite certain amount of bidder to participate in the bidding and choose trading partners in accordance with the legal or conventional procedure. It consists of two parts---tendering and bidding. The former part is invitation of unspecified natural persons, legal persons or other organizations in a certain way. The latter part is the participation of bidding competition in response to the bid inviting party. The bidding process cannot be completed without any of the tendering or bidding party. Tendering and bidding are the category which is mutually corresponding. In the tendering legislation and rules of international organizations and nations over the world, the process is commonly called tendering, like international competitive tendering, national competitive tendering, limited tendering, etc. But they all make regulations and limitations to the bidding process. As the effective market behavior of selecting trading objects, tendering and bidding reveal principles of competition, openness and fairness. Besides, tendering and bidding can make sure that suppliers and contractors to seek fair treatment. And it also plays an important role in improving transparency and objectivity. In the saving of procurement funds and maximizing procurement efficiency, tendering and bidding can also contribute a lot.

5.3.2 Types of tendering

The mode of tendering and bidding decides the degree of competition and is also a significant means of preventing improper transaction. The procurement legislations and rules in the world and relevant international organizations have regulating the tendering modes, including open tendering, inviting tendering and negotiation tendering, etc.

- Open tendering, also known as competitive tendering, is the mode that a tenderer invite s unspecified legal persons or other organizations to participate in the bidding competition in the form of bidding announcement and chooses the best alternative from the outstanding bidder. According to the degree of competition, open bidding can be divided into national and international competitive bidding competitive bidding. International Competitive Tendering refers to the tendering in worldwide. Both domestic and international legal persons, alone or in combination with other legal entities or organizations, will participate in the tender. And the settlement currency is in accordance with the provisions of the tender documents during the bidding activities. National Competitive Bidding involves national legal persons who are consistent with the tender documents. It is an activity which settled with domestic currency. The tender documents are only in national language and the tendering advertisements are only shown in domestic media.
- Inviting tendering, also known as restricted tendering or selective tendering is the process that tender invites specific legal persons or other organization for the bidding in the form of invitation to bid. There are certain features of restricted tendering. First, it does not use the form of an open invitation to tender notice. Second, only those who have accepted the invitation to bid are the qualified bidders. Third, the number of bidders is limited. According to the size of the tender project, the number of bidders is usually between 3~10.
- Negotiation tendering, also known as limited tendering is the mode of determining the winning bidder through negotiation. There are different types of

negotiation tendering. The first is direct invitation negotiation tendering. Under this circumstance, the tender or its agent prefers to invite one specific legal person or organization to negotiate and select the successful bidder rather than give open invitation. They will sign the procurement contract after reaching an agreement. If the negotiation fails, they will invite another legal person or organization until the negotiation succeeds. The second is price negotiation tendering. It has the characteristics of invitation and negotiation. Generally, it is used for small-scale and simple projects as well as procurement of goods and services. Basically, the tender will send purchasing requirements to several selected legal persons or organizations and ask them to give the offer within the agreed time. The tender will choose a bidder with reasonable offer after comparison. After these processes, they will negotiate on details of schedule, quality, payment terms, etc. and sign the contract after reaching to an agreement. The third is competitive negotiation tendering. It is the common method used in selecting projects designs. Usually, the open competition is organized. Some designing agencies which have been selected in advance can be invited to participate in the competition. The tender will provide the basic requirements of design and the amount of investments. Some basic information like feasibility reports or design plans, site conditions and environmental conditions, as well as the relevant provisions of design department will be offered. Those who attend the competition will put forward their own initial design plans based on the provided information. They have to explain advantages of their plans and the staffing, time schedule, total estimated investments, etc. which will be submitted to tender later. The tender will invite experts to form an evaluation commission to select the qualified one. They sign contract with the winner while compensating for the losing part.

The tendering and bidding involved in the carrier selection in this thesis is the internet tendering. The specialized tendering e-business platform network is used in the tendering work. It indicates that the release of the tendering information, the scrutiny to the qualification of tenders and bidders, the sale of the bid document, the opening and evaluation of bid and the contract signing will be conducted online. And the final successful bidder will also be announced online. The information of internet tendering and bidding has a wider coverage. Thus it can do contribution to the principles of transparency and fairness. It can also transform the traditional tendering into a simpler and more convenient process. With the increasingly vigorous development of internet in China, the internet tendering and bidding is expected to have a promising future in China. The carrier selection through internet tendering has several distinctive advantages.

