# Comparison of Electrical Coal Pipeline Transport and Rail Transport Based on Social Costs

Zhou Hongmei, Yi Zhenglin , Huang Zhilong
School of Transportation, Wuhan University of Technology, Wuhan, P.R.China, 430063
(E-mail: redplum@whut.edu.cn ,752090383@qq.com ,st-winds@qq.com )

**Abstract:** So far in China, since the capacity of railway transportation is in shortage, especially for the transportation of electrical coal, it's interesting to study the best way to overcome this problem. Through the comparison of the financial and social cost between two kinds of transportation, namely pipeline and railway, the authors argue that, in a long-distance, large-scale coal transportation, pipeline transportation is a more environmentally friendly and economical option.
**Keywords:** Electrical coal transport; Social cost; Railway transporting; Pipeline transporting

## 1 Introduction

China's electrical coal resources mainly concentrate in North China and northwest, but the electricity coal expends mainly concentrates in the coast, south and Central China area, large quantities of electricity coal must transport over long distance from the north to the south, from West to East[1]. In recently, with china economic level's fast growth, various regions' electricity coal demand grew day by day, the electricity coal's shortage had spread from formerly the peak to the off season of the same time, and transformed from formerly the peak to the off season of the same time, and transformed from the lack of total quantity to lack the constitutive property. In the long run, to solve the electricity coal supply's tense aspect fundamentally, one important way is to develop the pipeline transportation. As a long distance operation's transport mode has not yet launched, compared to the railway transportation whether there is cost advantage, what influence to the environment, and what state of the water resources consume, which are the questions urgently need to be solved. The existing literature mainly pays attention to the pipeline or railway transportation's technical economy analysis, but rarely carries on the complete cost comparison analysis from the social cost angle [2]. Therefore, in view of the long distance and the large-scale electrical coal transportation, utilizing the social cost theory, quantitative analysis and comparing both financial transportation cost, the environmental costs and the traffic safety cost, have practical significance.

## 2 Social Cost Composition of Electrical Coal Transportation

Traditionally Costs of pipeline and rail are compared simply in terms of finance, while ignoring their impact to environment and security, especially ignoring their occupation of water resource in under-watered district or simply carry out qualitative analysis. This paper, after introducing the idea of social cost, discusses and compares the social costs of pipeline and rail transport.

Social cost is calculated from the angel of society, which is the sum of production cost and the burden it lays on society (external cost). In this article, social cost of electrical coal transportation is the sum of social cost of electrical coal transportation in terms of finance and external cost. The former is its financial cost while the later includes transport security cost, resource cost and environment cost. Just as what is illustrated in Eq. 1, social cost of electrical coal transportation is the function of these three. B is financial cost, S means transport security cost, S is resource cost, that is the resource consumed, and E is environment cost, i.e. the extent of noise and air pollution.

$$C = f(B, S, R, E) \quad (1)$$

## 3 Comparison Between Financial Costs of Pipeline and Rail Electrical Coal Transportation

### 3.1 Features of financial costs composition of pipeline and rail electrical coal transportation

The cost of electrical coal transportation can be divided into fixed cost and variable cost. In rail transport cost of electrical coal, there are two outstanding features: the cost that is not related to the volume, i.e. route, communication device, huge size building, running and maintaining cost of technological building and the salary of administrators, which makes up 50% of all; handling cost in

departure and arrival station make up another 18%, approximately. So, its cost is high when haul distance is short, and can only be depressed when the haul distance is long enough. When compared with pipeline, the fixed cost of railway is higher and its variable cost is lower respectively.

**3.2 Function of transportation cost (including model hypothesis, model, and parameter explanation)**

We set up the financial transportation cost function, e.g. (2), on the basis of the features of financial transportation cost of both pipeline and railway. The cost per unit $UC_i$ of transportation means of i is the function of fixed cost $FC_i$ and variable cost $VC_i$, i.e.

$$UC_i = \frac{FC_i + VC_i}{Q_i} \tag{2}$$

$Q_i$ is the annual coal volume of traffic means of i.

