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Multimodal transport cost analysis of coal transport from Datong to WH power station

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Multimodal Transport Cost Analysis of Coal Transport from Datong to WH Power Station

By

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A research paper submitted to the World Maritime University in partial Fulfillment of the requirement for the award of the degree of

MASTER OF SCIENCE

In

INTERNATIONAL TRANSPORT AND LOGISTICS

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

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ABSTRACT

There are different types of Multimodal Transport operations which are combined to make international trades easier and costless. There are five basic modes of Multimodal Transport including water transport, road transport, rail transport, air transport and pipeline transport.

As China entered into WTO in 2001, our country faces more opportunities and challenges. Multimodal Transport is mainly used in container transport and it is the direction for the development of modern transportation. Since the cost of transportation is one part of the logistics cost, and it is the reference for government to set relevant policies and prices of transportation, the study of how to calculate the transport cost and how to apply it into practice is very important.

The main objective of this dissertation is to develop transport system of China coastal ports by using multimodal transport to reduce cost and improve service performance. Both quantitative and qualitative method will be used in this paper. Data of the case study from various sources and companies will be used to analyze the cost model and to test the elements affecting the choice of model and route. The aim of this model is to find out the most effective route with a less cost.

Keywords: multimodal transport, coal transport, Beresford Cost Model

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Chapter 1 Introduction

Multimodal transport is the modern development direction. It is not only the mainstream method for container transport, but also appears in bulk cargo transportation. However, compared with international intermodal transport, the intermodal transport in domestic began to develop from the 1980s. And the domestic intermodal transport still needs further study.

Accession in WTO brings unprecedented opportunities for the development of multimodal transportation in China. The growth of import and export trade volume and the importation of foreign technology provide a good prospects for the future. Also, with the continuous improvement of railway transportation, our international multimodal transport has been promoted.

Railway transport, as a part of multimodal transport process, can not only meet the demand of long-distance transport, but also an indispensable mode for short-distance transport. The modern logistics industry makes higher requirements for the construction of railway transport system.

Multimodal transport is based on one contract, two or more modes of transport, by the multimodal transport operator to transport goods from one location to another premise. It can achieve the entire transport process with one consignment, one payment, and one vote. To accelerate the pace of development of multimodal transport can promote the cooperation of various modes of transportation and also can realize the optimal allocation of resources. Thus, multimodal transport can adapt to Chinese economic growth and foreign trade development.

Each mode of transport has different technical and economic characteristics, for example, road transport is suitable for small quantities of short-distance, while railway transport is suitable for large quantities of long-distances. It is better for rational allocation of transport resources to realize multimodal transport and therefore it can optimize the whole transport network. Transport by sea-rail modes can expand the economic hinterland from port to inland area. It can improve the collection and distribution conditions of the ports and enhance the competitiveness of rail transport.

It is important and meaningful to study about how to scientifically calculate the cost of transportation during the development process in the modern multimodal transport. Multimodal transport can greatly reduce the cost of the entire transportation process and to maximize the profits. This dissertation mainly studies how to make the lowest overall costs of goods transport. A new model based on Beresford Cost Model will be raised to discuss the coastal and inland coal transport development in China.

From the points of view in existing researches, the model of transportation cost is difficult to be integrated since the calculation of transport cost is limited by the modes, routes and many other factors. And the components of transport costs are also not unified. But obviously, the freight rates and fuel costs are mentioned in most of the calculations about multimodal transport.

Chapter 2 Literature Review

With the development of transportation, the study of Multimodal Transport – both in foreign countries and in China – has never stopped.

This chapter will review the literature of Multimodal Transport studied by scholars from foreign countries and China. It will be divided into three parts – the concept of Multimodal Transport, five basic modes of Multimodal Transport, and different cost models of Multimodal Transport.

2.1 The concepts of Multimodal Transport

According to HMSO (1966), the term “through transport” has been defined as “the methods of distribution and transport which give through flow of traffic, from the point of origin to the final point of destination, with minimum transhipment and delay”. Only a single document named Through Bill of Lading is used in the movement of through transport. And the modes could be truck to truck, rail to rail, ship to barge, barge to ship or mixed modes from these medias.

Later, the concept of combined transport was defined. Combined transport means “the carriage of goods by at least two different modes of transport, from a place at which the goods are taken in charge situated in one country to a place designated for delivery situated in a different country” mentioned in the International Chamber of Commerce Rules (1975). That means, the combined transport is an integrated process of transport – not only by two different modes, but at least two different modes.

In USA, combined transport is also taken for inter-modal transport. These two concepts are often confused because of their interpretation. Both of them are involved with different transport models and the different models are combined in the transportation. According to Bukold (1993), in practice, the concept of combined transport is involves with railroad and barge/road combinations. That is to say, combined transport is used in a more limited sense. Lowe (2006) claimed that traditionally speaking combined transport represents road-rail transport rather than other combinative modes.

Combined transport has grown significantly in European transport. It helps to relieve the pressure of road congestion, to reduce the truck emissions and to solve the deficit of railways in Europe, for example, rail-road combined transport takes about 40% of shipments between Cologne and Milan areas.

The definition of intermodal transports provided by the OECD (organization for economic cooperation and development) Glossary of Statistics is “movement of goods (in one and the same loading unit or a vehicle) by successive modes of transport without handling of the goods themselves when changing modes.” According to Marlow and Boerne (1992), “Intermodalism should be high on the list of priorities for those concerned with the efficiency of the transport industry, the generalized cost of transport and the environment”. The costs of transport involve different modes and therefore the choice of transport modes and the technologies used in the transport is important. In practice, the container is the most useful and successful technology in intermodal transport and it can reduce the transport cost in some extent. Thus, intermodalism is perhaps to be an attractive option and should be considered in further studies.

In May 1980, the United Nations adopted the Convention on International Multimodal Transport of Goods (MT Convention). The term “International Multimodal Transport” has been defined in MT Convention as “the carriage of goods by at least two different modes of transport on the basis of a multimodal transport contract from a place in one country at which the goods are taken in charge by the multimodal transport operator to a place designated for delivery situation in a different country". According to Van Goor et al (1996), multimodal transport's objective is provide the most cost and time effective way to move the goods from origin to final destination through the entire transport chain. Multimodal transport is an integration of other transport modes. It is similar to combined transport, but the biggest difference between is the adoption of the electronic data interchange (EDI) (Wong, 1997). In the future, multimodal transport system will be a world-wide system dealing with international freight transportation.

2.2 Five Basic Modes of Multimodal Transport

Banomyong (2000) indicated that transport corridor such as maritime transport, land corridor transport and air transport system as a convergence connect the hub centers and provide a group of routes to move the products from the original place to the final destination in the process of trade. As the transportation in logistics system continues to be integrated in the global trade, the modes like air, water, and land used in transportation are combined with each other and thus the transportation system becomes more complex.

Generally speaking, there are five basic modes of transport: rail, road, water, air and pipeline. Table 2.2 shows the different performance rating of four transport modes (air, water, rail and road). All the terms in Table 2.2 should be considered in the transport modes' decision making process.

Decision making process	Transport mode			
	Rail	Road	Water	Air
Cost	3	2	4	1
Transit time	3	4	2	5
Reliability	4	5	2	3

Capability	5	4	2	3
Accessibility	4	5	2	3
Security	3	4	2	5
Best Performance= 5 and Worst Performance=1				

Table 2.2 Performance Rating of Transport Modes
Source: Adapted from Coyle et al. (2003)

Each mode has its own advantages and disadvantages which show in Table 2.2 and Table 2.3. For example, air transport is fast but costly while water transport is slow but cheap. And rail transport is cheap in a fixed route while road transport is relatively expensive with a flexible route.

Mode	Advantages	Disadvantages
Air	Fast and safe High security Long and short distance transport	High Cost Weight and volume Constraints More packing
Water	Low cost Large volume and weight Suit long distance transport	Slow Speed Slow transit time Low security
Rail	Low cost in long distance Safe Large volume Medium weight Relative high Speed	Fix cost Fix route Infrastructure constraints Inefficient management
Road	Fast Flexible route Flexible time	High cost Weight and volume constraints High congestion Heavy pollution (e.g. CO)
Pipeline	Highly specialized products	Fix product High building cost High fix and maintenance cost

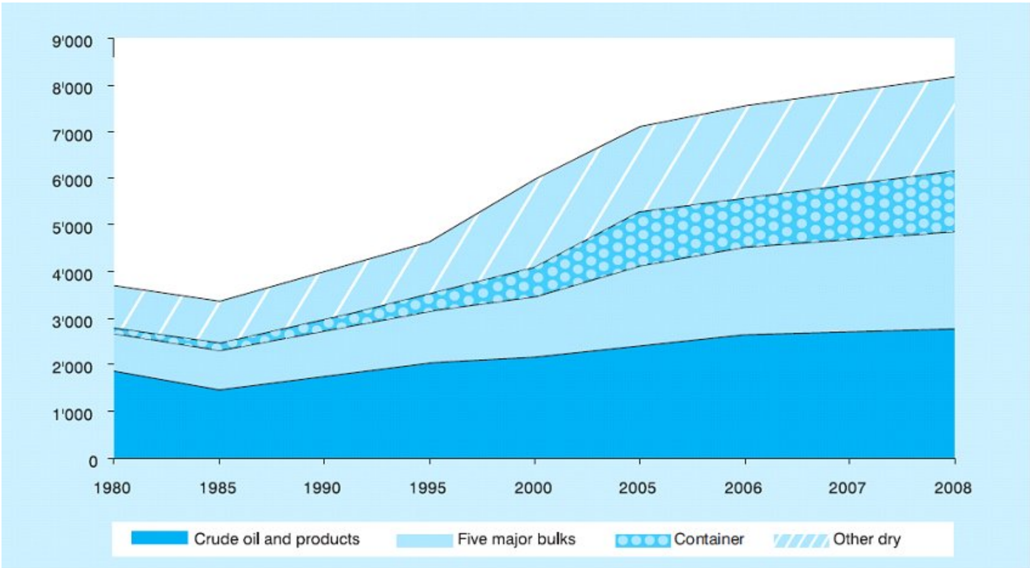
Table 2.3 Strengths and Weaknesses of Five Basic Modes of Transport
Sources: Author's interpretation of the literature

2.2.1 Water transport

World seaborne trade was increased by almost 40 per cent during the past 20 years. Sea transport plays a central part in the global trading trade (Peters, 2001). More than 8.17 billion tons of goods of international seaborne trade were loaded in the world's port in 2008, and the dry cargo was continuing to occupy the largest share (66.3 per cent) of total seaborne trade (UNCTAD 2009) (see Figure 2.1).

