Optimizing Supply Chain Management in Coal Power Generation

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Abstract: Indonesian government launched Fast Track Program Phase-1 in 2009 to increase national electricity ratio by installing 35 coal power generations with total capacity 10,000 Mega Watt. However only 25 coal power generations had been installed by now, spread all over Indonesia. Coal necessities were supplied by 14 domestic coal mining companies. There are two factors that affect the price of coal i.e : distance and unit price. Distance between supplier and coal power generation would determine the transportation cost while unit price would determine the price of procurement. The aim of this research is to minimize total price of coal by optimizing the distance and unit price (USD/Ton), allocating the coal necessities and scheduling the delivery. The optimization would be simulated using software What'sBest. By this simulation, 24 power plants were suggested to change their existing suppliers, while only one power plant was fitted. This change could reduce USD 27 Million/year for total price of coal.

1 INTRODUCTION

One of the important factor in increasing the national economic development is the availability of low cost energy (Wang, Feng and Tverberg, 2013). Therefore every country tries to minimize the fuel cost in electricity supply. As a development country, Indonesia is in progress to install coal fire power plants with lower cost. The coal power plants spread all over the country, while coal suppliers are concentrated in particular island. The price of coal consists of two factors: transportation cost (USD/nautical mile) and unit price (USD/ton). So the transportation factor will dominate the cost of coal procurement since Indonesia is an archipelago country (PT PLN (Persero) Coal Procurement Division, 2013).

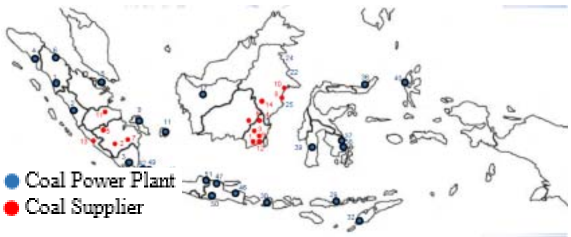

Figure 1: Map of Coal Power Plant and Coal Supplier Spread in Indonesia.

Every power plant requires a specific coal that must be supplied by appropriate supplier. In consequence of this problem, the utility should arrange the best supply chain management to minimize the cost. In case utility could minimize the distance between power plant and appropriate supplier, the cost would be minimal.

There are 25 power plants with specific coal requirement and 14 coal supplier that would be optimized in this paper. The purpose of this paper is to optimize supply chain management by minimizing the distance between power plant and appropriate supplier and ensure that production capacity of supplier could serve the power plant as long as contract duration. Software What'sBest is used to simulate this problem. The results of the simulation are the demand – supply mapping, allocating the coal requirement and scheduling of shipping.

2 METHOD

This paper simulated the coal supply chain management planning according to the real condition. The simulation would be processed by What'sBest software. The first step in this research was data collection. Data used in this simulation;

- Information about coal power plant as a demand, involving the name of Power Plant, the location,

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the quantity of coal demand, the quality requirement of power plant, safety stock level, and jetty capacity.

- Information about coal supplier, involving the name of supplier, the quality of coal, unit price (USD/ton), transportation cost (USD/Nautical miles), productivity (ton/year), contract duration and ship capacity.
- Information about ocean condition in Indonesia yearly, involving the height of wave, the velocity and direction of wind (Fig.2).
- Distance and lead time between supplier and demand. The distance is determined by Geographic Information System (GIS) Directorate General of Marine Transportation, The Indonesian Ministry of Transportation. Therefore the distance is not straight line, but following the cruise lane (fig.3).

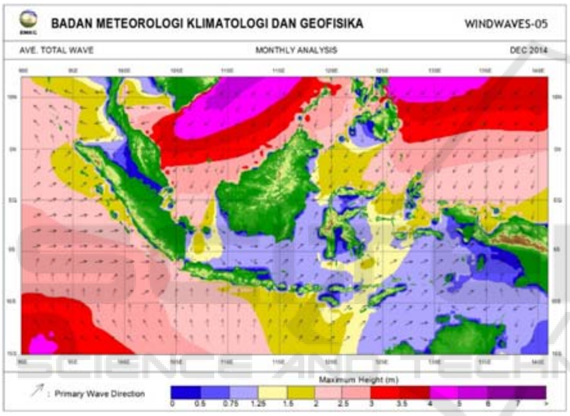

Figure 2: Wind and Wave Ocean Condition in Indonesian.

Based on Fig.2 above, the information is converted in binary number. Number 1 means a high wave that affect the ship velocity, and number 0 means normal condition that not affect the ship velocity.

Figure 3: Wind and Wave Ocean Condition in Indonesian.

The velocity of ship in Fig.2 and the distance between supplier and demand in Fig. 3 results in determining lead time.

All of data above were processed into a database. The next steps were allocating the coal necessity and scheduling. The steps in simulation process could be seen in Fig.4 as follow:

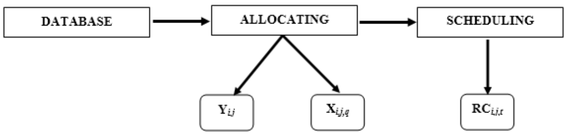

Figure 4: Steps of Simulation Process.

