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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (22): 6751-6755, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.6751.6755

Management and Control of the Middle Transport Costs of Coal Reserve and Transit Centers Based on IP

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Abstract: The study proves the effectiveness of the management and control of the coal middle transport costs to the development of the coal supply chain and transport corridors in the centers of the coal strategic reserves and transit. The method is an optimization model based on Integer Programming (IP) to the quantitative calculation under the demand conditions between middle transit centers and the coal customers. The result shows that the purpose of the original ideas is achieved to control the cost of the management to the coal during transport by the optimization model. So, the method based on IP can be applied to the development of the coal supply chain and transport corridors more effectively. At the same time, the result is proved by the actual cases.

Key words: Integer programming, transport cost, coal transit, transport corridors

INTRODUCTION

It is a very important task of the building strategic bases or centers for coal reserve and coal transshipment in China under the conditions of mainly relying on coal consumption pattern of energy situation to ensure the supply of energy and promote the healthy development of coal industry. The coal reserve bases retain the strategic coal reserved at ordinary times to respond to the urgent needs of war, natural disasters and other emergencies coal and improve energy security. At the same time, coal transport centers are logistics resources for the integration the 14 major areas of coal producing in China (Zhang *et al*., 2012; Zhu, 2011). According to the customers demand, the coal transport centers can realize the point-to-point distribution in one-time processing of using modern logistics technology for secondary processing of energy configuration. From the recent situation analysis of several major coal shortages in China, the main coal production areas are mainly distributed in the northwest regions while the consumers mainly concentrate in the southern coastal line. The coal traffic conditions of these producing areas generally drop behind others so that transport corridors of coal are confronted with very large pressures.

Therefore, the construction of large coal reserve bases and transshipment centers can achieve reality to fast move resources for the south and shift the bases forward which may break the coal logistics problems effectively (Yi, 2010; Research Association of Logistics Diagnose, 2012). A large number of literatures have given a lot of research about this at home and abroad. However, these literatures were rarely recognized to use what method in the concrete to manage and control the coal logistics nodes. In this study, it gives an integer programming model to optimize comprehensive coal logistics network. (i.e., trade, logistics, information, settlement, etc. illustrated in Fig. 1) (Wolsey, 2011).

There are many ways to the currently targeted research. This article uses integer programming model to put forward a new management mode for coal transportation to resolve the management issues of the costs from the coal origin to the reserve and transit bases and the transportation costs from the reserve and transit bases to the users.

Integer programming (IP) model of the transportation costs

Model variables: The constraints and objective function of integer programming can be optimized for many practical problems in logistics management. Only mathematical model to study the problem of 0-1 variables is generally seen as a logical question in the integer programming with all or part of the decision variables. To determine whether it is feasible by turning into the original problem constraints until it determines all feasible solution which is the optimal solution to the original problem (Xiong *et al*., 2011). The intermediate costs of coal transportation channel can be optimized by integer programming model. First of all, introducing the variables of the model (Table 1) (Wu, 2012).

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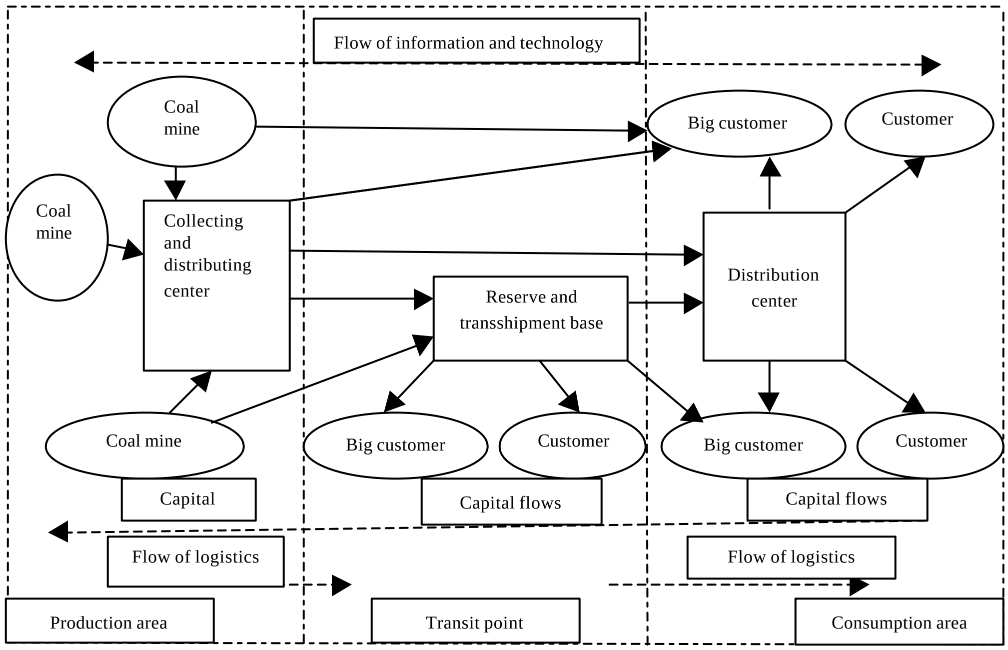