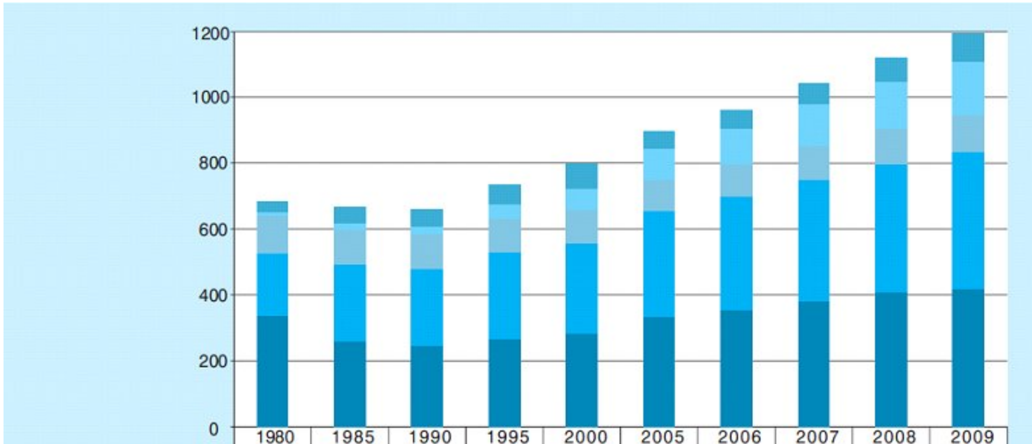
According to EU, "over 80 % of world merchandise trade by volume was carried by sea". It indicates that the maritime transport is the main mode of transportation which supports the global trade development.

In world fleet, oil tanker and dry bulk are two main vessel types and these two types of ships are accounted for 71.2 per cent of the world total tonnage in 2008 (UNCTAD 2009) (see Figure 2.2).



Source: *Review of Maritime Transport*, various issues. Data for container trade based on Clarkson Research Services, Shipping Review Database, Spring 2009.

Figure 2.1 International seaborne trade, selected years (millions of tons loaded)
Source: UNCTAD Review of Maritime Transport, various issues.



	1980	1985	1990	1995	2000	2005	2006	2007	2008	2009
Other	31	45	49	58	75	49	53	63	69	85
Container	11	20	26	44	64	98	111	128	145	162
General cargo	116	106	103	104	101	92	96	101	105	109
Dry bulk	186	232	235	262	276	321	346	368	391	418
Oil tanker	339	261	246	268	282	336	354	383	408	418

Source: Compiled by the UNCTAD secretariat, on the basis of data supplied by Lloyd's Register – Fairplay. Cargo-carrying vessels of 100 gross tons and above.

Figure 2.2 World fleet by principal vessel types, selected years (beginning-of-year figures, millions of DWT)
Source: UNCTAD Review of Maritime Transport 2006, various issues.

Water transport is the cheapest mode in the global trade which can help to carry a big volume to achieve a lead-time condition and optimum cost (McKinnon, 1989 and Banonyong, 2000). However, maritime transport prefers to the movement of goods with following characteristics – large volume, low price and long life cycle goods such as raw materials.

2.2.2 Rail transport

Rail transport is a major mode for cargo shipment in many countries because of the cost-effective. According to Lowe (2006), rail transport is "specifically designed to carry ISO containers, standard swap bodies, or whole vehicle combinations". DiBenedetto (2008) pointed out, "Companies are pooling equipment and loads, moving full container and truckloads, and going to alternative transportation modes - especially rail - while trying to optimize inventory by finding the right mix of warehouse and distribution locations.

Shippers are trying to ensure that containers are fully loaded, and they're using more cross-docking and intermodal rail".

Because of the trend of internationalization and standardization in global trade by railway transportation, it is essential for the carriers to expand their market share in railway freight industry. Lower cost is another factor for the carrier to consider when they choose a multimodal transport model. High customer service performance with a low cost of railway transport is the key element of core competence.

As mentioned in the *Review of maritime transport 2009*, rail traffic accounts for around 40 per cent of transport share by volume in the United States, while in Brazil it accounts for only 26 per cent of the freight volume. However, at the end of 2008, due to the economic crisis, some countries suffered a particularly dramatic decline of the rail freight volumes. In Asia, railway growth (in ton-kilometres) was positive in 2008, though less significant than the year before. For example, China has seen a growth of 3.5 per cent in 2008 and India, 8.4 per cent.

Yet more attention should be paid to the lead-time of rail transport since it is the biggest disadvantage in the rail transport. Actually the world environment of freight transport market is always changing.

2.2.3 Road transport

In the UK, 89 percent of freight tonne-miles are done by road (Roth, 1996). Because of the integration of transport modes, the demand for road transport increases comparatively.

In 2008, many trucking companies in the United States paid more attention to the fuel cost and the financial environment. Due to the economic crisis in 2008, road transport suffered a recession as the trade growth went down. As estimates in *Review of Maritime Transport 2009*, “United States road haulage traffic will grow at a subdued average annual rate of slightly above 1.2 per cent measured in millions of ton-km” during the period of 2009-2013.

Although rail haulage is cheaper than road transport, the road transport is more flexible for a door-to-door service as mentioned in Table 2.3. With the advantages like fast transit time and high speed, shippers prefer to choose road transport to link the goods movement, especially in short distances (Kiesmuller et al., 2005).

However, the road congestion and environment problems like CO_2 emission lead to a heavy pressure on the shippers.

2.2.4 Air transport

Because of the large demand of rapid services, the air transport becomes an important role in the transportation system during the last five decades. In Table 2.3, the key advantage of air transport is the short transit time and speedy delivery. Also air transport service is reliability for the customers due to its punctuality, safety, accuracy and dependability.

However, the higher cost of air transport than of any other transport mode is the main reason that impedes the development of air transportation (Park et al., 2009). Meanwhile, the small space of aircrafts is another drawback. Compared with seaborne transport, air transport can only carry a small volume and weight. In practice, aircrafts always carries the goods with a high value to overcome the small capacity. Since the air technology has been developing in recent years, the cost of air transport is gradually reduced.

2.2.5 Pipeline transport

Pipeline transport is very different from other modes of transport. It is used for the specific cargos like gas, liquid cargoes (e.g. oil) and chemicals. The advantage of pipeline transport is less pollution and more security when carrying dangerous cargos. According to the *Annual Report of the Fostering Seamless Transport in the European Union* (2008), “Consideration must be given to pipeline infrastructure. Transporting oil by road, where this is not necessary, unnecessarily adds to pollution and insecurity on roads. Pipeline infrastructure should be able to accommodate Europe's demand for oil to the maximum possible, avoiding pollution and congestion by road transport.”

Figure 2.5 Existing and planned natural gas pipelines to Europe
Source: Energy Information Administration, Major Russian Oil and Natural Gas Pipeline Projects

Although the pipeline transport is useful for the delivery of liquid bulk products, the building cost is very high compared with other transport modes. To deal with the growing demand of pipeline transport, one way is to rebuild the existing pipelines and the other way is to build some new ones in Europe (see Figure 2.5).

2.3 Cost Models of Multimodal Transport

With the development of multimodal transport, many multimodal models can be found in large amount of literatures and in practice some of the multimodal models will be used to solve the problem such as route decision. Three main cost models and many other models will be reviewed in this part of this dissertation.

2.3.1 Hayuth Diagram Cost model

According to Hayuth (1987), technology, networks, transport modes, information, communication and logistics are five key issues of the decision variables or options for transportation. These five major groups are close related to four major viewpoints: the users, the operators, the sociopolitical-economic system, and the government (see Figure 2.6).

