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Optimum Blending of Coal by Linear Programming for the Power Plant at Seyitömer Coal Mine

K.Erarslan, H.Aykul, H.Akçakoca & N.Çetin
Dumlupınar University, Department of Mining Engineering, 43100, Kütahya, Turkey

ABSTRACT: In this study, a linear programming model is developed to determine the optimum coal blend in terms of quality and quantity. Coal with various features is mined from different panels of Seyitömer Lignite Coal District and fed to a nearby power plant. The quality of the coal is extremely variable through the horizontal and vertical directions, which entails the precise planning of coal blending during the mining and stockpiling stages. Otherwise, a large penalty has to be paid to the power plant. In this study, the objective is to match the calorific values required by the power plant. The quality features and production capacities of coal from different panels are determined and are used in quality constraints. The power plant requires coal in two groups, which are of different qualities and quantities. Therefore, two linear programming models complementing each other are developed in order to determine the blending conditions that satisfy the needs of the plant. The models are introduced and solved m the LINDO package program. Reasonable solutions are obtained and optimal amounts of blending are handled. The model also allows the evaluation of coal panels of low quality.

1 INTRODUCTION'

Linear Programming (LP) is one of the most widely used methods of operation research for decision problems. This method is a reasonable and reliable procedure for determining the optimum distribution of resources, optimal production, minimum cost, maximum profit, etc., which comprise the objectives (Öztürk, 1997). In this method, decision parameters to make the objective optimal are linear or assumed to be linear (Taha, 1992, Hillier and Liebermann, 1995).

The general form of the problem is formed by objective function and subjected constraints;

$$max/min\ Z = c_1X_1 + c_3X_2 + ... + c_nX_n \tag{1}$$

Subjected to

$$\begin{aligned} a_{11}X_1+a_{12}X_2+...+a_{1n}X_n &\le b_1 \\ a_{21}X_1+a_{22}X_2+...+a_{2n}X_n &\le b_2 \\ \square \quad \square \quad \square \quad &\square \\ a_{m1}X_1+a_{m2}X_2+...+a_{mn}X_n &\le b_m \end{aligned} \tag{2}$$

where;
Z= objective of the model
Cj = coefficient of/* decision variable *(1=1,2....N)*
Xj = /* decision variable
a_{ij} = i^{th} coefficient of j^{th} decision variable *(i=l,2,..,m)*
b, = limited resource for i'* constraint

LP approximation is widely used in mining as well as in other industrial fields. Open pit limits, production scheduling, material flow in processing plants, blending, equipment selection, method selection, transportation, etc., are its main applications (Chanda and Wilke, 1992, Dijilani and Dowd, 1994, Huang, 1993, Mann and Wilke, 1992, Meyer, 1969, Smith and You, 1995). However, investment, planning, or selection, in other words any actions requiring decision, can be optimized.

Especially in open pit mines and underground mines feeding coal to power plants, the quality and quantity of coal is crucial because the burner blocks of power plants are designed according to specific features of coal. Inability to match coal quality and quantity to these specific features results in either penalty costs for the coal enterprise or a decrease in the power plant's efficiency. In addition, inconsistent coal features lead to wear in the power plant's burning units and all integrated components. In this respect, coal-producing enterprises try to match their coal features to power plants' specifications by blending and homogenizing coal extracted from different panels and levels. Satisfying the requirements of the plant is achieved by selective mining and/or blending. In this study, a relevant case is considered. Seyitömer coal enterprise in Kütahya, Turkey has problems of quality and quantity in supplying the nearby power plant. A well-planned and organized blending procedure and, accordingly, production plan is necessary. In this paper, the problem, is modeled in terms of linear programming and reasonable solutions are obtained.