First, the logistic costs can be reduced to a large extent. When the multimodal transport operator accepts a transport task, he may choose sub-carriers through internet tendering if he thinks the self-operating cost is high or he is not familiar with the transport sections. Compared to the traditional tendering for selecting partner, the internet tendering can strengthen the competition among carriers. Thereby the transport time and costs can be saved. Meanwhile, participants of tendering and bidding can communicate with each other online. This will benefit the tendering time and administrative expenses. Second, the management efficiency can be increased since the carriers can be selected in a wider range. There is no geographical restriction in internet tendering. Thereby it is possible for large quantity of carriers to participate in the tendering activity. And this enables the operator to determine carriers with reasonable price, transit time and transport route. As long as the potential carriers have access to the internet, they can participate in the bidding at the same time. The multimodal transport operator can obtainer information of the bidders and have more choices than that in tradition tendering mode. Besides, thanks to the automatic and systematic management of internet tendering, the multimodal transport operators can improve their management efficiency. Third, it can contribute to the integration of logistics resources. Through internet tendering, the multimodal transport operator can seek for the qualified carriers with purpose of strategic development. It can help alter the phenomenon of resource waste due caused by the improper distribution. The utilization of social resources can therefore be improved. Fourth, it can help operator enter the targeted market. The operator can choose proper partners to enter the market at the initial stage of business across regions. Except for reducing the costs of building logistic infrastructure, the operator can establish his client relationship network through internet tendering. This is of great benefit for future selection. Fifth, it can instantly reflect market dynamics. Multimodal transport operators can take advantage of modern internet tendering platform to deliver information of supply and demand, and transport costs, etc. At the same time, feedback on bilateral cooperation is conducive to distinguish between market traders' credibility, which can help to establish a good market credit mechanism. Finally, it can avoid rent-seeking behaviors. Through internet tendering, multimodal transport operators can choose carriers who know nothing about each other. With established specialized evaluation process, secret operations and bribery can be reduced to some degree. Thus it better accord with the transparent and fair ideas of internet tendering

5.4 Tendering process of carrier selection

5.4.1 Assumption and introduction

Without loss of generality, it can be assumed that the multimodal transport operator has a logistic task with volume Q, time period t. it starts from A to B through water, road, and railway transport. It is set that i=l represents waterway transport enterprise, i=2 represents road transport enterprise, i=3 represents railway transport enterprise. Each transport enterprise has n transport enterprises for selection (also means the number of enterprises participated in the bid). Thus the j candidate enterprise in category I can be expressed as Wij, ($j \in n$). This thesis assumes that only one sub-carrier will be selected in each segmental transport and transport volume cannot be segmented. Meanwhile, the multimodal transport operators mentioned in this dissertation has no means of transport. They enter into a contract with a shipper and issue a combined transport document. They are not involved in the actual transportation. They will sign transport contracts with carriers in each segment to complete the carriage of cargos by signing transport contract with them.

5.4.2 Design of the tendering process

After multimodal transport operators accept transport tasks, they will determine the transport path and transport requirements in each segment of the entire transport process according to the cargo owners' requirements as well as previous transport experience. And then they will select the standard of bidding and build the evaluation system. The tendering mode will be used in the carrier selection after the tendering information is published. The specified processes are as follows.

a) Release the bidding information: After obtaining the logistics transport tasks, multimodal transport operators will determine the transport path, bidding standard, bidding mode as well as bidding time based on the goals they are to achieve. And then they will entrust these information to authorized tendering agencies to release tendering information on the internet.