Fig. 1: Network of coal logistics structure

Table 1: Model variables of the coal transportation chaunel

Variables categories		Connotations of variables
Production bases	i	i-th coal production base
	I	Total number of coal production bases
	N_i	Amount of production constraints of the i-th coal production base
Reserve and transit centers	j	j-th coal reserve and transit center
	J	Total number of reserve and transit centers
	C_j	Operating cost of reserve and transit centers
	G_j	Cost of the j-th coal reserve and transit center
	e_j	Whether to use the control variables in the j-th coal reserve and transit center
Coal users	k	k-th coal user
	K	Total number of coal users
	H_k	Demand amount of the k-th coal user
Comprehensive variables	TC	Total cost of the coal logistics transportation
	C_m	Cost of loading and unloading operation
	C_4	Cost of each loading and unloading operation
	T	Large enough control variable
	ç	Proportion of direct delivery from production bases
	Q_k	Demand amount of coal
Between production bases and transit centers	C_{ij}	Transport cost between the i-th production base and the j-th transit center
	C_1	Unit transport cost between the i-th production base and the j-th transit center
	d_{ij}	Distance between the i-th production base and the j-th transit center
	q_{ij}	Transport quantity between the i-th production base and the j-th transit center
	F_{ij}	Connection variable between the i-th production base and the j-th transit center
	t_{ij}	Transport time between the i-th production base and the j-th transit center
Between transit centers and coal users	C_{jk}	Transport cost between the j-th transit center and the k-th coal user
	C_2	Unit transport cost between the j-th transit center and the k-th coal user
	d_{jk}	Distance between the j-th transit center and the k-th coal user
	q_{jk}	Transport quantity between the j-th transit center and the k-th coal user
	D_{jk}	Connection variable between the j-th transit center and the k-th coal user
	t_{jk}	Transport time between the j-th transit center and the k-th coal user
Between production bases and coal users	C_{ik}	Transport cost from the i-th production base to the k-th user
	C_3	Unit transport cost from the i-th production base to the k-th user
	d_{ik}	Transport distance between the i-th production base and the k-th user
	q_{ik}	Transport quantity between the i-th production base and the k-th user
	Z_{ik}	Connection variable between the i-th production base and the k-th user
	t_{ik}	Transport time from the i-th production base to the k-th user

Structure of model for the transportation costs: The coal transportation costs of reserve and transit centers include the shipping from coal production bases to reserve and transit centers and the freight from reserve and transit centers to the users and the direct delivery cost between coal production bases and users and other costs, such as loading and unloading, handling related costs associated with transit centers (Hu *et al*., 2008; Melo *et al*., 2009).

The constraints include the coal amount sent to all reserve and transit centers and users from a coal production base should be less than the total quantity from each coal production base's production limited N_i; the amount of coal reserve and transit centers would not be much more than their purchase amount (Li, 2009).

When using a reserve and transit center, the corresponding control variable e_j is 1, otherwise 0 and the coal production base should meet the demand of each user to be sent directly (Xie, 2009). At the same time, if coal production bases send coal to users directly or between transit centers and the users, the connections variable is 1, otherwise 0.

F_{ij}, D_{jk}, Z_{ik}, respectively set as the user's connection variables: between coal production bases and transit centers, between transit centers and users; between coal production bases and the users. When the transport relation is set between two, the connected variable is 1, otherwise 0.Based on these conditions, the optimization model for transportation costs is structured as following (Yang, 2009):

The objective function: min $TC= C_{ij}+ C_{jk}+ C_{ik}+C_j+ C_m$.
Among:

$$C_{ij} = \sum_i^I \sum_j^J C_1 \times d_{ij} \times q_{ij} \times F_{ij}$$

$$C_{ik} = \sum_k^K \sum_j^J C_2 \times d_{ij} \times q_{ij} \times D_{ij}$$

$$C_{ik} = \sum_k^K \sum_j^J C_3 \times d_{ik} \times q_{ik} \times Z_{ik}$$

$$C_j = \sum_j^J (G_j \times e_j)$$

$$C_m = C_4 \times \left(\sum_i^I \sum_j^J F_{ij} + \sum_k^K \sum_j^J D_{jk} + \sum_k^K \sum_i^I Z_{ik} \right)$$

The specific constraints are shown in Table 2.