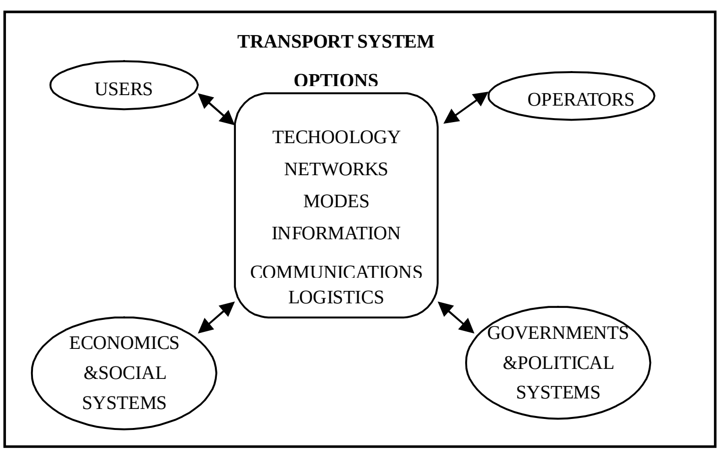


Figure 2.6 Decision Variables and transport system options
Source: Adapted from Hayuth (1987)

Hayuth's findings provide a useful strategic planning that can help the freight industry to evaluate the main factors involved in any decision-making process. However, the biggest weakness of Hayuth findings is that lots of other factors not mentioned in the model will affect the choice of modes of transport. It will be sufficiency if every element related to the modes' choice is considered in this model. But it must be recognized that large amount of factors considered in one decision model will make a mess. For example, the crucial element in Hayuth's model related to the transport is not the cost but the transit time when analyzing the air and sea transportation. However, in practice, customers may consider the question which is the effective freight movement. Sometimes cost-effective modal will be better than the time-effective modal according to different demands of customers.

2.3.2 Mckinnon Modal Choice

Mckinnon Modal Choice researched by Mckinnon 1989 is factors affecting freight modal choice which includes three components: traffic-related, consignor-related and service-related (see Table 2.4).

Traffic-related	**Consignor-related**	**Service-related**
Length of haul; Consignment weight; Dimensions; Value; Value density (value: weight ratio); Urgency; Regularity of shipment; Fragility; Toxicity;	Size of firm; Investment priorities; Marketing strategy; Spatial structure of production and logistical systems; Availability of rail siding; Stockholding policy; Management structure; System of modal/	Speed(transit time); Reliability; Cost; Product care; Customer relations; Accessibility; Availability of special vehicles/ handling equipment; Monitoring goods in transit (progress information);

Perish ability; Type of packaging; Special handling characteristics.	carriers evaluation.	Unitization; Provision of ancillary services (e.g. storage, breaking of bulk); Computing facilities/compatibility; Accuracy of documentation.

Table 2.4 Factors affecting freight modal choice

Source：Adapted from McKinnon (1989)

McKinnon (1989) believed that in order to aim the properties such as least cost, best time and greatest reliability, a uni-modal approach should be chosen in the transport operational circumstance. That is to say, one factor is against another factor, if you decided to choose the cheapest route, the time and the reliability should be given up in the operational circumstance.

2.3.3 Beresford Cost Model

The Beresford Cost model was originally proposed by Boerne (1990) and developed by Beresford and Dubey (1990). This cost model is stand-alone and flexible enough to be applied to any operational circumstances and to a supply chain of any length. There are several main elements involved are transport (road, rail, inland waterway, sea), intermodal transfer (ports, rail freight terminals, inland clearance depots), cost, time and distance. The aim of this model is to find the most competitive route cost or time wise or in terms of risk as well as cost and time (Banomyong and Beresford, 2001; Beresford, 1999).

"The Beresford Cost Model assumptions are based on the premise that unit costs of transport vary between the modes, with the steepness of the cost curves reflecting the fact that, for volume movements, sea transport should be the cheapest per tonne-km, road transport should normally be the most expensive (at least over a certain distance), and waterway and rail unit costs should be intermediate. At ports and inland terminals, a freight handling charge is levied without any material progress being made along the supply chain; a vertical 'step' in the cost curve therefore represents the costs incurred here. The height of the step is proportionate to the level of the charge." (Beresford, 1999)

The Beresford cost model has four development stages from origin form （Figure 2.7a）through two steps（Figure 2.7b, 2.7c）in the intermediate zone to the final mature form（Figure 2.7d）.

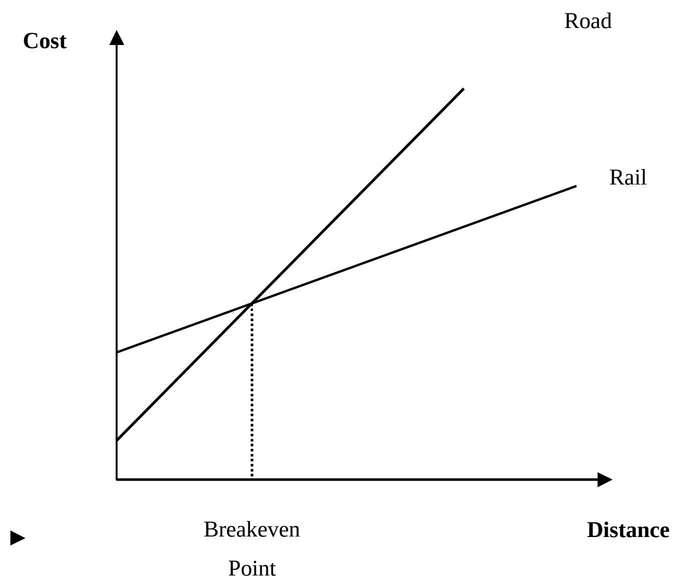


Figure 2.7a Uni-modal Alternatives: Road v Rail

Source：Adapted from Beresford and Dubey (1990)

Stage 1 (Figure 2.7a): costs and distance are considered in the two types of transport (road and rail).

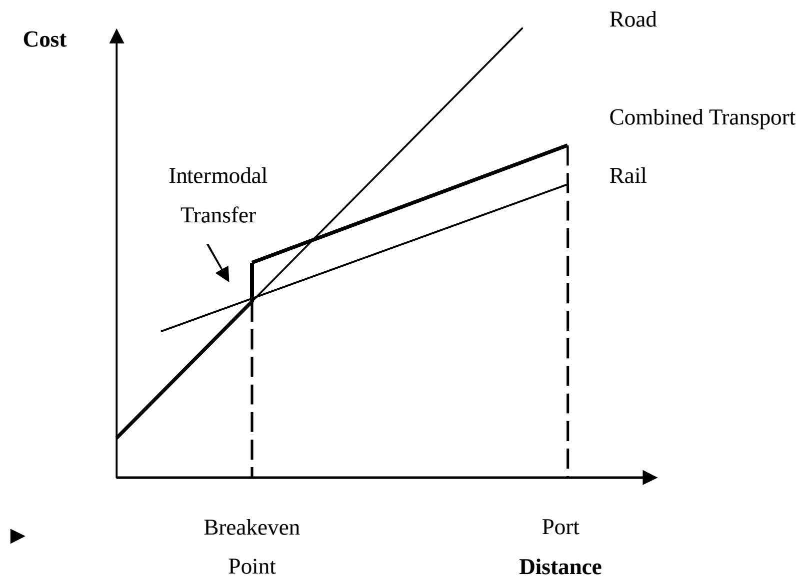


Figure 2.7b Combined Transport: Road-Rail

Source：Adapted from Beresford and Dubey （1990）

Stage 2 (Figure 2.7b): if the distance of a transport chain is less than the breakeven point length, a uni-model transport can be used in a supply chain. But if the distance is long and over the breakeven point length, a single transport is not a wise and competitive choice (Beresford, 1999). Therefore in the second stage of Beresford Cost Model, a combined transport is used to reduce costs.

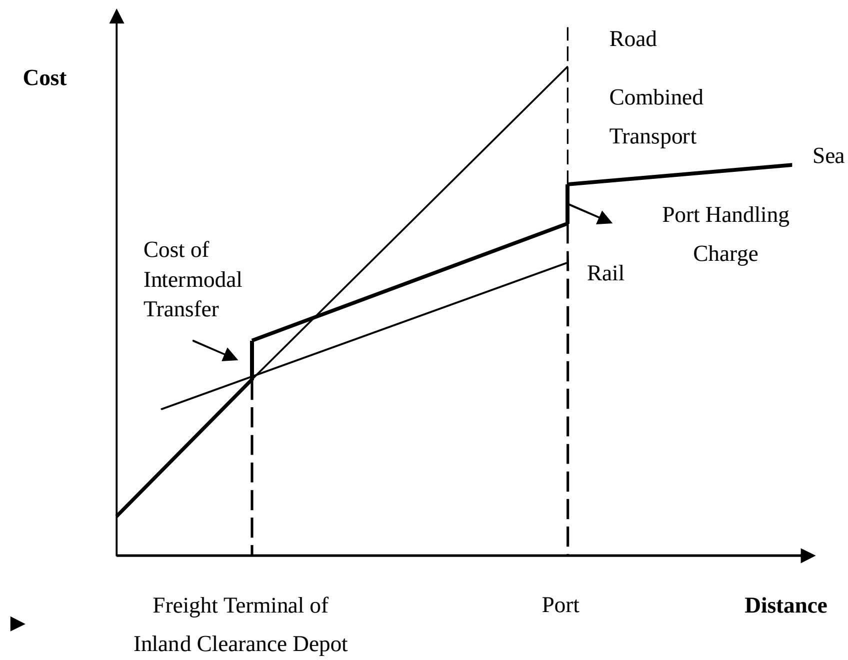


Figure 2.7c Combined Transport: Road-Rail-Sea

Source：Adapted from Beresford and Dubey (1990)

Stage 3 (Figure 2.7c): Because of the relatively high cost of rail transport, the sea transport is chosen to be one part in the transportation system.