The frozen annual cost of pipeline transported coal includes depreciation cost D, maintenance cost Fm, amortization cost $F_t$, salaries of administrators and financial cost $F_f$; variable cost mainly includes direct management cost $F_a$, salaries of workers we, resource (fuel and motive power) costs and water cost $F_w$, which can be illustrated as

$$FC_{pipe} = D + F_m + w_a + F_t + F_f \tag{3}$$

$$VC_{pipe} = F_a + w_e + F_e + F_w \tag{4}$$

The cost of rail transported coal can also be divided into fixed cost and variable cost. In some documents, the cost of railway transport is exclusive of handling cost. This paper, taking financial cost into consideration, regards handling cost $F_z$ as variable cost. Fixed cost is made up of depreciation cost, salaries of administrators, financial cost and amortization cost. Among them, capital cost include the price for right of way, building of roadbed, laying track and assembling of control system; appreciation cost includes the appreciation cost of both track, device and locomotive. And variable cost is the sum of direct administrative cost, handling cost, fuel and motive power and salaries of workers. Its difference from pipeline is that, railway cost does not include the cost for water consumed.

$$FC_{rail} = D + F_m + w_a + F_t + F_f \tag{5}$$

$$VC_{rail} = F_a + w_e + F_e + F_z \tag{6}$$

**3.3 Calculation and comparison of transportation costs**

Taking a electrical coal pipeline transportation or a railway investment projects for example, we undertook comparative analysis of the financial cost about the pipeline and rail coal . The project is proposed between Shanxi Binxian and Wuhan Yangluo and building a total length of 1,000 km pipeline or a length of 1,100km railway, which will directs the Wuhan Yangluo construction of a major coal reserve base of coal logistics strategy. In this paper, simulation program for 15 years, cconduct quantitative cost analysis between the railway and pipeline coal.

Assumed that the pipeline from Binxian to Yangluo design capacity are 10 million tons coal / year, invest 9 billion yuan; railway design capacity are 20 million tons coal / year, 8.0 billion investment. Railway in its first year reached 10 million tons, 15 million tons next year, the first five years 15 million tons; the first year of pipeline transportation capacity are 500 million tons, the second year to 800 million tons, to the fifth annual transport capacity to meet the design. Annual inflation rate is up to 5%.

Pipeline transportation of values based on the following parameters: assumed depreciation period T is15 years(calculate in terms of straight-line method). Reference to the American black Mesa pipeline operating experience, The whole process adopt centralized management model. Set nine pumping stations, pulp and pump input Capacity 110 people, 30 service centers, dewatering system Capacity 60, the initial average wage at 30,000 yuan / (person • years), employee benefits 14% of wages. Management accounting for 10% of total number of employees and maintenance costs are taken as depreciation costs of 8%, finance costs including 8-year period of interest-bearing loans and liquidity, the liquidity line infrastructure investment to take 4%, interest-bearing part 70%. Amortization period of eight years, the object is in other cost components of construction costs, and other costs are by Capacity * 8,000 yuan / (person • years) calculation [4]. The direct management fee takes 2 times of wages for the workers. Pipeline required water in accordance with 1:1 consumption, water is from the Jing River of Binxian, water take Binxian local industrial water price, namely 4.3 yuan / ton.

Railway coal-related parameters Values [7]: assume that the initial construction of the railway cost is 8.0 billion, the depreciation period of 15 years(calculate in terms of straight-line method), taking the

residual value of 5%. Need to train with 14 workers and 2340 for coal transportation, the price of each coal train 10 million / vehicle, its depreciation limited to 15 years, the salvage value of 5% ,initial annual per capita wage of 30,000 yuan, the employee benefits to wages 14%. Handling costs take 5.5 yuan / ton. Its management staff salaries, amortization costs, maintenance wages are the same as the values of the railway. Assumed that the use of diesel-driven locomotives, diesel price of the initial 7-year yuan / liter, trains consume 24.6kg of diesel per ton kilometer, power costs by taking 5% of fuel costs. Finance charges include eight-year period of the loan interest and liquidity, working capital investment in infrastructure to take line * 4%, interest-bearing portion of 60%.

Related parameters are substituted into the pipeline transport and railway transport's financial cost function, then calculate the two modes transport's unit transportation costs, variable costs and variable costs proportion. Shown in Table 1.

**Table 1 The Financial Cost Comparison Between Railway Transporting and Pipeline Transporting**

| Year | Railway transporting（yuan/ton-km） | | | | Pipeline transporting（yuan/ton-km） | | | |
|---|---|---|---|---|---|---|---|---|
| | Traffic volume（ten thousand ton） | Unit variable costs | Unit transportation costs | Proportion of variable costs | Traffic volume（ten thousand ton）） | Unit variable costs | Unit transportation costs | Proportion of variable costs |
| 1 | 500 | 0.016 | 0.157 | 9.92% | 1000 | 0.041 | 0.112 | 36.70% |
| 2 | 800 | 0.015 | 0.104 | 14.84% | 1500 | 0.035 | 0.088 | 39.97% |
| 3 | 800 | 0.017 | 0.106 | 16.31% | 1500 | 0.035 | 0.085 | 41.27% |
| 4 | 800 | 0.018 | 0.106 | 16.82% | 1500 | 0.036 | 0.083 | 43.40% |
| 5 | 1000 | 0.018 | 0.089 | 20.28% | 2000 | 0.033 | 0.071 | 46.23% |
| 10 | 1000 | 0.022 | 0.085 | 25.51% | 2000 | 0.042 | 0.087 | 48.42% |
| 15 | 1000 | 0.027 | 0.090 | 29.48% | 2000 | 0.054 | 0.099 | 54.67% |