An example of G coal group

Analysis of model for the transportation costs: The above quantitative model is an optimization way to coal logistics network. This method is reasonable to decorate structure of the strategic coal reserve and transport bases.

Table 2: Constraints of 0-1integer programming

Items of constraints	Expressions of constraints
Constraints of production bases	$\sum_j^J q_{ij} + \sum_k^K q_{ik} \le N_i, \forall i \in I$
Constraints of transit centers	$\sum_i^I q_{ij} \ge \sum_k^K q_{ik}, \forall j \in J$
	$q_{ij} - T \times F \le 0, e_j = \sum_j^J X_{ij}, \forall i \in I, Aj \in J$
Constraints of coal users	$\sum_j^J q_{ik} + \sum_i^I q_{ik} \ge H_k, \forall k \in K$
	$q_{jk}+T \times D_{jk}= 0, \forall j \in J, \forall k \in K$
	$Q_{jk}+ T \times Z_{ik}= 0, \forall i \in I, \forall k \in K$
0-1 connection variables	$F_{ij}, D_{jk}, Z_{ik} \in \{(0,1) i \in I, j \in J, k \in K\}$
Constraints of direct delivery	$\sum_i^I \sum_k^K q_{ik} = \eta \sum_k^K Q_k$

Table 3: Annual fixed costs of these coal producing and transit centers of G coal group (ten million RMB)

Production bases	Annual fixed cost	Transit centers	Annual fixed cost
1	35	1	40
2	45	2	20
3	40	3	60
4	42		
5	40		

More practical purposes of building strategic coal reserve and transit bases are in order to reduce the total cost of transport corridors in coal logistics system. In general, the cost of transportation is the main part of the total cost of coal logistics system. And coal transportation costs include the transportation cost from the pitheads of major coal producing areas to reserve and transshipment bases and the transportation costs from reserve and transshipment bases to the users and other management fees.

Scientific and rational control of coal logistics transportation cost is practical value significance. Especially the influence of factors in the current world economic crisis, the coal enterprises how to improve their economic benefits is particularly important in this environment and the control of the logistics transportation cost as a priority of coal enterprises (Gan *et al*., 2005). But the current study for the coal logistics cost, especially in the process of control methods and means to the costs of reserve and transit transportation have been in a state of the surface (Wang, 2012). The purpose of this study is to enhance the efficiency of the management for the transportation costs of the middle of the coal transport corridors and break through bottlenecks in coal transportation.

An example of model: G coal group which owns five coal producing areas and three large reserve and transit centers, mainly supports coal for the four coal power plants. Annual fixed costs of these coal producing and transit centers are shown in Table 3.

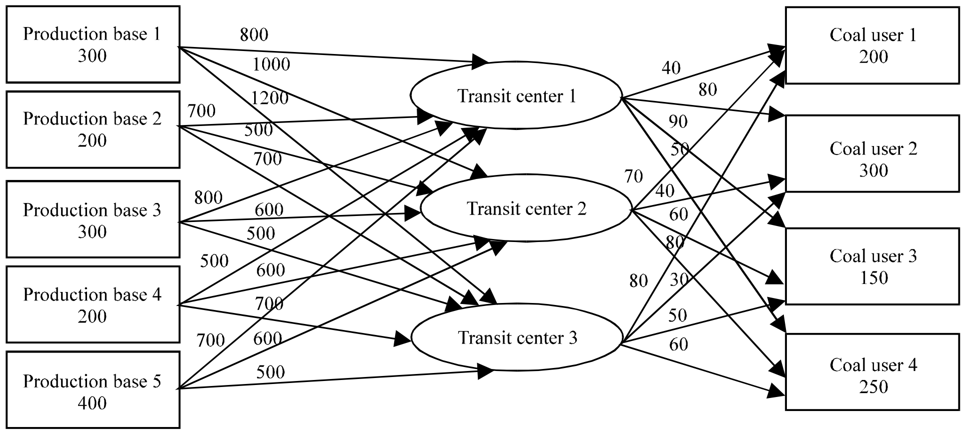

Fig. 2: Shipping expenses, annual production and annual demand (10,000 tons)

