Modelling of Coal Terminal Location Determination for Steam Power Plants in Java Island

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Coal Terminal Location Determination

Abstract

PT. The X facility will change the coal distribution system with the addition of a supplier and a power plant. This is because mixing coal in each PLTU can cause disruption due to supply errors. The coal terminal functions as a means of blending coal. Coal blending is the mixing of two or more coal qualities to produce new coal qualities. The existing coal terminal will make the coal arriving at the PLTU ready for use and according to the coal calorie needs of the PLTU. Alternative coal terminal facilities are located at 19 PLTU. This research discusses the modeling of coal terminal location determination. The location determination is carried out using a linear programming optimization approach to obtain a location with the aim of minimizing coal logistics costs and investment costs. This study considers two shipping methods, namely direct delivery and transshipment, coal quality, expansion demand, and time. The selected coal terminal is Cilacap, serving PLTU Cilacap, Cilacap EXP and Pelabuhan Ratu. The construction of a coal terminal was carried out in the first year and required a cost of IDR 459,145,572,029,289.

Keywords
linear programming, coal terminal, location determination

1. Introduction

PT. X seeks to make an additional facility that functions as a blending plant or coal terminal located between the supplier and the PLTU (PLN, 2019). This has been stated in the RUPTL which aims to guarantee the supply and quality as well as greater utilization of coal. The construction of the facility will change the coal distribution system at the PLTU. The initial distribution system using a direct delivery system changed to supplier delivery - coal terminal - PLTU. The shipment from the coal terminal to the PLTU is a shipment in accordance with the needs of the PLTU so that it is expected to improve the smooth operation of the plant. An alternative location for the facility has been determined, namely in the Java and Kalimantan PLTUs. According to Wilkey and Macal (1976), the development of a centralized blending facility can be profitable because it can reduce blending costs, reduce bulk purchase costs and reduce transportation costs. The production process at each PLTU requires coal quality according to the engine design and generating capacity. This can be seen from Table 1.1. The most commonly used indicator of coal quality is the calorific value. The quality of coal that is in accordance with the design of the plant will result in high efficiency. PLTU tends to choose quality coal to get more electricity (Yucekaya, 2013). However, using high quality coal will increase the cost of coal at the PLTU (Whyatt, J.D. and Metcalfe, S.E, 2004).Coal needs for PLTU in Java Island are supplied by coal suppliers spread across the islands of Sumatra and Kalimantan. A coal supplier generally owns several mines with different coal qualities. The difference in coal quality, trademarks, and coal transportation can cause the cost of obtaining coal in each PLTU to experience differences.

1.1 Objectives
This study aims to develop a model for selecting a coal terminal location by taking into account the blending process, coal quality, and construction time.

2. Literature Review
Wu and Li (2014) examined the coal supply chain in Shanxi involving mines, markets and DC. The research objective is to determine how many DCs should be built and to minimize the total cost. This study uses a dynamic model with respect to demand uncertainty. However, in this study the DC capacity is considered to be unlimited. This research was completed in Java. Yu, Normasari and Luong (2015) improve further research with the capacity for each DC. This research integrates location, production and distribution simultaneously. The method used is pure integer linear programming with a 10 year period. Serdar and Al-Ashhab (2016) also examined multiproducts, multiperiods, and multiple echelons to determine location and allocation in order to maximize profits. This study uses mixed integer linear programming (MILP) to solve it. This research determines polisher, facilities, distributors and consumers. This study takes into account the costs of not being used for facilities, transportation and fixed costs of building facilities. Fatrias et al (2018). Fatrias conducted research to find the quality of coal blending by using supplier selection and allocation approaches in the cement industry. The research method uses linear programming and optimal results are obtained. This study found that coal calories are an important feature of coal. The existence of differences in quality will lead to customer dissatisfaction. Assaya et al (2019) conducted research with the aim of designing a simulation of a coal blending model. This study uses a visual basic to find the blending ratio of coal. Amini et al (2019) conducted a similar method using robust optimization that will maximize the total profit of the mining party by paying attention to coal contract penalties. Chakraborty and Mitra (2019) solve blending problems using hybrid multi criteria decision making between PROMETHEE and GAIA. The alternative criteria used are the quality of the coal (CV, ash, sulfur and humidity) and the cost of the coal. This modeling assumes a linear relationship with no correlation between coal qualities.