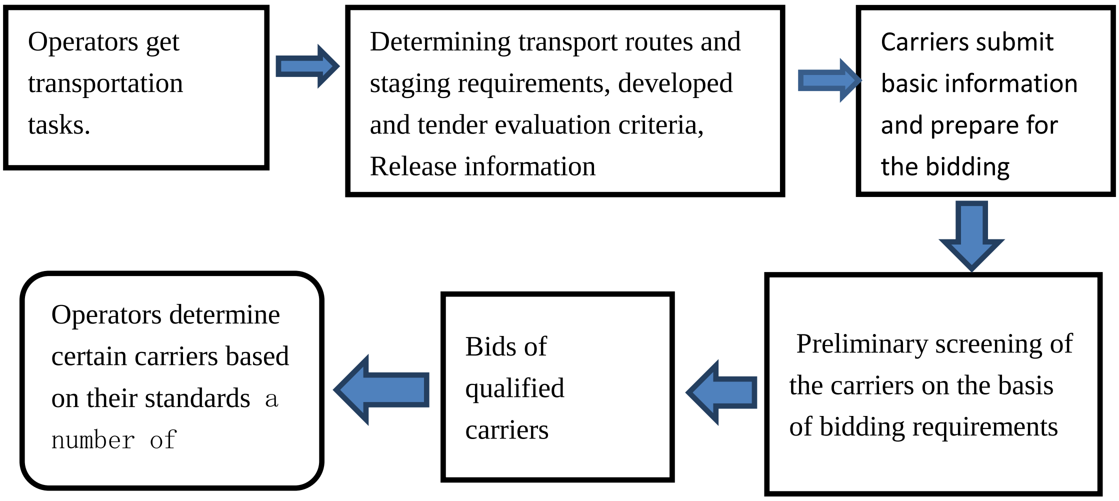
b) Register tendering: According to the tendering notices, carriers submit basic information to the authorized bidding institutions, including firm size, enterprise software and hardware facilities, the transport solutions, etc. Authorized tendering agencies will select qualified carriers based on the requirements of multimodal transport operators. Every sub-carrier will be assigned to each a secret serial number to prepare for the tendering.

c) Bid of carriers: Under the circumstance of partly knowing the cost information of other competitors, carriers start the bidding on the basis of its transport capacity, transportation cost, and estimated transport time, etc.

d) Finish the tendering: The multimodal transport operators sort with the result of carriers' bidding on the basis of the cost, transit time, etc. They choose carriers who have lower bid and shorter transit time to be the candidates.

e) Determine carrier in each segment and sign the contract of carriage: Among the candidates selected above, multimodal transport operator will choose the combination of carriers in the entire transportation with lowest bids and reasonable transit time. Finally, the operator will sign a contract of carriage with them and establish cooperative relationship.

For purpose of clearance, the entire process is shown in the following chart.



5.4.3 Carrier selection modal

A. The establishment of selection model

In accordance with bidding results of carriers of each category, multimodal transport operator will sort with them based on the bid of each carrier bij and the bidding transit time Tij. And they will screen on Mi carriers who offer relatively lower price and shorter transportation time for the final selection. Assuming that the multimodal transport operator has a maximum transport budget on the total costs according to their own experience, the budget is set as c. The operator expects to choose the combination of carriers with lowest total bid and transit time meeting the requirements from final selection of 3mi carriers. The assumption enables the operator to deliver goods to the destination on time with lowest costs.

Then, the target of multimodal transport operators is:

$$\text{Min: Cp} = \sum_{i=1}^{3}\sum_{j=1}^{m_j} b_{ij} X_{ij} \quad (5.1)$$

$$\text{S.T:} \sum_{i=1}^{3}\sum_{j=1}^{m_j} b_{ij} X_{ij} \leq \bar{C} \quad (5.2)$$

$\sum_{i=1}^{3}\sum_{j=1}^{m_j} T_{ij} X_{ij} \leq$T（5.3）

$\sum_{j=1}^{m_j} X_{ij}$=1（5.4）

Target function type (5.1) represents that the multimodal transport operator select the carrier combination with minimum transport costs. Constraints condition (5.2) represents the transport total cost of transport combination of each carrier. It is also the bid quotes which are not greater than maximum budget cost of multimodal transport operator. Constraints condition (5.3) means the transport combination of carriers meet the requirements of transport time segment carrier of transport combination meet time requirements; constraints condition (5.4) indicates the selection of cooperation partner in the carriers of each segmental transport part. Xij =1 means that the Wij candidate carrier is selected, otherwise Xij=0

B. Solution of selection model

In view of the model, the popular genetic algorithm can be applied to the solution. There are already massive literatures which have made researches and analysis on such algorithm. In this thesis, the algorithm will not be discussed in detail since the purpose of the modal is to select optimal carrier in each segment for the multimodal transport operator. And this dissertation is to give multimodal transport operator suggestions on the modal and algorithm.