Table 4: Integer programming constraints of G coal group

Items of constraints	Expressions of constraints
Constraints of production bases	$X_{11}+X_{12}+X_{13} = 300F_1$, $X_{21}+ X_{22}+ X_{23}= 200F_2$, $X_{31}+ X_{32}+X_{33}= 300F_3$
	$X_{41}+X_{42}+X_{43}= 200F_4$, $X_{51}+X_{52}+X_{53}= 400F_5$
Constraints of transit centers	$Y_{11}+Y_{12}+Y_{13}+Y_{14}=900D_1$, $Y_{21}+Y_{22}+Y_{23}+Y_{24}=900D_2$, $Y_{31}+Y_{32}+Y_{33}+Y_{34}=900D_3$
	$X_{11}+ X_{21}+ X_{31}+ X_{41}+ X_{51}=Y_{11}+Y_{12}+Y_{13}+Y_{14}$
	$X_{12}+ X_{22}+ X_{32}+ X_{42}+ X_{52}=Y_{21}+Y_{22}+Y_{23}+Y_{24}$
	$X_{13}+ X_{23}+ X_{33}+ X_{43}+ X_{53}=Y_{31}+Y_{32}+Y_{33}+Y_{34}$
Constraints of coal users	$Y_{11}+ Y_{21}+ Y_{31}=200$, $Y_{12}++Y_{23}+Y_{32}=300$
	$Y_{13}+ Y_{23}+ Y_{33}=150$, $Y_{14}+Y_{24}+Y_{34}=250$
Nonnegative constraints	$X_{ij3}=0$, $Y_{ij}=0$, F_i, D_j 0-1 Integer programming

Table 5: Optimization process between coal producing bases and transit centers

	Center 1	Center 2	Center 3				
Base 1	0	0	0	0	<=	0	300
Base 2	0	200	0	200	<=	200	200
Base 3	0	0	300	300	<=	300	300
Base 4	0	1.30E-13	0	1.30E-13	<=	1.30E-13	200
Base 5	0	0	400	400	<=	400	400
	0	200	700				
	=	=	=				
	0	200	700				

The shipping expenses (yuan/ton), annual production and annual demand from coal production bases to the reserves and transit centers, are shown in Fig. 2 (Gan *et al*., 2005).

According to 0-1 integer programming model and its constraints, it is not difficult to manage and control G coal group among logistics transportation cost and other costs which make its total cost is minimum. X_{ij}, Y_{ij}, respectively set as the transport quantity between the i-th coal producing base and the j-th transit center; the delivery amount from the j-th transit center to the k-th coal user. F_i, D_j, respectively set: whether to use the 0-1 integer variable for using the i-th coal producing base and whether to use 0-1 integer variable for using the j-th coal transit center.

Therefore, the transport costs among the bases, centers and users in the logistics costs of G coal group can be minimized the objective function which is expressed as:

$$\text{Min } f(x)=800X_{11}+1000\ X_{12}+1200\ X_{13}+700\ X_{21}+500\ X_{22}+700\ X_{23}+800\ X_{31}+600\ X_{32}+500\ X_{33}+500\ X_{41}+600\ X_{42}+700\ X_{43}+700\ X_{51}+600\ X_{52}+500\ X_{53}+40\ Y_{11}+80\ Y_{12}+90\ Y_{13}+50\ Y_{14}+70\ Y_{21}+40\ Y_{22}+60\ Y_{23}+80\ Y_{24}+80\ Y_{31}+30\ Y_{32}+50\ Y_{33}+60\ Y_{34}+35\times10^7F_1+45\times10^7F_2+40\times10^7F_3+42\times10^7F_4+40\times10^7F_5+40\times10^7D_1+20\times10^7D_2+60\times10^7D_3$$

Constraints are shown in Table 4.

Optimization process and the calculation results between coal producing bases and transit centers are as (Table 5).

Optimization process and the calculation results between transit centers and coal users (Table 6).

In accordance with 0-1 integer programming algorithm, it is easy to get: G Coal Group just spend the costs (RMB 4.5 billion yuan) on completing various tasks in its transportation process among the coal origin, transit

Table 6: Optimization process between transit centers and coal users

	Center 1	Center 2	Center 3			
User 1	0	200	2.80E-14	200	>=	200
User 2	0	0	300	300	>=	300
User 3	0	0	150	150	>=	150
User 4	0	0	250	250	>=	250
	0	200	700			
	<=	<=	<=			
	0	900	900			

centers and coal users. The transport costs plus a variety of fixed costs, the final total cost is RMB 7.005 billion yuan which is also the advantage of the 0-1 optimized model to get the minimum transport costs of G coal group. Of course, this is the charm of integer programming.

CONCLUSION

In currently, the higher middle transport costs become the bottleneck problem of coal transport corridor development in China. Especially, it happens in those large coal reserve and transit bases. This belongs to management and control problems in state coal strategy (Wang, 2012). But the existing control methods and means are still being in the surface of the coal supply chain management. This article puts forth integer programming model to optimize the transit process costs for the coal market to achieve the minimum for the purpose of the transport costs of the coal logistics. At the same time, the study proves the theoretical and practical value through the practical cases by using this optimization method.

ACKNOWLEDGMENT

The author would like to thank for the support by Foundation item: Ph.D programs foundation of the Ministry of Education of China (20100023110002).

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