From the Table 1, the pipeline initially low variable costs can not compensate for its high investment, railway coal handling is more competitive at the beginning, with operating year increasing, gradually traffic has reached the design capacity. From the tenth year, pipeline transportation unit cost is lower than rail transport, the competitiveness is increasingly apparent. From the cost structure, in the operation 15 years, pipeline variable costs are increasing in the proportion of total costs year by year, but compared to the pipeline transportation, the railway is still slower than the growth in variable costs. Because of cheap labor and energy costs, variable costs, annual fee advantage starts to turn the railway to pipeline. In the 15th years, the pipeline unit transportation cost is 0.09 yuan per ton • km, and the rail unit transportation cost is 0.099 yuan per ton • km, pipeline unit transportation cost saves 0.01 yuan per ton • km, the annual cost saves 10 million yuan (calculated at 10 million tons).

Pipeline variable costs is much lower than the fixed costs, even in the case of large output it is true. But, the pipeline scale economic is still very significant. Foreign studies have shown that if the capacity of pipeline transportation can double, the unit transport costs can be reduced by 30% [5]. But these are based on the premise of adequate electricity demand, in the current domestic situation, coal demand in the long period provides with adequate safeguards.

## 4 The Comparative Analysis of External Costs

External cost is the transportation brings others' and social losses. Including the traffic safety costs, environmental costs and resource consumption costs[8].

Coal pipeline transport is a very environmental mode of transport. The external costs include: some certain water consumption, low noise pollution and very little emissions. External costs of rail transport mainly include the cost of traffic safety, the occupation of land resources, noise pollution and so on.

### 4.1 Comparative analysis of traffic safety cost

Traffic safety cost E is calculated as:

$$E = E_{direct} + \mathrm{E}_{injury} + \mathrm{E}_{society} = f(E_{direct},\ \mathrm{X}_a, C_s, E_{society})$$

$E_{direct}$:direct economic loss;

$E_{injury}$: personnel casualty loss;

$E_{society}$:personnel services Loss;

$X_a$: the casualties's social work value loss;

$C_s$:the casualties relatives's mental loss.

Railway traffic safety costs mainly lie on the locomotive brake and line bridge equipment safety, with the gradual overloading of coal transportation train, the value of $E_{society}$,$E_{direct}$,$E_{injury}$ shows some increasing trend.

In contrast, pipes buried in the ground which have almost no conflicts with above ground objects, and will not cause disruptions due to inclement weather, so it is a safer mode of transport.

**4.2 Environmental cost comparison analysis**

The environmental impact of the coal transportation by railway mainly includes the occupation of the land resources, noise pollution and coal dust off and pollution, etc. Once railway is builted, land resources alone the line cannot be used for others, as the occupation of the land resources is permanent. According to the size of the railway planning red line, if the width of the railway planning red line is 20 meters, 1 km railway is to occupy 2 hectares of land resources, which makes the cultivated land shortage problem more outstanding. Railway noise mainly comes from the wheel and rail contact vibration noise, and "the land of railway regulation" shows the boundaries of the railway should be 30 m from the center line of railway track; "the city five kinds of environmental noise standard" shows the noise around the mainline railway at night should not be more than 55 decibels. Actually, when the train passed, on both sides of the railway noises are more than 120 decibels. In addition, railway locomotives have produced air pollution in China in recent years. Because most of the railway finished electrification and modernized transformation or reconstruction, almost all traditional steam locomotives are eliminated; diesel and electric have become the main energy consumption. Therefore, the internal combustion engine emission — CO, HC, NOX and smoke emission have become major air pollutants.

However, all coal transportation by piping except a few outside pumping stations does not occupy the land resources, and piping noises mainly come from liquid through the pipe. Because of deep underground, their influence ranges are tiny. In addition, coal transportation by piping mainly consumes electric energy, as the pipeline does not belong to power equipments, emissions are very little.

**4.3 Analysis of water resources consumption**

Strictly speaking, the water consumption of two coal transport ways is just one aspect of energy consumption, in addition to fuel consumption, power consumption. As the former has been included in finance costs, and the water resources consumption is particularly important in the water short western areas. Therefore, this paper analysis water resources consumption separately.