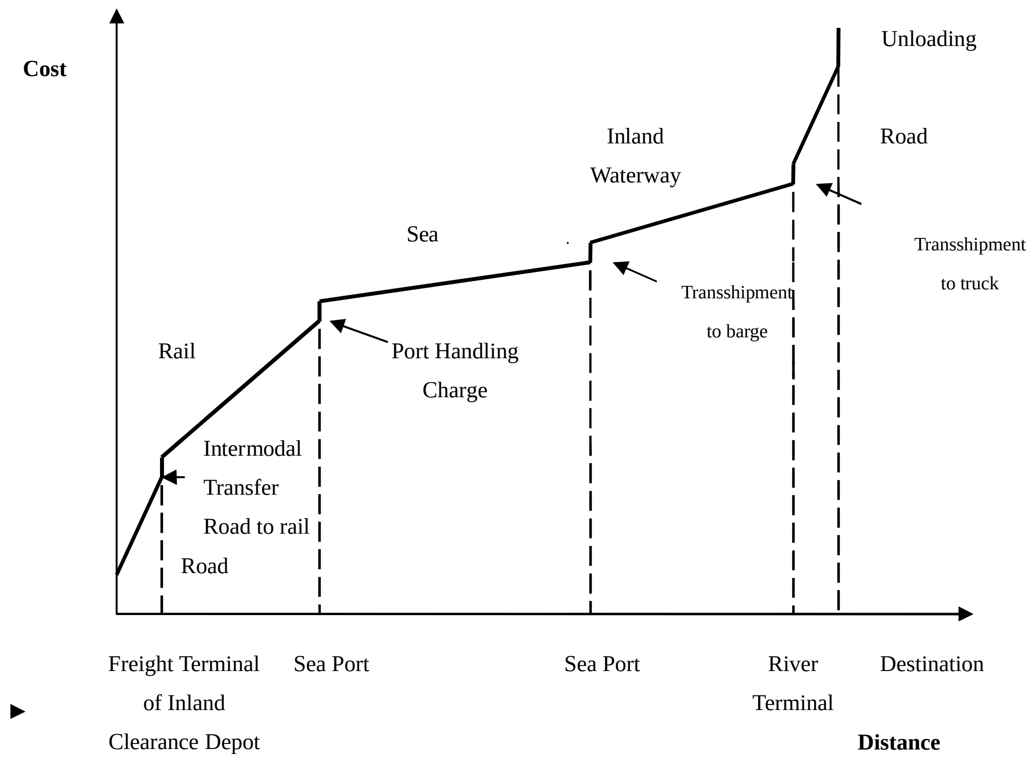


Figure 2.7d Combined Transport or Multimodal Transport from Origin to Destination

Source：Adapted from Beresford and Dubey (1990)

Stage 4 (Figure 2.7d): in the final mature form, there is a combined route including road, rail, sea and waterway. The total cost of this stage includes the transport cost as well as the transfer cost. In stage 4, the transit time should also be regarded as a key element during the whole transport system.

Most traditional models are simply used cost-distance methods which were indicated by Fowkes el al. (1989), McKinnon (1989) and Hayth (1992). Through cargo transport process, according to their point, only one model was used over a centre distance. Fowkes el al. (1989) indicated that it is the customers' willingness that decides the modes' choice. The traditional models are useful but to some extent they are limited. Most of them can't meet the needs of really transport environment. In these models, many elements are considered in the selected route. However, an effective freight movement should not include all elements but some key and interrelated factors to meet the needs of customer. This dilemma has been solved in Beresford Cost Model. As mentioned before, according to Beresford (1999), this model is "stand-alone" and "flexible". And "the model may be readily adapted to compare routes for their time performance or schedule reliability as distinct from monetary cost of specific logistics operations" (Beresford, 1999).

2.3.4 Other Cost Models

Linda K. Nozick and Mark A (2001) analyzed a direct-transport problem. They supposed that the transport cost of every truck in one route was fixed. In their uni-cycle model, only one supplier offers the goods to one certain point, which simplifies the transport problem and route design. Anily and Federgruem (1990) developed a single-product under a certainly demand model to minimize the average transport and inventory cost in an infinite range. Their method is that every retailer can be allocated different routes during the same period, and each route perhaps only covers one part of retailer's total demand. Vaidyanathan Jayaraman and Hasan Pirkul (2001) described the transport cost as a nonlinear cost model based on the transport volume. In their model, cost equals to the multiplication of rate and transport volume. Many researches of transportation system are using large amount of assumption to study how to minimize the total cost of transportation with different capacities, service areas and transit time arrangement. Milan Janic (2007) indicated the total cost model of container multimodal transport. This model analyzed series policies of European Union to find out to what extent these policies would affect the competitiveness of multimodal transport in the freight movement market. But this cost model is limited to the range of European Union countries. For the country outside European Union, this model might be not applicable.

The cost model of multimodal transport in China is rare. Most of the researches focus on the modes of multimodal transport and single transport cost. In this dissertation, a cost model for Chinese multimodal transport based on Beresford Cost Model will be studied by a case of Shanghai to some Chinese Northern Ports. And some conclusion will be made to improve our country's transportation system with a lower cost level and higher service level.

Chapter 3 The Coal Transport System from Datong to WH Power Station

The year 1978 has seen a great policy been issued which is the China's reform and opening policies. Since then, the transport systems in China became more important to be optimized. The government takes some active and essential measures to realize the rapid development of transport construction, such as increasing road maintenance fees. Thus, transportation infrastructure in China has been improved and different modes has been more effective and a comprehensive transportation system was been established.

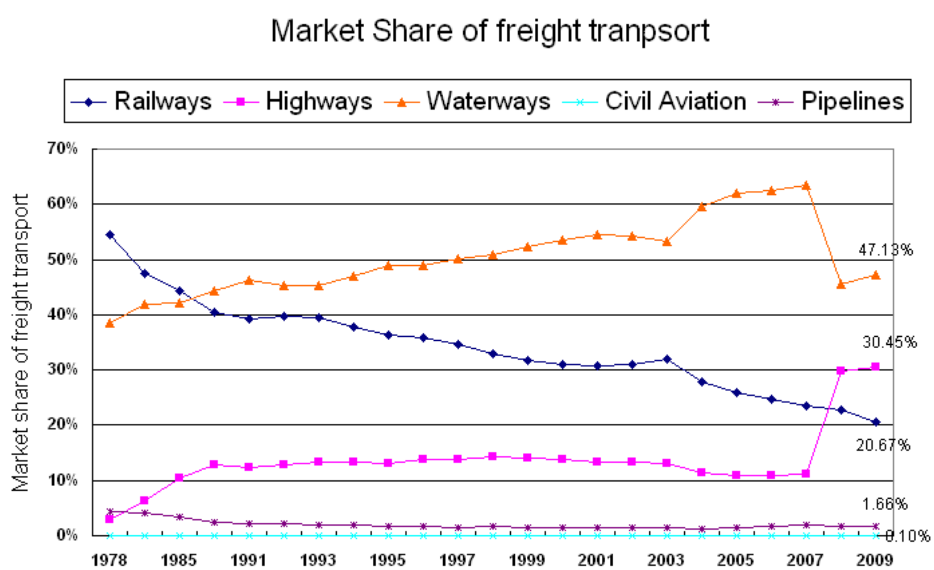


Figure 3.1 Market Share for Freight Transport in China
Source: Chinese Statistics Yearbook 2010

3.1 Current Coal Transport System

Coal transport in China mainly depends on railway, road and water transportation. Railway is the main mode of coal transportation, and coal has always been the main cargo of rail transport. The volume of coal railway transport has accounted for more than 60% of the total freight volume and for the railway freight volume, it accounts for 40%.

Figure 3.2 The Main Route of Coal Railway Transport in China
Source: China Coal Resources Network

As shown in Figure 3.2, the rail transport system of coal transportation is based on Shanxi Province, Mongolia, Henan Province, which shows the characteristic of center-radiation. Three west areas have three main corridors to the north area, middle area and south area. The route which will be used in the next chapters from Datong to Qinhuangdao is the important transportation route in the north corridor.

The problem of rail transport is the limited capacity. Without abundant investment, railway transport can't exactly meet the needs of coal transport demands.

Another proble of rail transport is that the limited transport system in Xinjiang and Mongolia area, and Xinjiang and Mongolia have the biggest reserve volume in China. The bottleneck of rail transport is always the bottleneck of the development of coal industry in China. Although there are big capacities in the market, but for coal transport, the capacities is still not enough.

In the whole system of rail transport, the railway mileage can't suit the development of size, population and economic in China. With the rapid development of social economic, the demand for rail transportation is continuous increasing.

Due to the high cost and freight rate, the rail transport still has its superiority. In theory, road coal transportation only suits short distance transport within a region. Nowadays, the freight rate of rail transport is about 0.1 yuan per ton-km. With a distance of 500 km, the freight rate is about 50 yuan per ton. But with the same distance, the freight rate of road transportation is almost 1.2 yuan per ton-km, which means the lowest rate is 600 yuan per ton. The difference is nearly 550 yuan per ton. Thus, the coal transportation carrier may take railway transport into first account. However, the capacity of rail transport is limited. The road transport is necessary for the coal transport.

Actually, road transport as an important supplement of rail and water transport can be seen in many coal production bases and transshipment port hinterland.

During the three years from 2008 to 2010, the capacity of rail transport from west to east has the increased volume to 102 billion, 127 billion and 97 billion. And the output of coal is increased 150 billion every year, which seems as a big presure for rail transport. But for road transport, it may be a big opportunity.