2 SEYİTÖMER COAL ENTERPRISE AND ITS PROBLEM

Seyitömer Lignite Enterprise (SLE) is located 20 km. northwest of Kütahya city center. The basin is characterized as Late Miocene-early Pliocene. The lignite seams in Seyitömer basin consist of two horizontal levels (0-7° S), referred to as A and B seams, according to their depths. The seams are separated from each other by waste interbedded formations whose thickness vary from 10 to 50 m. These two seams may exhibit variation according to their occurrence in three sub-regions (Seyitömer, Aslanlı, Ayvalı), where the geological coal formation has been determined by drill holes. The thickness of the A seam, located at the top level of the basin, varies in the range of 5-25 m. {Sofrelec, 1967). The thickness of B seam varies in the range of 2-30 m. In the basin, these two seams are rarely observed together. The seam defined as A İs deposited only in the Seyitömer region and the coal occurrences in the Aslanlı and Ayvalı regions. The B seam consists of 3 different sublevels, referred to, from Üie top to the base of the seam, as B[, B_2, Bj Their calorific values decrease towards to the seam base as the interbedded layers get thicker. The upper level coal seams B| and B2, which have a high calorific value and are produced in sorted size and quality (+100 mm), have supplied the market for public heating. The B_3 coal, which is of low quality and contains fine coal (-100 mm) from the processing plant, is sold to the power plant.

At the enterprise, production is performed by the open pit mining method. The overburden, whose thickness varies from 35 to 60 m., is loosened by drilling and blasting. The stripping method is the excavator and truck and dragline method. The electrical excavators have a 10-yd[1] bucket volume and the dragline has a 70-yd bucket capacity. Production and transportation are also by excavator-truck and loader-truck meüıods. It is impossible to process the coal with wet washing techniques. For this reason, only crushing, sieving and sorting can be applied to the coals of the region. There are three plants working for the power plant and three plants working for the market in the enterprise. The coal is dispatched to the market or the power plant according to its quality.

Recently, in terms of quality and quantity the demands of the plant have not been fulfilled and in order to overcome the problem selective mining has been used. Consequently, there is an increasing tendency to use ripping and bulldozers and loaders (Aykul, 2000).

3 APPLICATION OF LINEAR PROGRAMMING IN SLE

3.1 *Definition of the Problem*

In Seyitömer Coal Mine, six different coal types produced from different panels and levels are treated. The terms for these coals, their average calorific values and annual quantity to be extracted according to İdeal planning are shown in Table 1. These coals need to be blended in accordance with the specifications required by the power plant's burning units.

Seyitömer power plant has four burning units. The operating conditions of these units are shown in Table 2. The annual coal requirement of the power plant is 6,000,000 tons: the first three burning units (Unit 1, Unit 2 and Unit 3), with the same requirements, need 4,500,000 tons, while the last burning unit (Unit 4) requires 1,500,000 tons.

Table 1. Determined features of coal types according to ideal planning in SLE

Coal Type	Calorific Value (kcal/kg)	Amount (ton/year)
FineCoal(-lOO) (From Plants)	1675	2,000,000
Stock of Kizik	1750	800,000
Stock of Marl	1428	> 250,000
B| Level	2000	< 600,000
B; Level	1800	< 600,000
B, Level	1600	> 1,500,000

Table 2. Operating Conditions of Power Plant

Power Plant Units	Base Heat Content (Kcal/kg)	Grain Size (mm)
Unit 1	1750± 100	0-200
Unit2	1750+100	0-200
Umt3	1750± 100	0-200
Unit 4	1600 ± ! 00	0-200

The blending requirements of the coal are as follows:

i. Coal coming from the processing plants (fine coal), and that produced from the stock of Kizik, stock of marl, the B_3 level, B2 level and B| level can supply Unit 1, Unit 2 and Unit 3.

it. Coal produced from the stock of Kizik, stock of marl and B3 level can supply Unit 4.

Two different linear models were developed since there are two design specifications in the power plant. Therefore, first, the amount of coal of the B3 level and stock of Kızık are determined fo.' Unit 4 with the help of the first linear program, and then the rest of the determined amounts are used in the second linear program developed for Unit 1, Unit 2 and Unit 3.

After determining these conditions, the main aim is to obtain coal blends that have the maximum heating calorific value in the range of specifications (Kaya, 2000).