Tabel 1 Literature Review

Name (Year)	Model																	Cost					
	Static	Dynamic	Single Produk	Multi Produk	Cargo	Bulk	Transhipment	Production	Inventory	Blending Production	Pinalty	Single Objectie	Multiobjective	Maximize Profit	Minimize Cost	Capapcitated DC	Uncapacitated DC	Production	Inventory	Transportation	Unit	Expansion Cost	Fixed Cost
Wu, J. Et al, (2014)		✓		✓		✓	✓								✓		✓			✓			✓
Yu, V.F. Et al (2015)		✓		✓				✓	✓							✓		✓	✓	✓			✓
Danandeh, et al (2016)		✓		✓		✓	✓			✓					✓								
Correia, I. Et Al (2017)		✓					✓	✓			✓	✓			✓			✓		✓		✓	✓
Serdar, et al (2017)		✓		✓										✓									
Irawan, et al (2018)	✓			✓								✓			✓	✓				✓			✓
Shankar , et al (2018)						✓							✓		✓								
Chakraborty, et al (2019)										✓			✓										
Amsya (2019)				✓						✓													
Amini, et al (2019)				✓						✓				✓									
Sharma, B., Ramkumar, at al (2019)			✓									✓								✓			
Fadhil, et al (2020)	✓		✓									✓			✓					✓			✓
Putri (2020)		✓		✓		✓	✓	✓		✓		✓			✓	✓		✓		✓	✓	✓	✓

3. Mathematical Model

Index :

i : Index for supplier
j : Index for coal terminal
k : Index for PLTU
a : Index coal quality
t : Index time

Parameter :

c_{ij} = Tranportation cost from $i\ to\ j$
c_{ik} = Transportation costs from supplier i to PLTU k
c_{jk} = Transportation costs from alternative coal terminal j to PLTU k
GCV_i = GCV value held by suppliers i
GCV_k = GCV value owned by PLTU k
Co_i = Supplier contract capacity to supply coal
D_k = Demand for coal quantity of PLTU k $(\frac{\text{Ton}}{\text{year}})$
$ACF_j = Coal\ terminal\ investment\ costs\ j$Decision Variable :
x_{ija}^t= Total coal shipments from supplier i to coal terminal j in period t with GCV quality a.
x_{jka}^t= Total coal shipments from coal terminal j to PLTU k in period t with GCV quality a
x_{ik}^t= Total coal shipments from supplier i to PLTU k in period t.

$$F_j^t = \begin{cases} 1, if\ there\ is\ development\ at\ Coal\ terminal\ j\ period\ t \\ 0, otherwise \end{cases}$$

$$Min\ \sum_t \sum_j F_j^t ICF_j + \sum_t \sum_j \sum_i c_{ij} x_{ij}^t + \sum_t \sum_k \sum_i c_{ik} x_{ik}^t + \sum_t \sum_k \sum_j c_{jk} x_{jk}^t \quad (3.1)$$
$$\sum_j x_{jk}^t + \sum_i x_{ik}^t \geq D_k, \forall\ k, t \quad (3.2)$$
$$\sum_j\ GCV_k x_{jk}^t + \sum_i GCV_i x_{ik}^t \geq D_k, \forall\ k, t \quad (3.3)$$
$$\sum_{t=1} \sum_{j=1} x_{ij}^t + \sum_{t=1} \sum_{k=1} x_{ik}^t \leq Co_i\ , \forall i, t \quad (3.4)$$
$$\sum\ GCV_i x_{ij}^t \leq \sum\ GCV_k D_{kt}\ , \forall j, k \quad (3.5)$$
$$\sum\ GCV_i x_{ij}^t = \sum\ GCV_k x_{jk}^t\ , \forall j, k \quad (3.6)$$
$$\sum_t \sum_i x_{ij}^t = \sum_t \sum_j x_{jk}^t, \forall j, k, t \quad (3.7)$$
$$\sum_t \sum_i x_{ij}^t = Cap\ Ytj, \forall j, k \quad (3.8)$$

The objective function of this problem is to minimize the total cost of both the investment cost, the purchase cost of coal and the cost of coal transportation. Equation (3.2) is an equation for the fulfillment of the demand for each PLTU in each year. Equation (3.2) only focuses on the quantity of demand per PLTU. Fulfillment of PLTU requests can be sent directly from suppliers and also from selected coal terminals. Equation (4.3) is a development of the previous equation, namely equation (3.3) has used GCV in each PLTU and every year. PLTU's calorie needs must also be fulfilled every year. Calorie fulfillment can be supplied directly from suppliers as well as shipments from selected coal terminals. Equation (3.4) is the contract limiting function for each supplier. The supplier has given an agreement in the form of a contract that must be fulfilled. The supply from the supplier must not exceed the contract that has been promised. The supply from the supplier can go out to the coal terminal and also directly to the PLTU. Equation (3.5) is the blending equation at the PLTU directly supplied by the supplier. Each PLTU already has the required calorie needs and the quantity of coal needed, therefore the incoming supply must be less than the quality multiplied by the quantity. Equation (3.6) is the blending equation at the coal terminal. This equation forces the mixing of coal qualities to produce quality coal products a. If this equation does not exist, then the coal terminal will not become a blending facility but only as a transit facility. Equation (3.7) is the CT function equation which shows that every amount that comes out of CT must be equal to the number that enters CT. Equation (3.8) is an equation that ensures that a CT is built when a number of items enter the CT.