Figure 3.3 The Water Transport Network of Coal Transport in China
Source: Chinese Coal Resource Network

Figure 3.3 shows the water transport network of coal transport in China. In the coastal ports of China, there are seven main ports in the north area for coal transportation. The throughputs of these seven ports are accounted for 97.78% of total national foreign trade shipments and for 82.30% of total domestic trade shipments. And Qinhuangdao Port, Tianjin Port, Huanghua Port and Jingtang Port are the four biggest coal transportation ports. The coal output from Shanxi Province and Mongolia is transported through Tianjin Port and Qinhuangdao Port and the coal output from Shanxi Province is transported through Tianjin Port and Huanghua Port. Also, the coal from Shandong Province is transported through Rizhao Port.

For the discharging areas, Zhejiang Province is mainly discharging the coal transported from Qinhuangdao Port and Tianjin Port, while Fujian Province is mainly discharging the coal from Qinhuangdao Port, Tianjin Port and Huanghua Port.

Rail-water transport is the key method for the coal transported from north to south. Which means the water transport is as important as rail transport in the whole coal transportation system. Since the development of water capacity and port construction, the water transport has become more marketization. According the statistics by one company, the construction of berths with 50,000-100,000-ton capacity has been accounted for 63% in the total berths of coal loading ports. With the diversification investment and large-scale fleet, water transport may play a more important role in coal transportation than rail mode.

However, the modern logistics system and distribution center is key strategy for the development of coal transportation. That is to say how about the further capacity configuration and optimization is what our country needs to consider.

3.2 The influencing factor of coal transportation cost

In transport organizations, the expense used in the transportation business processes is called transportation cost, which includes the employee's salary, materials like office supplies, fuel, electric power and depreciation expenses of the fixed assets and administration expenses for different services.

The transportation cost is a very important index which can provide an integrated view of the whole transport process. It can thoroughly reflect the level of operation control and the technique in a transportation company.

In practice, there are various kinds of transportation expenses. In this dissertation, I will classify each transportation expenses and try to find out the proportion of them in the transportation costs. Also I will analysis the structure of all costs involved in a transportation process.

Based on the cost elements, the transportation cost can be divided into six sorts: salary, material, fuel, electric power, depreciation and others. Salary is the fixed and regular (usually be paid monthly) payment to the employees. The material cost is the expense of things used in transportation process. Fuel cost is the expense of fuel consumption used for vehicle's operation. The cost for electric power is mainly occurred in rail transportation. Depreciation is the decrease in value of an asset due to obsolescence or use. Others include welfare, expense for business trips, rent, payments for accidents and so on.

Also, some external factors will affect the level of transportation cost, like congestion, pollution, or accident. Congestion cost is the expense occurred by the loss of time, the wear of machine and the fuel consume of the vehicle. And also it will influence the environment condition. The cost of pollution is the expense that occurs by the pollution like CO_2. Because of the pollution, the global environment becomes worse. For the short term, harmful gas makes the air pollution. But for a long term, gas pollution will lead to air breakup. Accident cost is the economic loss which due to the accident and the part could be profit if the accident was not happened.

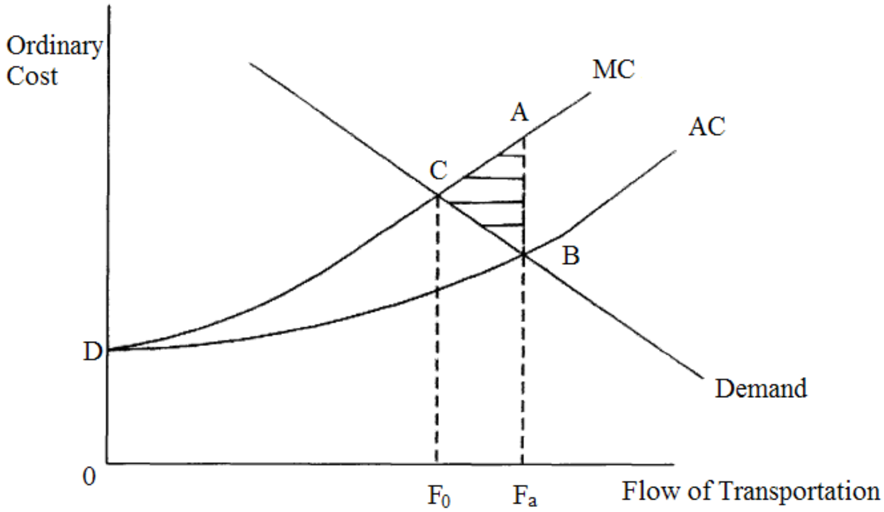


Figure 3.4 Congestion Cost

In this figure, AC is the average cost under a level of transportation flow and MC is the marginal cost when the number of vehicle is increased. Thus, F_0 is the optimal level of flow, while F_a is the real level of flow. Then we know that area of CBA is the increased cost due to the congestion.

3.3 The Route Choices and Data Collection from Datong to WH Power Station

The coal transportation market is mainly thermal coal transportation in coastal area of China. The shipment route is often from northern ports to southern electric power plant. Sometimes the power plant will use railway to transship its coal resources after shipping from northern ports. We know the cost of multimodal transport will be cheaper than one-way transportation. So in this chapter, one real case will be studied to analyze the multimodal transportation cost.

Actually, the shipping market is facing an over-capacity situation. All shipping companies want to occupy a key position in the market. So through multimodal transport to control and reduce the cost is very important.

Here I will present the movement of coal transportation from Datong to WH Power Station. Actually, there are many corridors available for coal transportation between Datong and WH Power Station. In this dissertation, four alternative routes will be analyzed (Table 5.1).

<table>
<tr><th>Route</th><th>Origin</th><th>Mode 1</th><th>Mode 2</th><th>Mode 3</th><th>Destination</th></tr>
<tr><td>1</td><td rowspan="4">Datong</td><td>Rail to Shanghai</td><td colspan="2">Road</td><td rowspan="4">WH Power Station</td></tr>
<tr><td>2</td><td>Rail to Shanghai</td><td colspan="2">Sea</td></tr>
<tr><td>3</td><td>Rail to Qinhuangdao</td><td>Sea to Zhangjiagang</td><td>Road</td></tr>
<tr><td>4</td><td>Rail to Tianjin</td><td>Sea to Lianyungang</td><td>Road</td></tr>
</table>

Table 3.1 Alternative Routes for coal transportation

All the distance data showed in the next chapters are collected by measuring on the electronic map. And the freight rate information is collected by a company which operates the transportation of coal from the loading places to the power stations.

Chapter 4 Building of Multimodal Transport Cost Model of Coal Transport

4.1 Cost Components

Based on the proportion of each kind of cost in total cost, there are two categories of costs will be mainly used in this dissertation.

One is internal cost, which includes transportation cost, time cost, and handling cost.

Transportation cost = Frequency of transportation Ｘ Unit transportation cost

= [(Demand volume / Capacity utilization rate) Ｘ Net weight] Ｘ Unit transportation cost

Time cost = Times needed for transport Ｘ Total transportation time Ｘ Unit time cost for one transport process

Handling cost = Times needed for cargo handling Ｘ Average handling cost for one transport process

The other is external cost, which is related to accident, pollution and other factors.

External cost = Frequency of transportation Ｘ Unit external cost of transportation

= [(Demand volume / Capacity utilization rate) Ｘ Net weight] Ｘ Unit external cost of transportation

4.2 Modes of Multimodal Transport

There are five modes mentioned in Chapter two. Due to the high cost of air transportation and this dissertation is mainly discussing the coal transportation, the mode of air will not being studied in this dissertation.

In practice, coal is mainly transported by bulk carriers, rail and road. Because the coal resource in northern area of China is rich, the coastal coal transportation flow is from north to south of China and the waterway transportation is first choice for coastal coal transportation. For the inland coal transportation flow, the railroad transport mode is the first choice for the coal resource transported from west to east of China.

The characteristics of railway transportation are large capacity, long distance, and low price, which can meet the demand of coal transport with a large volume and long route in China. Also, railway transport can further expand to the hinterland. The criss-cross of railway transportation network offers the condition for coal to transport by railway.

Road transport has a wide-distribution, few-transit-links and flexible characteristic. It can achieve the advantage of ‘door-to-door’ transport. However, road transport has its limitation, such as small traffic capacity, consumption of energy and high cost. So road transportation is generally suitable for short-distance transport within the region, such as the internal transport stations and ports.

Water transport of coal includes sea and river transport. Main seven northern ports in China are Qinhuangdao Port, Jingtang Port, Tianjin Port, Huanghua Port, Qingdao Port, Rizhao Port and Lianyungang Port. And ports of Nanjing, Hong Kong, Wuhan, Wuhu, Zhicheng, Jiujiang are also big coal ports in the region of Yangtze River. Ports for coal unloading are ports of Shanghai, Ningbo, Guangzhou, Nantong, Zhenjiang, Hangzhou, and Ma'anshan. Qinhuangdao Port, Tianjin Port and Huanghua Port are the most important ports for coal to transport and in southeast region; almost 60% of coal for electric power is loaded in these three ports. Seven Northern Ports have their rail or road links, such as rail route from Datong to Qinhuangdao.

Research, design, equipment manufacturing and construction of pipeline transport have begun in China. The length of one pipeline in Shanxi province is 104km and diameter is 229mm, which has the capacity of 2 million tons annually.