3.2 *Constitution 0/the Model*

The objective function for Unit 4 maximizing the first blend's calorific value, which has a maximum limitation by the constraints, is shown in Equation 1 :

$$\text{Max } Z = \frac{1750.X_2 + 1428.X_3 + 1600.X_6}{1,500,000} \quad (3)$$

Subjected to Equations 4 to 11:

$$X_2 + X_3 + X_6 = 1,500,000 \quad (4)$$

$$\frac{1750.X_2 + 1428.X_3 + 1600.X_6}{1,500,000} > 1500 \quad (5)$$

$$\frac{1750.X_2 + 1428.X_3 + 1600.X_6}{1,500,000} < 1700 \quad (6)$$

$$X_2 < 800,000 \quad (7)$$

$$X_2 > 300,000 \quad (8)$$

$$X_3 > 250,000 \quad (9)$$

$$X_6 < 1,500,000 \quad (10)$$

$$X_2, X_3, X_6 \geq 0 \quad (11)$$

Here,

X2 : Amount of coal from stock of Kızık, t.
Xj : Amount of coal from stock of marl, t.
Xé : Amount of coal from B3 level, t.

The objective function for Unit 1, Unit 2 and Unit 3 maximizing the second blend's calorific value restricted by a subjected constraint is shown in Equation 12.

$$\max Z = \frac{1675X_1 + 1750.X_2 + 2000.X_4 + 1800X_5 + 1600X_6}{4,500,000} \quad (12)$$

The restrictions are shown in Equations 13 to 21.

$$X_1 + X_2 + X_4 + X_5 + X_6 = 4,500,000 \quad (13)$$

$$\frac{1675X_1 + 1750X_2 + 2000X_4 + 1800X_5 + 1600X_6}{4,500000} > 1650 \quad (14)$$

$$\frac{1675X_1 + 1750X_2 + 2000X_4 + 1800X_5 + 1600X_6}{4,500000} < 1850 \quad (15)$$

$$X_1 = 2,000,000 \quad (16)$$

$$X_2 = 300,000 \quad (17)$$

$$X_4 < 600,000 \quad (18)$$

$$X_5 < 600,000 \quad (19)$$

$$X_6 > 750,000 \quad (20)$$

$$X_1, X_2, X_4, X_5, X_6 \geq 0 \quad (21)$$

where,

X_1 : Amount of fine coal from processing plants, t.
X_2 : Amount of coal from stock of Kızık, t.
X_4 : Amount of coal from B| level, t.
X_5 : Amount of coal from B2 level, t.
X_6 : Amount of coal from B3 level, t.

3.3 *Solutions of Models*

The LINDO package program is used to solve the models. The optimum quality and quantity results of the final tables for Unit 4 are shown İn Table 3 (Kaya, 2000).

Table 3 Final results of model for Urul 4

Coal Types	Coal Amount (ton/year)	Heal Content (kcal/kg)
Stock of Kızık (X,)	500.000*	1750
Stock of marl (X,)	250,000*	1428
B, Level (X,)	750.000*	1600
Blend of Coals	1,500.000	1620 5*

*Optimam values ai 7th iteration

As it may be seen in Table 3, the blend quality of the coal is found to be 1620 kcal/kg. This value is within the range of the specific design values of Unit 4. The final tables for Unit 1, Unit 2 and Unit 3 are shown in Table 4.

Table 4. Final results of model for Unit 4

Coal Types	Coal Amount (ton/year)	Heat Content (kcal/kg)
Fine coal (Xi)	2,000,000*	1675
Stock of Kızık <xî)	300,000*	1750
B| Level	600,000*	2000
B_2 Level	600,000*	1800
B, Level (X*)	750,000*	1600
Blend of Coals	4,500,000	1721.8*

• Optimum values 7^{st} iteration

As it may be seen in Table 4, the quality of the blended coal is found to be 1721.8 kcal/kg. This value İs within the calorific value range of Unit 1, Unit 2 and Unit 3.

If the results of these tables are considered together, it can be seen that the production goals are reached. In addition, İt is crucial that the production of 1,750,000,000 tons of coal from B_3 allows the utilization of low quality coal and high productivity.

4 CONCLUSIONS

In this study, the blending problem of the Seyitömer coal region is modeled and solved by the linear programming method. The district has coal seams with coal of different quality and quantity, which results İn an inability to fulfill the requirements of the nearby power plant. By considering the needs of the plant, together with the availability and physical structure of the region, the optimum coal blend, satisfying both quality and quantity provisions, is calculated. The models are solved by the LINDO operations research software package. It is possible for the B3 seam, which contains low quality coal, to be utilized İn the blending process rather than be treated as waste material. Less coal from the B] and B2 seams is used with the addition of B3 coal. The models reveal concrete and reasonable results.

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