Chapter 32
Based on the Method of Baumol – Wolfe Empirical Research on Blending Center Site Selection Problem

Li-jun Liu

Abstract The paper analyses the necessity of developing power coal blending, and discusses the effect of it in the rational utilization of coal mining resources, reducing logistics cost, improving the economic benefit of coal enterprises, promoting energy conservation and emission reduction, and protecting the mining area environment. Based on this, the paper researches the site selecton problem of coal blending center in the coal mining, and determines the location and number of logistics nodes by establishing Baumol – Wolfe model.

Keywords Power coal blending • Site selection • Baumol-Wolfe model • Blending center

Introduction

China as a coal producer and consumer of main energy in coal, it is very important practical significance to achieve the effective and reasonable utilization of energy to realize "saving energy and emission reduction" targets. However, in the coal resources utilization, there is the problem on low combustion efficiency, the serious waste and environmental pollution, and etc. Therefore, it is effective measures that adopt actively power coal blending technology, raise the proportion of power coal blending , at the meantime, strive to develop coal selected by washing, improve the quality of coal, is to improve the efficiency of burning coal mining, reduce the waste and pollution, and protect the environment. Power coal blending technology is to variety in different categories and coal quality is processed after a certain proportion. The coal physical, chemical properties and burning characteristic are

L.-j. Liu (✉)
College of Management Science and Engineering, Shandong Institute of Business and Technology, Yantai, China
e-mail: llj2002-1@163.com

R. Dou (ed.), *Proceedings of 2012 3rd International Asia Conference on Industrial Engineering and Management Innovation(IEMI2012)*,
DOI 10.1007/978-3-642-33012-4_32, © Springer-Verlag Berlin Heidelberg 2013

changed, so as to come up to the complementation of coal quality, optimize the structure of products, meet the user requirements with combustion equipment of coal, in order to improve efficiency and reduce combustion pollutants.

The importance of power coal blending in the following (Da-guang Xiang 1988; Feng-jun Jia 2006; Pei-ao He and Yan-ping Dong 1988):

(1) Contribute to adjust the industrial structure, saving energy and reducing consumption, to formate of coal resources centralized processing, storage, distribution, management pattern in origin so that play to the advantages of coal origin, realize the integration of coal production and marketing of coal industry, and improve the overall economic benefits.
(2) Contribute to reduce logistics cost, meet the different needs of customers. Coal is matched in network node according to user requirements of quantity and quality reasonable blending, formed new coal products, and transported to users with the most economical and convenient through the highway and railway. This can effectively reduce the coal purchasing and transportation cost, and drives the development of downstream of logistics industry, promote the economic development, boost the economy development.
(3) Contribute to promote coal quality, create brand of coal. At moment blending technology research and application is more mature at home and aboard, therefore advanced blending technology can be utilized to improve "the coal brand" degree of satisfaction in the consumers mind, and promote the core competitiveness.
(4) Contribute to the effective utilization of coal resources and protecting the environment. Advanced power coal blending technology can effectively reduce the coal consumption per unit, thereby reduce the consumption of coal resources, slow down coal mining speed, and reduce the damage for environment and land resources. At the same time, the dynamic blending coal can reduce coal consumption, increase the combustion efficiency, and reduce harmful emissions.

From the above, we can choose proper nodes existing in logistics network of mining area, and engaged in coal washing and blending operations. This can be integrated coal resources, improve the quality of coal, and increase coal variety so as to meet different varieties of users demand. At the same time, it is useful to achieve the goal of "energy conservation and emission reduction" for and the local ecological environment protection.

Establishing Location Mode

We establish Baumol – Wolfe model and determine the position and number of blending node based on the principle of minimum total cost integrating with mining area and user distribution (Fang Zhang and Bing-wu Liu 2007; Jing Hou and Yi-kun Zhao 2006; Li-juan Ma 2008; Xia Li 2008; Xiang-you Gui and Yun-dong Ma 2005).

Problem Description

As shown in Fig. 32.1, coal mining logistics flow: raw coal is transported to coal blending nodes via the highway, then processed circulation (blending operations). It is divided into different kinds of products according to customer's demand and transported coal to the user.

Therefore, the location problem (Fang Zhang and Bing-wu Liu 2007; Pei-ao He and Yan-ping Dong 1988) can be described as: for m coal mining, selecting a certain amount of nodes in n location choice, for q user product in coal, and getting the selected node distribution the total cost of the minimum requirements in the premise during the planning period. Among them, in the planning period, coal mine transport to node n_1 times, node to user n_2 times.