4.3 Formulas of the Concept Cost Model

Beresford Cost Model analyses the data through figure. By this kind of image method, it can offer an easy understanding about the cost level of multimodal transport. But when the data does not have a big difference, then use image can't offer an accurate analysis.

In this part of the dissertation, I will offer a concept model which is based on the Beresford Cost Model about multimodal transportation cost.

During the cargo assembling or disassembling stage,

Q_k: the total quantity of demand

M_k: the net weight of the vehicle

λ_k: the utilization rate of capacity

f_k: the frequency of transport in K area, which is in direct proportion to Q_k and varies inversely with the M_k and λ_k.

d_{k1}: the distance from the original place to the first load/unload place

$C_{ok}(d_{k1})$: unit transportation cost which indicates the cost every vehicle finish one transportation process.

δ_k: the average distance during the continuous process

d_{k2}: the distance from the last load/unload place to the joint station

During the stage of transportation between joint stations,

Q: the total quantity of shipments

f: the frequency of shipment

c_i: the internal cost

c_e: the external cost

w: the deadweight of vehicle

d_{js}: the distance between joint stations

α_1:unit time cost of loading/discharging in the joint stations

α_2: unit time cost of transportation between joint stations

Thus, the formula are as following:

Assembling or disassembling stage:

$C_{tr} = (Q_k/\lambda_k M_k)C_{ok}(d_k)$, which is the internal transportation cost.

$C_{ti} = Q_k \cdot \alpha_k \cdot t_k$, which is the time cost.

$C_l = Q_k \cdot t_k \cdot c$, which is the loading/discharging cost.

$C_e = (Q_k/\lambda_k M_k)c_e(d_k)$, which is the external cost.

$C_c = C_{tr} + C_{ti} + C_l + C_e$

Stage of transportation between joint stations:

$C_{tr} = (c_i(QT(\alpha_1+\alpha_2)/c_i+c_e)/2)^{0.5}$

$C_{ti} = (QT(c_i+c_e)/(\alpha_1+\alpha_2))/2^{0.5}+Q\alpha(d_{js}/v+D)$

$C_l = Q \cdot c$

$C_e = Q \cdot c_e+c_e((QT(\alpha_1+\alpha_2)/c_i+c_e)/2)^{0.5}$

$C_c = C_{tr} + C_{ti} + C_l + C_e$

Chapter 5 Cost Comparison of Four Coal Multimodal Transport Routes form Datong to WH Power Station

5.1 Route 1 – Datong – Shanghai – WH Power Station (Rail – Road)

For simple calculation, the external costs and the time costs in four routes are converted into the freight rate.

Step	Leg	Mode	Transit Time	Distance (km)	Freight Rate (Yuan/ton)
1	Datong – Shanghai	Rail	15 hours	1,771	204.2
	Handling at Shanghai Railway Station		1 hour per 2,000 tons		3.0
2	Shanghai – WH Power Station	Road	6 hours	341.6	119.56
Notes: Different modes have different capacity. In this table, the transit time is only the time used for one transport process by unit vehicle of transportation, not the whole process.					

Table 5.1 Distance, Freight Rate, and Transit time of Route 1

Rail transport accounts for about 60% of the total coal transport in China, with the sea transport for about 30% and the road transport for about 10%.

Assume one truck can load 60 tons and each railway has 50 trucks, then one railway trip's capacity is 3,000 tons. As the data shows in Table 5.2, the total cost for rail transportation is calculated as following:

$$204.2 \times 3{,}000 = 612{,}600 \text{ Yuan.}$$

The biggest difference between rail transport and road transport is the capacity. We know that railway transport can carry a big volume, but the road transport can only carry a small volume. Each train can carry 3,000 tons and each truck can only carry 20 tons. So in Route 1, after the coal is transported from Datong to Shanghai by train, it needs to be distributed into small quantities for truck. Thus the handling cost exists. For easy calculation, the unit handling cost equals to 3.0 Yuan per ton as freight rate. So the handling cost for 3,000 tons of coal is calculated as following:

$$3.0 \times 3{,}000 = 9{,}000 \text{ Yuan}$$

Generally speaking, a road transport fleet is about 10 to 20 trucks. In this case study, one road transport fleet has 15 trucks. According to the 20-ton capacity of one truck, the frequency of road transportation is 10 times. The transport cost for road transport is calculated as following:

$$119.56 \times 3{,}000 = 358{,}680 \text{ Yuan}$$

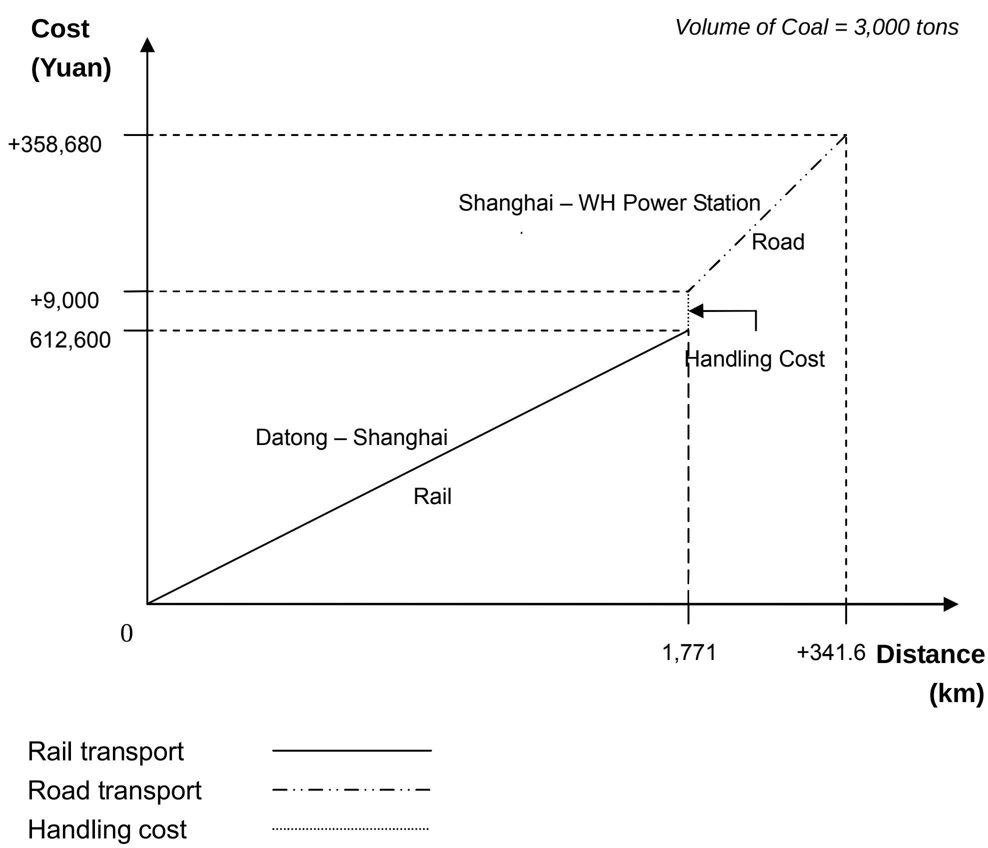


Figure 5.1 Rail – Road Transport in Route 1

5.2 Route 2 – Datong – Shanghai – WH Power Station (Rail – Sea)

Step	Leg	Mode	Transit Time	Distance (km)	Freight Rate (Yuan/ton)
1	Datong – Shanghai	Rail	15 hours	1,771	204.2
	Handling at Shanghai Railway Station		1 hour per 2,000 tons		3.0
2	Transfer from Shanghai Railway Station to Coal Terminal	Road	2 hours	*50*	*50*
	Handling at Shanghai Coal Terminal		1 hour per 2,000 tons		3.0
3	Shanghai – WH Power Station	Sea	20.2 hours	448.184 (242 nm)	35
Notes: Different modes have different capacity. In this table, the transit time is only the time used for one transport process by unit vehicle of transportation, not the whole process. The italic number is the presumptive number.					

Table 5.2 Distance, Freight Rate, and Transit time of Route 2

First step in Route 2 is the same situation as in Route 1. However, we know that road capacity is small. Here sea transport is chosen to be the final step. The reason for this choice is that sea transport has the characteristic that capacity is big and the unit cost is low. And for coal transportation, time factor is not very important. So sea transport is always the first choice for power station to choose.

But due to the draft limitation in waterway of Yangtze River and the bridge height limitation of Nanjin Bridge, the vessel type for coal transportation to WH Power Station can only be the Handysize with 10,000 DWT or 20,000 DWT. So in Route 2, the volume of coal is assumed to be 9,000 tons.