5.5 Conclusion of carrier selection modal

At present, the qualitative analysis, the quantitative analysis, and the combination of the two methods are mainly applied to the carrier selection. Qualitative method is the selection of carriers based on multimodal transport operators' experience and relationships. It can take all criteria into consideration and it is also subjective. Thus it is not widely used in actual application. The most common method used in quantitative analysis is the linear weighted method mentioned in 1991 by Webber. For combination of quantitative analysis and qualitative analysis, the AHP modal and multi-agent method is widely used. In this thesis, the modal based on the tendering and bidding theory can be regarded as the combination of quantitative analysis and qualitative analysis. In this thesis, the multimodal transport, operator chooses several qualified carriers through internet tendering and builds the selected modal. And then the optimal combination of carriers can be determined based on the popular genetic algorithm. On one hand, with this method, the total costs of operators can be reduced. On the other hand, the potential carriers can participate on the tendering competition based on their practical transport capability and the information they have grasped. Besides, the method of internet tendering can help operators select their partners more effectively based on their own requirements. Therefore, they can quickly and efficiently complete the multimodal transport tasks. In the actual multimodal transport, this method is suggested to be applied to choose carriers.

5.6 Summary

In this chapter, different types of tendering and bidding are introduced. 3 criteria are mentioned when selecting actual carriers, namely, capability, compatibility and commitment. It proves out that the three criteria are quite importance when multimodal transport consider to select the actual carrier. It also gives the advantages of internet tendering and bidding which is used in the carrier selection. And then in this chapter, it designs the tendering and bidding model and the genetic algorithm is suggested to be the solution of the model.

Chapter 6 SUGGESTIONS AND CONCLUSIONS

6.1 Suggestions on China's multimodal transport development

In this section, this dissertation will first give some suggestions on Shanghai's multimodal transport development. For one thing, Shanghai is chosen as the study subject of the Yangtze River region in path selection. For the other, Shanghai is not listed in the 16 multimodal transport demonstration projects. Therefore, the suggestions will help Shanghai to develop multimodal transport to some extent. And then this thesis will suggest on China's multimodal transport development in accordance to the existing problems mentioned in previous chapter.

✧ Suggestions on multimodal transport development in Shanghai

(1) Container multimodal transport is the main subject in development Shanghai's multimodal transport. The government should help to improve the capacity of railway transport and port through policy and funds support. The inland container transshipment station construction should be enhanced to realize better convergence of the Yangtze River inland container multimodal transport and Shanghai international container multimodal transport. Government in Shanghai and relevant departments should devote to improving the technology of container and the speed of being in line with international practice. And they should place certain attention on developing inland container transport tools and techniques which are suitable for domestic situation. The barriers of protectionist among departments, industries and local regions should be broken to lay the foundation for Shanghai's multimodal transport development in both technical and managerial level. This is not only the responsibilities of Shanghai government, but also the bounden duty of cities and provinces in the Yangtze River basin.

(2) Facing with increasingly fierce competition at home and abroad, Shanghai should enhance the construction of international shipping center and join in the competition positively. It should accelerate the transport infrastructure construction of Yangshan Deepwater Port and Pudong coastal railway transport to form modern integrated transport system. Besides, the collection and distribution ability should be improved to guarantee the efficient convergence of multimodal transport.

✧ Suggestions on China's multimodal transport development

(1) Establish the unified transportation management department. The multiple management in the transport management department of the government will not only

cause fragmentation and redundancy among the various modes of transport which may do harm to the formation of efficient integrated transport network, but also lead to the waste of resources and repeat infrastructure construction. Besides, it is not beneficial to the optimization and integration of resources. It may affect the overall benefits to development of multimodal transport, and is not conducive to unity of macro-control of the government. In view of this, it can be suggested that the national authorities should lead to establish the unified management and coordination agency, which can integrate and coordinate all aspects of multimodal transport operations and can be committed to the long-term development plan to promote multimodal transport development and meet the needs of economic reform.