Comprehensive considering and solve problems as follow in modeling process: what locations become alternative nodes, how to arrange delivery plan, namely traffic of the coal to each node and each node to each user can realize the planning of the minimum total cost targets to meet with the user requirement.

Hypothesis of Model

The location problem that this paper studies in mining area is to choose a certain number of nodes from the alternative nodes which establishes coal center and carries on coal processing (blending operations) and distribution. Expenses indicator in model including: fixed investment costs on building node, the product transportation costs from coal mine to node, the product distribution costs from node to customers and the product processing costs in the node due to blending coal. The first term is fixed costs, after three for variable expenses. The expression of expenses can be obtained on the analysis of the main factors that affect the cost and make total cost the minimum or close to the minimum (Cai-sheng Dai 2000; Fang-li Zhao and Ya-li Niu 2007; Fang-min Zhang 2001; Ge-fei Ma 2000; Hua-ting Fan 2006; Ji-chun Zheng 2006; Jing-kun Liang 2004).

In order to facilitate solving the model, and making the model unapt too complicated and practical value, the assumption:

(1) Only consider the car distribution of coal products and coal product quantity of distribution according to the number of transportation to calculate.
(2) Only in optional nodes range to choose.
(3) A node can supply by multiple coal mine, a user needs by multiple nodes can provide, don't consider nodes between the supply.
(4) The coal transportation in network includes from coal mine to nodes and from nodes to users.
(5) Transportation cost is proportional to the traffic.
(6) The transportation costs among coal mines, nodes and users is known constants.

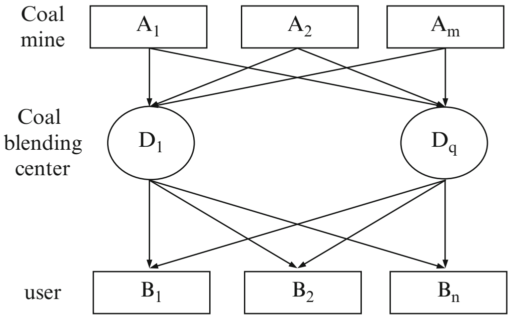

Fig. 32.1 Coal flow diagram

(7) Each user demand for coal products is known constants.
(8) The fixed investment cost of establishing and managing nodes is known.
(9) The treatment costs of nodes is concave function of flow, and the unit treatment cost of nodes are known.
(10) The number and capacity of nodes is restricted.

The Target Function and Constraints

To construct the model of the location, the related parameters and the relevant decision-making variables are defined as follows:

(1) *The parameters for the mode*:

m—The number of coal mine.
n—The number of optional nodes.
q—Number of users.
n_1—The number of coal mine supply coal to the node during the planning period.
n_2—The number of the node supply coal to user during the planning period.
a_{ki}—The unit cost of transportation from k coal mine to i node.
c_{ij}—The unit distribution costs from i node to j user.
A_k—The total supply capacity from k coal mine to nodes.
D_j—The quantity demand for j user.
M_i—The maximum capacity of i optional node.
f_i—The fixed cost of i node.
v_i—The product processing cost coefficient of i node.
θ—The economic performance indicators considering scale,$0 \leq \theta \leq 1$.
P—The maximum number of nodes are selected.

(2) *Model variable*:

x_{ki}—The carryings from k coal mine to i node at every turn.
y_{ij}—The distribution volume from i node to k user at every turn.

z_i—0–1 Integer variables, When $z_i = 1$, how i node get the nod; When $z_i = 0$, show i node not get the nod.

(3) *Objective function*:
During the planning period, the total costs made up by four parts: the total transportation cost of coal from supplying place to nodes, the total distribution costs of coal from node to users, expenses for handling the product in nodes and the total fixed expenses of nodes. The total expenses are for the four sums of minterms, according to the principles of economics, need the total cost E minimum, namely:

$$MinE = \min\begin{pmatrix} \sum_{k=1}^{m}\sum_{i=1}^{n} n_1 a_{ki}x_{ki} + \sum_{i=1}^{n}\sum_{j=1}^{q} n_2 c_{ij}y_{ij} + \\ \sum_{i=1}^{n} z_i v_i W_i^{\theta} + \sum_{i=1}^{n} z_i f_i \end{pmatrix} \tag{32.1}$$