Another situation is that direct transfer from rail transport to sea transport can't realize in this route. Thus, short road transportation has to be used from Shanghai Railway Station to Shanghai Coal terminal. Considering the transportation circumstance, external cost and time cost, the freight rate for road transport is assumed as 50 Yuan per ton. Then the total cost for road transportation is calculated as following:

$$50 \times 9{,}000 = 450{,}000 \text{ Yuan}$$

And total cost for rail transportation is calculated as following:

$$204.2 \times 9{,}000 = 1{,}837{,}800 \text{ Yuan.}$$

The final step in Route 2 is sea transport. The distance between Shanghai and WH Power Station is about 242 nm, which equals to 448.184 km. The freight rate is 35 Yuan per ton. Then the total cost for sea transportation is calculated as following:

$$35 \times 9{,}000 = 315{,}000 \text{ Yuan}$$

In Route 2, the unit handling cost equals to 3.0 Yuan per ton. So the handling cost of Shanghai Railway Station and Shanghai Coal Terminal is calculated as following:

$$3.0 \times 9{,}000 = 27{,}000 \text{ Yuan}$$

$$27{,}000 \times 2 = 54{,}000 \text{ Yuan}$$

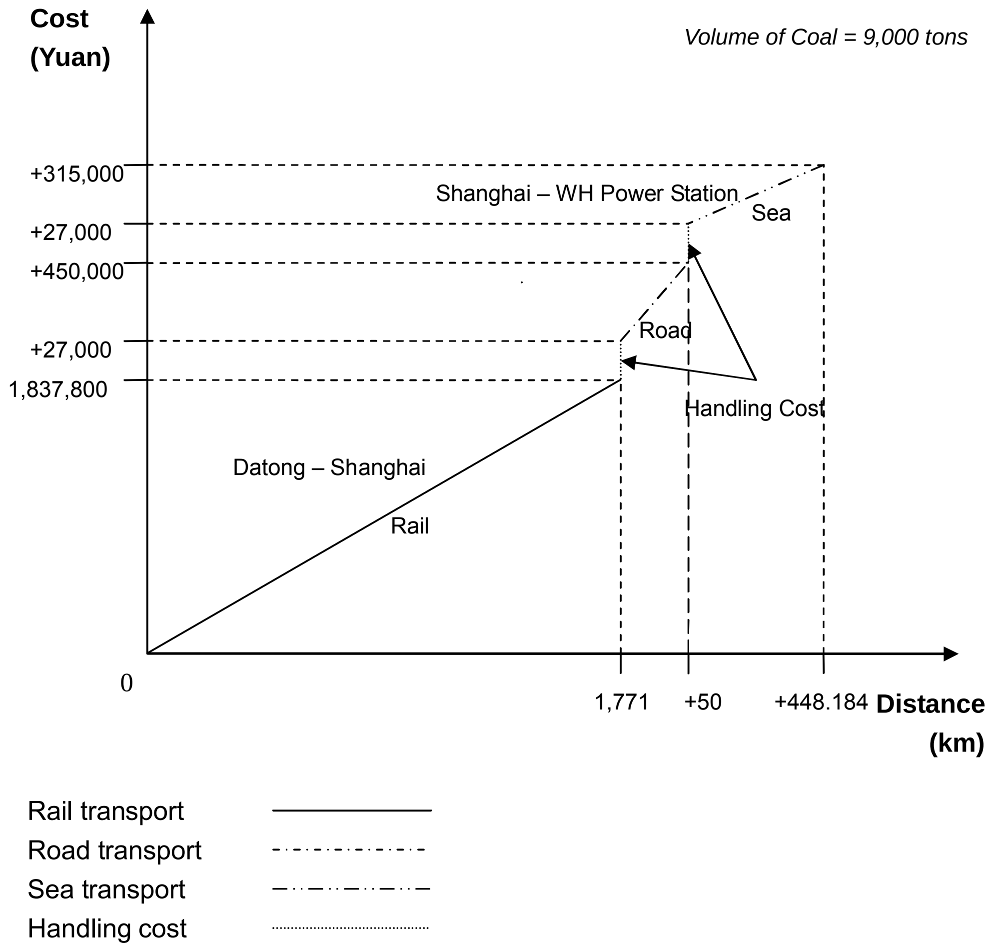


Figure 5.2 Rail – Sea Transport in Route 2

5.3 Route 3 – Datong – Qinhuangdao – Zhangjiagang – WH Power Station (Rail – Sea – Road)

Step	Leg	Mode	Transit Time	Distance (km)	Freight Rate (Yuan/ton)
1	Datong – QHD	Rail	6 hours	644	86.6
	Handling at QHD		1 hour per 2000 tons		3.0
2	QHD – ZJG	Sea	73.2 hours	1623.056 (878 nm)	55
	Handling at ZJG		1 hour per 2000 tons		3.0
3	ZJG – WH Power Station	Road	5.5 hours	313.32	109.7
Notes: Different modes have different capacity. In this table, the transit time is only the time used for one transport process by unit vehicle of transportation, not the whole process.					

Table 5.3 Distance, Freight Rate, and Transit time of Route 3

As mentioned before, rail transport accounts for about 60% of the total coal transport in China. And the railway network in China has eight vertical routes and eight horizontal routes. It covers the whole land of China. In the coal transportation, railway line from Datong to Qinhuangdao is the famous one.

The distance between Datong and Qinhuangdao is only one-third of the distance between Datong and Shanghai. Meanwhile, the unit cost for transportation in this route is lower than in Route 1. The freight rate is 86.6 Yuan per ton. Considering that the sea transportation between Qinhuangdao and Zhangjiagang has no draft limitation, Handysize vessels with 40,000 DWT or 50,000 DWT are chosen in Route 3. Then the volume of coal transport is assumed as 45,000 tons.

Thus we can calculate the following costs:

Cost for rail transportation: 86.6 × 45,000 = 3,897,000 Yuan

Cost for sea transportation: 55 × 45,000 = 2,475,000 Yuan

Cost for road transportation: 109.7 × 45,000 = 4,936,500 Yuan

In Route 3, the handling cost expended between two modes is calculated as following:

3.0 × 45,000 = 135,000 Yuan

And the total handling cost is 270,000 Yuan.

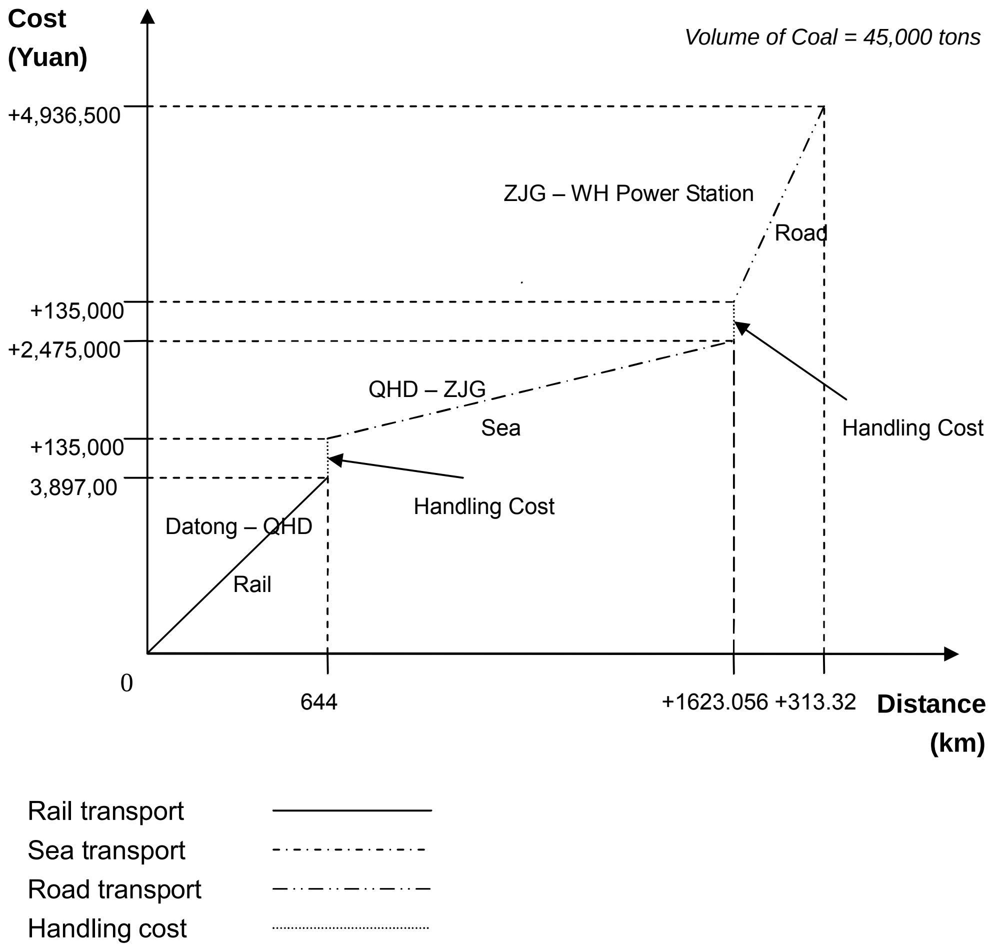


Figure 5.3 Rail – Sea – Road Transport in Route 3

5.4 Route 4 – Datong – Tianjin – Lianyungang – WH Power Station (Rail – Sea – Road)

Step	Leg	Mode	Transit Time	Distance (km)	Freight Rate (Yuan/ton)
1	Datong – Tianjin	Rail	5.2 hours	614	80.1
	Handling at Tianjin		1 hour per 2000 tons		3.0
2	Tianjin – Lianyungang	Sea	40.1 hours	890.812 (481 nm)	60
	Handling at Lianyungang		1 hour per 2000 tons		3.0
3	Lianyungang – WH Power Station	Road	7.4 hours	443	155.05
Notes: Different modes have different capacity. In this table, the transit time is only the time					

used for one transport process by unit vehicle of transportation, not the whole process.

Table 5.4 Distance, Freight Rate, and Transit time of Route 4

Tianjin Port is another biggest port for coal shipment. And Lianyungang Port is the middle port between Tianjin Port and WH Power Station, which has its own coal berth. Both ports have no draft limitation, and they can handle the Capasize vessels. So in Route 4, bulk ships with 50,000 DWT or 60,000 DWT are chosen because this type of vessels is the ordinary one for coal shipping in China. And the volume of coal transport is assumed as 60,000 tons.