4. Results and Discussion

The objective function of this problem is the minimization of the objective function by minimizing the cost of coal logistics which consists of distribution costs and the cost of building facilities within 9 years. The construction of this facility needs to be carried out for 9 years due to changes in the existing demand for each PLTU. There are 23 suppliers used in this problem, 19 PLTUs and 8 types of coal calories. The function of the coal terminal development is coal blending. With this development, the coal that has been received by the PLTU does not need coal blending because the incoming coal is in accordance with the needs of the PLTU. This model takes into account the direct distribution and also through the coal terminal.

The results of the running model can be seen in the Table 2. The model used is a type of integer linear programming (ILP). However, in reality this model can be referred to as mixed integer linear programming (MILP). This is because the writer relaxes the variables $x_{ija}^{t}, x_{jka}^{t}, x_{ik}^{t}$ without having to be an integer. This relaxation will cause the running time of the optimization program to be faster. Variabel F_j^t is a binary variable so it is classified as an integer. This type of problem solving is branch and bound because it uses integer linear programming. The resulting status is global optimal which indicates that the result of this running is the best result that can be done and there is no better result. The number of variables used is 61,606 variables, there are 3,632 constraints used, and this problem running takes 8 minutes. This is a relatively fast time considering the number of variables and constraints used.

Tabel 2 Running Results

No	Category	Results
1	Model	*Integer Linier Programming* (ILP)
2	Solver Type	B-and-B
3	State	Global Opt
4	Objective	4.59146e+014
5	Variable	61606
6	Constrain	3632
7	Iteration	6484
8	Runtime	00;08;21

The results of running the software show that there is a coal terminal construction located in Cilacap and Cilacap EXP in 2020. However, we can conclude that there is 1 coal terminal to be built, namely in the Cilacap PLTU area. This is because Cilacap and Cilacap EXP are located in the same area but have different calorie requirements. The calories required for the Cilacap PLTU are 5200 and the Cilacap EXP PLTU is 4500. The Cilacap Coal Terminal will supply the PLTU in Cilacap and PLTU Pelabuhan Ratu. PLTU Pelabuhan Ratu has a requirement of 4400 calories totaling 3,700,000 tons / year. The PLTU Pelabuhan Ratu will be supplied entirely through the Cilacap coal terminal. The Cilacap coal terminal will produce 3 kinds of calories, namely 5200, 4500 and 4400 calories which will handle 3 PLTUs.

The choice of coal terminal location at PLTU Cilacap is influenced by the location of the PLTU which is in the northern part of Java Island. The northern part of Java Island is the farthest distance from suppliers, namely Kalimantan Island and Sumatra Island. This has resulted in high transportation costs from the supplier to the PLTU. Meanwhile, the locations of PLTU Cilacap and PLTU Pelabuhan Ratu are close together, resulting in low transportation costs from coal terminal to Ratu Harbor. Even though there are differences in the types of calories needed, the three PLTUs namely Cilacap, Cilacap EXP and Pelabuhan Ratu have similarities, namely the suppliers used. The three PLTUs use HE suppliers located in South Sumatra with 4400 calorie types. PLTU Cilacap and Cilacap Exp are also supplied from the same supplier, namely TME which is located in South Sumatra. The location of the supplier and the power plant can be said to be close together. Although the supplier is closer to the Pelabuhan Ratu PLTU, the demand for coal in the Cilacap area is greater, so the coal terminal location is located in the Cilacap area.

6. Conclusion

The model developed in this study can be used to determine the location, allocation of coal shipments, coal blending in a 9-year time horizon. The number of selected coal terminals is one, namely the Cilacap coal terminal with a total cost of Rp 459,145,572,029,289 for 9 years. There are 3 PLTUs served by the Cilacap coal terminal, namely PLTU Cilacap, PLTU Cilacap EXP and Pelabuhan Ratu. The construction time of the Coal Terminal is in the first year. This research is strategic in nature, only considering the number, location and capacity of the coal terminal. If this research is to be developed into operational, it requires further study, namely simulation. This is because this research has not considered uncertainties such as the need for ship frequencies, and the length of time for ship transportation.

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Biography

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