(2) Transform the government functions and separategovernment functions from enterprise management. Our governments should learn from the successful experience of foreign countries to realize the transform and separation. The reform should be accelerated to reduce administrative examination and transactional work. The government should to be freed gradually from the daily trivial work to put their priority on the development planning, regulation and policy formulation. The market operations should be standardized and the coordination and supervisory should be strengthened to encourage competition among enterprises. Only in this way, it can promote the balance and rapid development of different modes of transport. In another word, the government should to be a truly macro-managing, planning, coordinating and supervising department.

(3) Reform the management system and accelerate the pace of the marketization. At present, the degree of the marketization of transport is quite low, and the transport management is not standardized. The railway transport market is even completely monopolized by the country. Owing to this, it is lack of competition in the market and the transport capacity is insufficient and the service is of low quality. The road freight market is completely open, but it suffers from the small scale of operation with serious safety and environmental issues. Among different modes of transport, the departments and enterprises, the lack of coordination and cooperation have side impact on the development of integrated transport capability. Based on this, the

government should set the transport market free while strengthening safety supervision. It should reduce intervention in transport enterprises to promote fair competition among various transport modes and transport enterprises. Under this circumstance, the multimodal transport capability and comprehensive transport capacity are expected to be improved.

(4) Reform the price mechanism. Thanks to the flexible and reasonable pricing of waterway transport and road transport, the road and waterway transport have witnessed rapid development in China. However, China has strictly controlled the price policy in railway transport. Relevant departments should accelerate the reform d railway freight rate and transit it to market price. The reasonable charging standard is advised to be formulated and various surcharges should be cleared. The railway pricing should be clearly marked to ensure one charge for the entire transport process. Only when various transport modes develop coordinately, can the multimodal transport be vigorously developed.

(5) Develop and improve the laws and regulations in the promotion of the development of multimodal transport. In addition to the current domestic regulations --"maritime law" in 1992, the Ministry of Communications and the Ministry of Railways jointly issued the "international container multimodal transport management rules" in March 14, 1997. The implementation of laws and regulations will further standardize multimodal transport market order in China. The market access standards and code of conduct will be confirmed. It will also help to protect the legitimate rights of the transport companies. The well-developed laws and regulations are beneficial to the scientific, standardized and systematic development of multimodal transport in China.

(6) Accelerate the establishment of multimodal transport system and the coordination and cooperation between different systems. The organization level of multimodal transport mainly depends on the coordination and cooperation of various transport modes in the entire transport process. Therefore, China should place importance on the establishment of multimodal transport system, and should continuously improve the organization and management level. At the same time, it should take full

advantage of the characteristics of different modes of transport which can strengthen the transfer and connection between different multimodal transport systems. The transport enterprises can seek for cooperation in the competition instead of purely compete with each other. They can cooperate to meet requirements of the entire so that multimodal transport can bind closely in transport coherence.

(7) Accelerate the construction of multimodal transport infrastructure. Container multimodal transport is developing trend in the future. China has a rapid development momentum in container transport. However, what is not commensurate with the rapid development is the poor infrastructure. In some regions of China, railway transport capacity is relatively low and inland container transshipment stations are still in short. It is suggested that the government should give support in both policies and funds to improve the capacity of railway transport and ports. Traffic facilities should be gradually optimized under the market allocation. Transport corridors are the key points in traffic facilities configuration. At the same time, vigorously promoting scientific and technological progress and improving technical equipment is an important task in China's multimodal transport development.

(8) Accelerate the development and application of EDI system to promote the information system. EDI system is the indispensable management tool in international container multimodal transport. It can help save an ocean of manpower, material and financial resources and complete information transfer in international multimodal transport fast, safely and easily. However, it has not been applied yet in railway and road transport in China. That is why a complete and effective multimodal transport system is hard to be built. Therefore, China has to organize relevant departments and enterprises to develop EDI system and put it into practice as soon as possible.

6.2 Conclusions and future endeavors

With the carrying out of 16 multimodal transport demonstration projects, china is facing the great opportunities in multimodal transport. As previously stated that the path selection and carrier selection are the important issues in multimodal transport development thanks to their important roles in transport cost, transport time and service quality and so on which are closely related to the multimodal transport. Therefore, this thesis has discussed these two issues with different models.Both quantitative and qualitative analyses are applied in this dissertation.