The water resources consumption is very little in Railway coal transport and can be ignored. Too much moisture will waste railway capacity, even result in inevitable losses.

The difference is that the coal liquefaction requires large amounts of water before transport by pipeline. because most China's coal origins are in the dry areas, the feasibility of coal pipeline exploring has become difficult. In fact, the water consumption of coal pipeline transportation is directly related to the coal's concentration, and the concentration also related to the economics of the pipeline. When the concentration is low, ton kilometre transport energy consumption will increase; while at high concentration, slurry viscosity and the resistance with slurry pipeline wall will increase so making energy consumption increases[6]. Therefore, it is critical to select a proper concentration on cost and power consumption, while there is accompanied by the most suitable water consumption. 1 ton of dry coal needs 1 ton of water. In above cases, 0.01 billion tons of coal transport consumes 0.01 billion tons water per year. As opposed to Jinghe 1.67 billion cubic meters of annual average runoff, the proportion is not high. Actually, the coal's own moisture content also makes the demand less. Data shows that the water consumption of coal pipeline transport is less than one-sixth of the amount needed in transferring coal heat energy into electrical energy[3]. In other words, under the prerequisite of selecting a suitable coal slurry concentration according to the situation on the ground, the water consumption of coal pipeline transporting does not have much impact on the local industrial and agricultural production.

## 5 Results of Social Cost Comparison

Through the above analysis, the speed of cost decline is divided into 4 levels-- very fast, fast. slow and very slow; the footprint is divided into many, more, less, and rarely; the degree of accidents and environmental pollution are divided into serious, less serious, general and rarely. Then it gets the cost comparison result between coal pipeline and railway transport as shown in Table 2.

**Table 2 The Social Cost Comparison Result Between Coal Pipeline and Railway Transport**

| Transport mode | Financial cost | Water consumption | Land occupation | Safety accidents | Environment pollution |
|---|---|---|---|---|---|
| Rail transport. | Unit cost drops slow year by year | negligible | more | safer | CO、HC、NOX; night noise should not exceed 55 dB; rarely |
| Pipeline transport. | unit cost drops fast year by year | 10 million tons less | rarely | rarely | rarely |

As can be seen from the table, under the premise that the transport scale reach 10 million tons and the transport distance reach 1,000 km, pipeline coal transport have obvious advantages in the environment and security costs, in addition to take more water than coal railway. Besides, the decline rate of unit cost in coal pipeline is faster than in rail. On the whole, coal pipeline transport is a more cost effective mode of transportation than rail.

## 6 Conclusions

The result based on the social cost theory's comparison between railway transportation and pipeline transportation indicates that in view of large-scaled and the long distanced electricity coal transportation, the pipeline transportation has advantages in the environmental effect and the financial cost. Although the western mining area lack water, the consumption certain water resources' pipeline transporting still can develop the long distanced transportation, which takes a way to supplement the railway, and raises its proportion gradually.

Because of the length and the data sources' limit, this article hasn't made the further exploration in the transportation scale. In the future it can further explore the exterior cost's contrast research, through each exterior cost function's establishment, impact further quantitative analysis of environmental effect and resources consumption between railway transporting and the pipeline transporting.

## References

[1] Wang Lan. Electrical Coal Supply and Demand Analysis in 2009[J]. China Power.2010,43(4) (In Chinese)

[2] Luo Fuxv. Our Country Coal Tar Pipe-line Construction Imperative[J]. Oil & Gas, 1995,14(1):4-7 (In Chinese)

[3] John J. Kania. Coal Slurry Pipeline Transport and Rail Transport Coal in the Economic Comparison[J]. Energy Economics, 1984,4

[4] Zhang Chuanping. Study on Techno-Economic Characteristics of Long Distance Gas Pipeline[D]. Doctoral Dissertation, 2006,52-59 (In Chinese)

[5] Tchourachev Viktor Nikolaevich. The Developing Prospects of Russia's Coal Transportation[J]. Northeast Asia Forum, 2004, 13(5)

[6] Frank Wicks. Analysis of Options for Increasing Pipeline Capacity[J]. Intersociety Energy Conversion Engineering Conference, 2002, 37

[7] Colin Cole. Heavy Haul Coal Train Dynamics Simulation Comparisons of the COAL Link and Central Queensland Systems[J]. Proceedings 7th International Heavy Haul Conference, 2001, 217-223

[8] Di Jing. Research on the Calculation Theory and Method of the External Cost of the Transportation System in China[D]. Doctoral Dissertation, 2010,6 (In Chinese)