(4) *Constraints*:
Supply constraint: the amount of coal from the supplying place to each node every time must not exceed its total supply capacity:

$$\sum_{i-1}^{n} x_{ki} \le A_k, k = 1, 2, \cdots, m \tag{32.2}$$

Demand constraint: Every time distribution, delivery of goods amounts from each node to a user can meet the user's total demand, namely:

$$\sum_{i-1}^{n} y_{ij} \ge D_j, j = 1, 2, \cdots, q \tag{32.3}$$

Balance constraint: Flow balance during the planning period, namely the stock equal shipments of each node:

$$n_1\sum_{k=1}^{m} x_{ki} = n_2\sum_{j=1}^{q} y_{ij} = W_i, i = 1, 2, \cdots, n \tag{32.4}$$

Capacity constrain: Each time, the sum of the goods of the supplying place which supply any node cannot exceed the biggest capacity of node:

$$\sum_{i-1}^{n} x_{ki} \le z_i M_i, i = 1, 2, \cdots, n \tag{32.5}$$

Number constraint: Number of the nodes to build less than a given P:

$$\sum_{i-1}^{n} z_i \leq P \tag{32.6}$$

Non-negative constraint: Variable in the model must be equal to or greater than zero, namely:

$$x_{ki} \geq 0, y_{ij} \geq 0,\ k = 1, 2, \cdots, m;\ \ i = 1, 2, \cdots, n;\ \ j = 1, 2, \cdots, q \tag{32.7}$$

Integer constraint:

$$z_i = \begin{cases} 1, & selected \quad node\ i \\ 0, & or \end{cases} \tag{32.8}$$

(5) *Model form*:
Comprehensive analysis, the location model of nodes is:

$$MinE = \min\left(\sum_{k=1}^{m}\sum_{i=1}^{n} n_1 a_{ki} x_{ki} + \sum_{i=1}^{n}\sum_{j=1}^{q} n_2 c_{ij} y_{ij} + \sum_{i=1}^{n} z_i v_i W_i^{\theta} + \sum_{i=1}^{n} z_i f_i\right) \tag{32.1}$$

s.t.

$$\sum_{i-1}^{n} y_{ij} \geq D_j, j = 1, 2, \cdots, q \tag{32.9}$$

$$n_1 \sum_{k=1}^{m} x_{ki} = n_2 \sum_{j=1}^{q} y_{ij} = W_i, i = 1, 2, \cdots, n \tag{32.10}$$

$$\sum_{i-1}^{n} x_{ki} \leq z_i M_i, i = 1, 2, \cdots, n \tag{32.11}$$

$$\sum_{i-1}^{n} z_i \leq P \tag{32.12}$$

$$x_{ki} \geq 0, y_{ij} \geq 0,\ k = 1, 2, \cdots, m; i = 1, 2, \cdots, n; j = 1, 2, \cdots, q \tag{32.13}$$

$$z_i = \begin{cases} 1, & selected \quad node\ i \\ 0, & or \end{cases} \tag{32.14}$$

Model Solving

Model Data Processing

This paper is based on the basic data of Ordos mining area logistics as an example for empirical research.

m values: The existing 276 coal mines will be merged into 13 big supply of coal area, namely $m = 13$.

n values: Ten optional node preliminarily will be selected, namely $n = 10$.

q values: The number of users on highway transportation in this model only take into account the power users, take $q = 24$.

n_1 values: Number of times for the supply of coal area to node in planning period (1 year), $n_1 = 13 \times 2{,}000$(vehicles) = 26,000 times/1 day = 9,490,000 times/1 year; $n_1 = 13 \times 2{,}000$ (vehicles) = 26,000 times /per day =9,490,000 times/year (1 year by 365 days).

n_2 values: The number of supply of material from nodes to users in planning period (1 year), $n_2 = 2{,}500$ times /per day =912,500 times /1 year.

a_{ki} values: The unit transportation cost from coal supplying area to each node is the basic same, take 0.40 yuans/t-km, the transportation distance from coal supplying area to each node take the average. Unit transportation cost see Table 32.1.

c_{ij} values: The unit cost of distribution from each node to users takes 0.45 yuan/t-km, the distribution distance from each node to users takes actual value. The unit cost of distribution from each node to the user in Table 32.2.

A_k values: The total capacity for supplying coal from the coal supplying area to nodes in Table 32.3.

D_j values: Each user's demand sees Table 32.4.

M_i values: The maximum capacity of optional node sees Table 32.5.

f_i values: The fixed fee of each node sees Table 32.6.

v_i values: The blending coal cost coefficient of each node is the same, $vi = 10$ yuan/t.

θ values: Consider economic performance indicators, all the raw coal entering nodes can deliver users after dressing by washing and blending, $\theta = 1$.

P values: The maximum number of nodes are selected, $P \leq 10$.