In the path selection part, 8 paths(4 are from Chengdu to Shanghai and 4 are from Guiyang to Shanghai) from southwestern China to Yangtze River Delta have been selected and Chongqing is chosen as the node of transport in southwestern region in some paths.AHP model is applied in the path selection. In both of the 2 path selection model, 2 cases are considered. Based on the quantitative and qualitative analysis, it is found that the rail-water-sea transport is the best alternative of transporting low value and low urgent cargos from both Chengdu and Guiyang to Chengdu and then to Rotterdam. The proportion of rail-water transport in China is quite low. Therefore, in Chongqing's multimodal transport demonstration project, the rail-water transport is suggested to place more importance. However, there are things to be improves. When transporting high value and urgent cargoes, road transport from Chengdu to Shanghai is better choice in the path from Chengdu to Shanghai and to Rotterdam while railway transport from Guiyang to Shanghai in the path from Guiyang to Shanghai and to Rotterdam is preferable. This indicates that multimodal transport operators still need take all aspects into consideration when choosing transport modes and transport paths. Due to the subjectivity of qualitative analysis, the qualitative indicators selected are not abundant. Besides, shanghai is the only city chosen as the objective in Yangtze River Delta. And this may lead to the lack of objective studied. In the future study, these parts will be improved.

In the carrier selection, this dissertation introduces the tendering and bidding theory of Game Theory based on the existing research. Owing to the large quantity of potential carriers and their incomplete information, the use of internet tendering modal enables the multimodal transport operator to select carriers based on their requirements. In the bidding process, the competition among carriers can contribute to the transport cost and time reduction for the operator. The genetic algorithm is advised to solve the modal. However, this dissertation doesn't give the algorithm in detail. In addition, only bidding transit time and costs are taken into consideration in the assumption of the carrier selection tendering model. It has not been applied into practice. With more researches and information, these are believed to be desired.

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Appendix 1

Questionnaire of Scores on Criteria in Path Selection

Dear sir/madam:

I'm the student of WMU-SMU MSc Programme in ITL (International Transport and Logistics) and I'm doing with my master dissertation recently. The topic of the thesis is "path and carrier selection in China's multimodal transport". In path selection part, AHP (Analytic Hierarchy Process) model is used. And a pairwise comparison matrix has to be built. Therefore, i'm inviting you to give scores on the criteria I selected in the dissertation. I'll be very appreciated for your help.
I promise that your answers in the questionnaire are only used for academic purpose. Any use for business purpose will be forbidden.

Importance is measued on an integer-value 1-9 scale with each number having the intepretation shown in the following table:

Value of a_{ij}	Interpretation
1	i is as important as j
3	i is slightly more important than j
5	i is strongly more important than j
7	i is very strongly more important than j
9	i is absolutely more important than j
2,4,6,8	Between the value

2 cases will be considered in the thesis. One is transporting 1 TEU cargo with low value and low urgency. The other is transporting 1 TEU cargo with high value and transport time is cared about a lot.
Six criteria (transport cost, transport time, transport quality, service level, resource utilization efficiency and environment effect) are chosen in the thesis to measure the selected multimodal transport path. And each two should be compared to obtain their weight. The pairwise comparison will be shown in the following table. And you are asked to give the value of importance according to the table above.

Case 1: transporting 1TEU cargos with low value and low urgency

Criterion i	score	Criterion j
Transport cost		Transport time
Transport cost		Transport quality
Transport cost		Service level
Transport cost		Resource utilization efficiency
Transport cost		Environmental effect
Transport time		Transport quality
Transport time		Service level
Transport time		Resource utilization efficiency
Transport time		Environmental effect
Transport quality		Service level
Transport quality		Resource utilization efficiency
Transport quality		Environmental effect
Service level		Resource utilization efficiency
Service level		Environmental effect
Resource utilization efficiency		Environmental effect

Case 2: transporting 1TEU cargos with high value and high urgency

Criterion i	score	Criterion j
Transport cost		Transport time
Transport cost		Transport quality
Transport cost		Service level
Transport cost		Resource utilization efficiency
Transport cost		Environmental effect
Transport time		Transport quality
Transport time		Service level
Transport time		Resource utilization efficiency
Transport time		Environmental effect
Transport quality		Service level
Transport quality		Resource utilization efficiency
Transport quality		Environmental effect
Service level		Resource utilization efficiency
Service level		Environmental effect
Resource utilization efficiency		Environmental effect

Thanks for your time and wish you a bright day!