Thus we can calculate the following costs:

Cost for rail transportation: $80.1 \times 60{,}000 = 4{,}806{,}000$ Yuan

Cost for sea transportation: $60 \times 60{,}000 = 3{,}600{,}000$ Yuan

Cost for road transportation: $155.05 \times 60{,}000 = 9{,}303{,}000$ Yuan

In Route 4, the handling cost expended between two modes is calculated as following:

$$3.0 \times 60{,}000 = 180{,}000 \text{ Yuan}$$

And the total handling cost is 360,000 Yuan.

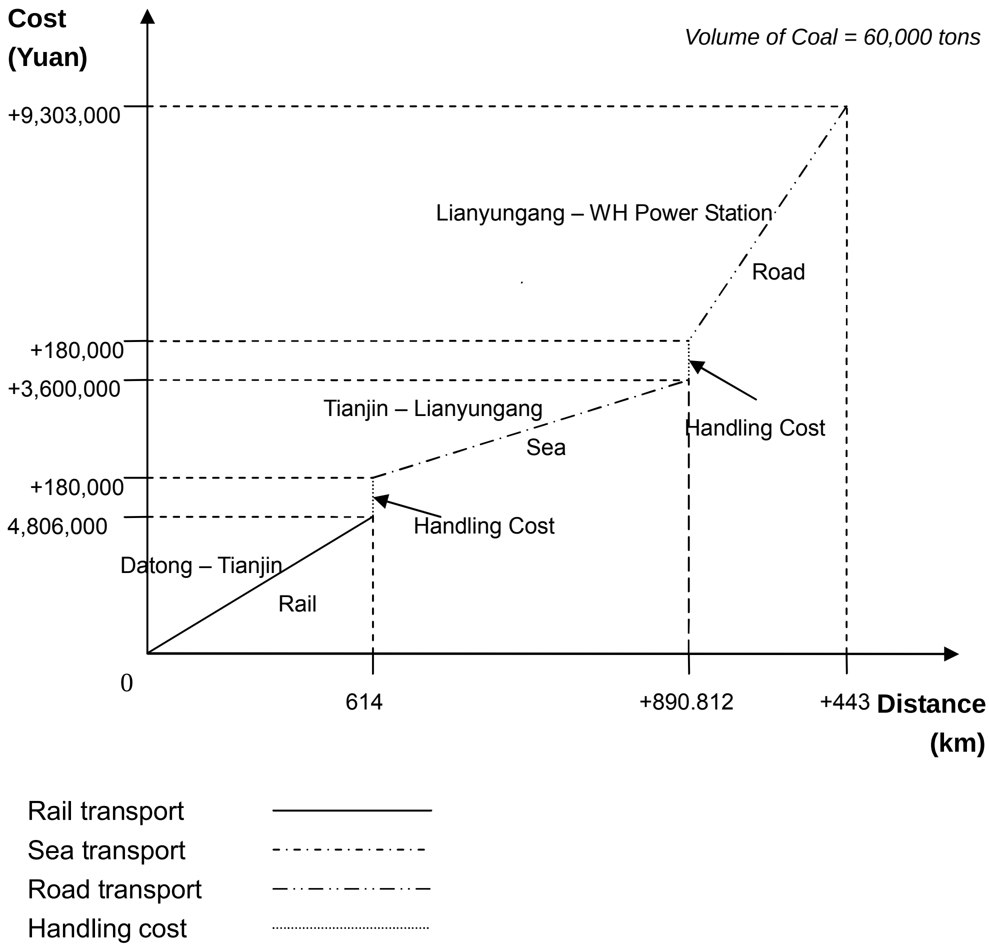


Figure 5.4 Rail – Sea – Road Transport in Route 4

5.5 Comparison of Four Routes

Take volume of 180,000 tons as an example for the coal transportation.

In Route 1, the whole transport process can only carry 3,000 tons. So if 180,000 tons of coal needs to be transported, the total cost should be multiplied by 60, which equals to 58,816,800 Yuan.

And the total time should be calculated as following:

Time (Rail) = 15 hours × 60 = 900 hours

Time (Road) = 6 hours × (180,000 tons / (20 tons per truck × 15))

= 3,600 hours

Time (Handle) = 180,000 tons / 2,000 tons per hour = 90 hours

Total time = 900 + 3,600 + 90 = 4590 hours = 191.25 days

Total distance = 1,771 + 341.6 = 2,112.6 km

In Route 2, the whole transport process can carry 9,000 tons. So if 180,000 tons of coal needs to be transported, the total cost should be multiplied by 20, which equals to 53,136,000 Yuan.

And the total time should be calculated as following:

Time (Rail) = 15 hours × 60 = 900 hours

Time (Sea) = 20.2 hours × 20 = 404 hours

Time (Handle) = 180,000 tons / 2,000 tons per hour = 90 hours

Total time = 900 + 404 + 90 = 1,434 hours = 59.75 days

Total distance = 1,771 + 50 + 448.184 = 2,269.184 km

In Route 3, the whole transport process can carry 45,000 tons. So the total cost should be multiplied by 4, which equals to 46,314,000 Yuan.

And the total time should be calculated as following:

Time (Rail) = 6 hours × 60 = 360 hours

Time (Sea) = 73.2 hours × 4 = 292.8 hours

Time (Road) = 5.5 hours × (180,000 tons / (20 tons per truck × 15))

= 3,300 hours

Time (Handle) = 180,000 tons / 2,000 tons per hour × 2 = 180 hours

Total time = 360 + 292.8 + 3,300 + 180 = 4,132.8 hours = 172.2 days

Total distance = 644 + 1623.056 + 313.32 = 2,583.376 km

In Route 4, the whole transport process can carry 60,000 tons. So the total cost should be multiplied by 3, which equals to 54,207,000 Yuan.

And the total time should be calculated as following:

Time (Rail) = 5.2 hours × 60 = 312 hours

Time (Sea) = 40.1 hours × 3 = 120.3 hours

Time (Road) = 7.4 hours × (180,000 tons / (20 tons per truck × 15))

= 4,440 hours

Time (Handle) = 180,000 tons / 2,000 tons per hour × 2 = 180 hours

Total time = 312 + 120.3 + 4,440 + 180 = 5,052.3 hours = 210.5 days

Total distance = 614 + 890.812 + 443 = 1,947.812 km

According to the calculations showed above, we get the table showed below:

Route	Mode	Total Cost (Yuan)	Total Time (Day)	Total Distance (km)
1	Rail – Road	58,816,800	191.25	2,112.6
2	**Rail – Sea**	**53,136,000**	**59.75**	**2,269.184**
3	Rail – Sea – Road	46,314,000	172.2	2,583.376
4	Rail – Sea – Road	54,207,000	210.5	1,947.812

Table 5.5 Total Transport Cost, Distance, Time for each route

Among all the modes of coal transportation in these four routes, sea transport is the cheapest one and the road transport is the most expensive one per ton/km.

In practice, we know that for Chinese coastal coal transportation, the power stations prefer to transport by waterway because of its low cost and big volume, although it takes time.

As the results showed in Table 5.6, the Route 2 is the optimal one. In Route 2, the rail transport is firstly chosen and then use bulk ships to handle the next stage of transportation. It is not the cheapest route. However, if we consider the time and distance factors as well as cost factor, we can easily find out that the Route 2 is the best one.

And we know that use multimodal transport, the total cost can be reduced accordingly.

Conclusion

In this part, a summary and findings of this dissertation and provides a better understanding of multimodal transport in China. Some limitations will be presented and some recommendations will be referred to for the future academic research.

Summary and Findings

In Chapter 5, the characteristic of sea transport is obvious. The sea transport is the mode with large capacity, low freight rate and small energy consumption. The freight rate of sea transport is one-sixth of road transport, and two-fifths of rail transport. It is easy to form scale and batch. Add with the industrial layout of power, metallurgy and petrifaction in China mainly modulated to coastal area, the dominance of sea mode for coal transport is much more patent.

However, the facilities in export coal terminals can’t match that in import coal terminals and the coal ships have a limited capacity, which leads to the phenomenon like the low turnover ratio, or many ships are waiting to berth.

So to establish large-scale distribution center is one way to release the situation described before.

Limitations of the Research

Due to time limitation, the data collection in this dissertation was limited. And although rail transport, sea transport and road transport are the common modes for coal transportation, the pipelines are developing in recent years. Only three of five modes were used in the case study.

There are many factors will effect the multimodal transport. Only three factors

– time, cost, and distance – are considered during the process of cast study.

And the route choice is only from Datong to WH Power Station, which is only one of the typical routes in real coal transportation.

Due to these limitations, the results of the case study may not give the suggestions to all areas in China. But it still has practical significance for the future study.

Utilities and Future Recommendation

With the easy understanding of figure based on Beresford Cost Model and the formula showed in Chapter 4, it has a great meaning for Chinese coal transport with multimodal transport methods.

It can help the operators or coal transport companies or power stations to design the most cost-effective or time-effective route during their transport process. And it is meaningful for the development of multimodal transport in China.

Also, for the future academic research, it gives a simple guide. With the development of pipeline transport, the pipeline mode can be added into the model and study how the pipeline performs during the coal transport process. And also, for other cargoes transportation, the model showed in this dissertation can offer a basic guide.

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