Model Solving

Except for fixed cost constant function in the selection of model established above, the others are linear functions, it belongs to the linear mixed 0–1 programming model. This model can be applied to solve LINGO software. Calculation results see Table 32.7.

Table 32.1 Unit transportation cost from supplying coal area to each node

Unit: yuan/t

	Nodes				
Area	M1	M2	M3	M4	M5
A1	16	18	20	15.2	24
A2	15.6	21.6	18.8	21.2	20.4
A3	16.8	15.6	17.6	20.4	18.4
A4	20.8	18	18.4	19.2	15.2
A5	18	18.4	20.4	14.8	19.2
A6	18.4	17.2	23.6	18.8	19.2
A7	15.2	18	15.6	19.2	22.8
A8	17.2	18.4	18.8	20.8	16.4
A9	14	21.2	18.4	18	17.6
A10	10.4	16.8	18.4	14.4	20.4
A11	20.8	11.2	14.8	18	21.2
A12	14	18.4	19.2	16.8	12.4
A13	16	17.2	15.2	18.4	16.8

Renewal table

	Nodes				
Area	M6	M7	M8	M9	M10
A1	22	17.6	13.2	18.4	25.6
A2	18.4	19.2	20	21.6	23.2
A3	20.8	18.8	19.2	21.2	15.2
A4	18.8	22.4	23.6	26.8	13.2
A5	22.4	14.8	20.4	15.6	16
A6	20.8	18.8	18.8	16.4	18
A7	18.8	21.2	18.8	16.8	17.2
A8	15.6	14.8	16.8	14.4	15.2
A9	22	26.4	14.8	16.8	22.4
A10	19.2	14	18.8	21.2	17.6
A11	14.4	18	13.2	21.2	16.8
A12	18.4	15.2	21.6	14.4	22
A13	13.2	18.4	20.4	14.4	19.6

Conclusion

In existing logistics network of mining area, choosing proper nodes and engaging in coal washing and blending operations can be integrated coal resources, improve the quality of coal, increase coal varieties and meet different users' demand. At the same time, it is in favor of achieving the goal of "energy conservation and emission reduction" and the local ecological environment protection. This paper analyses the necessity of developing power coal blending in mining area, and studies location problem of coal logistics network nodes. At last, the node location and number of area is made sure by establishing Baumol – Wolfe model.

Table 32.2 Unit distribution cost from each node to user

Unit: yuan/t

	Nodes				
Users	M1	M2	M3	M4	M5
D1	22.5	24.75	18	20.25	27
D2	20.25	22.5	24.75	27	22.5
D3	20.25	24.75	29.25	27	24.75
D4	22.5	29.25	24.75	20.25	15.75
D5	18	22.5	13.5	29.25	31.5
D6	27	20.25	29.25	15.75	18
D7	24.75	22.5	20.25	18	29.25
D8	29.25	18	24.75	22.5	27
D9	20.25	22.5	31.5	27	18
D10	13.5	24.75	20.25	29.25	33.75
D11	27	22.5	24.75	29.25	20.25
D12	18	22.5	27	31.5	33.75
D13	22.5	29.25	24.75	20.25	18
D14	15.75	20.25	33.75	29.25	24.75
D15	24.75	22.5	27	20.25	18
D16	20.25	24.75	29.25	27	22.5
D17	29.25	24.75	20.25	15.75	20.25
D18	15.75	24.75	20.25	29.25	24.75
D19	18	24.75	29.25	20.25	15.75
D20	22.5	29.25	20.25	24.75	20.25
D21	24.75	22.5	20.25	24.75	29.25
D22	20.25	24.75	22.5	18	15.75
D23	22.5	29.25	20.25	15.75	27
D24	24.75	22.5	20.25	15.75	18

Renewal table

	Nodes				
Users	M6	M7	M8	M9	M10
D1	22.5	20.25	27	24.75	27
D2	27	31.5	18	24.75	29.25
D3	18	20.25	24.75	29.25	15.75
D4	18	27	24.75	20.25	29.25
D5	31.5	24.75	20.25	27	20.25
D6	27	22.5	24.75	20.25	24.75
D7	24.75	15.75	31.5	33.75	15.75
D8	18	13.5	27	18	22.5
D9	22.5	31.5	24.75	20.25	15.75
D10	24.75	20.25	27	22.5	24.75
D11	15.75	27	24.75	33.75	36
D12	29.25	24.75	20.25	15.75	27
D13	27	27	22.5	18	29.25
D14	20.25	29.25	24.75	20.25	20.25
D15	15.75	20.25	24.75	29.25	22.5

(continued)

Table 32.2 (continued)

Renewal table					
	Nodes				
Users	M6	M7	M8	M9	M10
D16	22.5	24.75	20.25	24.75	20.25
D17	33.75	29.25	20.25	29.25	20.25
D18	24.75	29.25	33.75	27	22.5
D19	20.25	24.75	33.75	15.75	20.25
D20	20.25	29.25	24.75	22.5	18
D21	15.75	29.25	20.25	33.75	18
D22	27	29.25	20.25	24.75	24.75
D23	22.5	18	24.75	20.25	24.75
D24	29.25	24.75	20.25	27	18

Table 32.3 Supplying coal capability list unit: ten thousands ton

A_k	1	2	3	4	5	6	7
Ability	16,000	6,000	6,000	6,000	1,200	1,200	1,200
A_k	8	9	10	11	12	13	
Ability	1,200	1,200	1,200	1,000	1,000	1,000	

Table 32.4 User's demand table unit: ten thouysands ton

UserD_j	1	2	3	4	5	6	7	8
Demand	795	330	50	330	300	150	100	300
UserD_j	9	10	11	12	13	14	15	16
Demand	300	150	100	300	300	300	150	300
UserD_j	17	18	19	20	21	22	23	24
Demand	287.5	307.5	150	150	250	300	300	1,200

Table 32.5 Node's maximum capacity unit: ten thousands teon

NodeM_i	1	2	3	4	5
Capacity	15,000	5,500	5,500	5,000	1,000
NodeM_i	6	7	8	9	10
Capacity	1,000	1,000	1,000	1,000	1,000

Table 32.6 Node's fixed charge table unit: ten thousands yuan

Nodef_i	1	2	3	4	5
Capacity	95,000	65,000	65,000	55,000	35,000
Nodef_i	6	7	8	9	10
Capacity	35,000	35,000	35,000	35,000	35,000

Table 32.7 The computational results

	M1	M2	M3	D1	D2	D3
A1	16.00	18.00	15.60	–	–	–
A2	21.60	16.80	15.60	–	–	–
M1	–	–	–	22.50	20.25	20.25
M2	–	–	–	24.75	22.50	24.75
M3	–	–	–	18.00	24.75	29.25

References

Cai-sheng Dai (2000) Research on power blending of theory and practical application [D]. China University of Mining and Technology Ph.D. thesis, pp 52–66 (Chinese)

Da-guang Xiang (1988) The research status of United States coal combustion technology. Power Stat Syst Eng 4:1–21 (Chinese)

Fang Zhang, Bing-wu Liu (2007) The location of logistics distribution center based on mixed integer programming model. Logist Technol 26(11):81–83 (Chinese)

Fang-li Zhao, Ya-li Niu (2007) Using simplex method to implement the optimization model of the dynamic blending. Henan Norm Univ (Nat Sci Ed) J 35(2):179–180 (Chinese)

Fang-min Zhang (2001) Linear programming optimization blending. Gas Heat Power 21 (2):138–139 (Chinese)

Feng-jun Jia (2006) Power coal blending technology and its significance. Ind Technol 2 (18):127–128 (Chinese)

Ge-fei Ma (2000) To determine the optimal blending index and blending option of power coal blending [J]. Zhongzhou Coal 107(5):3 (Chinese)

Hua-ting Fan (2006) Calculation of coal blending technology principle and characteristics of coal quality parameters about the power plant [J]. Coal Technol 5(5) (Chinese)

Ji-chun Zheng (2006) Logistics node location model and empirical research [D]. Beijing Jiaotong University Ph.D. thesis, pp 1–44 (Chinese)

Jing Hou, Yi-kun Zhao (2006) Dynamic mathematical model and optimizationof coal blending. Taiyuan Univ Sci Technol J 37(4):486–488 (Chinese)

Jing-kun Liang (2004) Based on the analysis of coal quality engineering of the dynamic blending optimization research. North China Electric Power University, Hebei, pp 1–4 (Chinese)

Li-juan Ma (2008) Logistics center location mathematical method. Logist Technol 5:32–35 (Chinese)

Pei-ao He, Yan-ping Dong (1988) The research situation of Japan coal technology experiment. Power Stat Syst Eng 4:35–64 (Chinese)

Xia Li (2008) Based on the Baumol – Wolfe model and algorithm in distribution center site selection application. Xi'an University of Architecture and Technology, Xi'an (Chinese)

Xiang-you Gui, Yun-dong Ma (2005) The application of nonlinear optimization theory in the power of the coal blending. China Min Mag 14(6):49–51 (Chinese)