Some decisive variables must be considered when allocating the coal demand. These variables are presented by mathematical equation;

- Supplier i only could send coal q to the power plant j as if coal q has the same specification with power plant requirement. In other word, the caloric value of the coal from supplier must be appropriate with caloric value required by power plant. This decisive variable is *capable or not*, noted by $Y_{i,j}$.
- Coal q ϵ Q was supplied by supplier i ϵ I to power plant j ϵ J. This decisive variable is the amount of each type of coal which is delivered by supplier, noted by $X_{i,j,q}$.

The purpose of this allocation is to minimize total cost (*f*) of coal. There were 2 main components contributing in total cost; procurement cost (f_1) and transportation cost (f_2). Therefore this function can be determined as follows:

$$\text{Minimize } f = f1 + f2 \qquad (1)$$

Procurement cost is multiplication between unit price ($P_{i,q}$)of coal *q* to supplier *i* with total amount ($X_{i,j,q}$) of coal *q* that is delivered by supplier *i* to power plant *j*. Therefore the formula of procurement cost (f_1) can be determined by:

$$f_1 = \sum_{i\in I} \sum_{j\in J} \sum_{q\in J} X_{i,j,q} \; P_{i,q} \qquad (2)$$

While transportation cost is multiplication between transportation cost ($TC_{i,j}$) from supplier *i* to power plant *j* with total amount ($X_{i,j,q}$) of coal *q* that is delivered by supplier *i* to power plant *j* with distance (R_{ij}) from supplier *i* to power plant *j*. Therefore the formula of transportation cost (f_2) can be determined by:

$$F_2 = \sum_{q\in Q} \sum_{i\in I} \sum_{j\in J} X_{i,j,q} \; TC_{i,j} \; R_{i,j} \qquad (3)$$

To achieve the optimal function above, then allocation model must comply with these limitation:

1. Maximum amount ($X_{i,j,q}$) of coal *q* that could be procured by power plant *j* is limited by

maximum capacity ($O_{i,q}$) of coal *q* which is available in supplier *i* comply with contract document between supplier and utility, this limitation could be formulated as:

$$\sum_{j\in J} X_{i,j,q} \leq O_{i,q} \quad \forall i \in I, j \in J, q \in Q \qquad (4)$$

2. Every power plant has its typical caloric value of coal. Delivery of coal could be processed as if caloric value of coal in supplier comply with power plant‘s caloric value. The coal which has caloric value beyond the range could be processed. This limitation could be formulated as:

$$Y_{ij} = \begin{cases} Y_{ij} = 1, \text{ if } CV_q \in [CV_{min}, CV_{max}] \\ Y_{ij} = 0, \quad \text{otherwise} \end{cases} \quad \forall i \in I, j \in J, q \in Q \qquad (5)$$

3. The coal *q* from supplier must be able to fulfil the demand (D_j) every power plant $_j$. This limitation could be formulated as:

$$\sum_{i\in I} X_{i,j,q} \geq D_{j,q} \quad \forall j \in J, q \in Q \qquad (6)$$

The final step of the simulation is *scheduling*, which time of delivery of coal would be determined. The limitation in scheduling is that power plant *j* only could receive of coal from supplier *i* once a day (t). This limitation can be formulated as $RC_{i,j,q,t}$

3 RESULT

The simulation gave a result that from total 25 existing power plant, there are 24 power plants should change their supplier due to cost optimizing. This simulation also gave the optimal amount of coal that should be procured by power plant, it calls optimal allocation. Therefore all of power plants could make a coal procurement plan effectively. The next step is scheduling. All of the limitations of allocating and scheduling are conducted by What'sBest software. The scheduling covers all information about when supplier must deliver their coal to power plant, how much coal that must be delivered to the power plant, when the coal would be received by power plant considering the ocean condition and how much coal that available in power plant inventory as consequence of lead time variance. The example of scheduling table could be seen in Table 1.

From Table 1 above could be seen that power plant "A" would be supplied by supplier "1" as much as 7,500 ton in September 24th (purple cell) and would be received by power plant "A" in September 29th (yellow cell). Safety stock level in power plant "A" in September 24th is 54,080 ton (orange cell). This safety stock level would be maintained in 25 operating days. Lead time is presented as green and blue cell. Green cell is for normal condition (weather) while the blue one is for bad condition (weather).

4 DISCUSSION

Total cost (procurement cost and transportation cost) before simulation and after simulation was compared to evaluate it significance. Transportation cost before simulation was not available due to poor of information. There was no data about the amount of coal that is delivered by supplier to power plant. While total cost after simulation is determined by model. The comparison before and after simulation could be seen in Table 2.

The Table 2 above informed that after simulation procurement cost decreased as much as 24,110,173.53 USD per year. In case it is assumed that amount of coal that is delivered by supplier to power plant before simulation is equal to after simulation, then it definitely results that transportation cost after simulation is less than before simulation. In other word we could say that there is a benefit after simulation.

Table 1: The Example of Scheduling.

Power Plant	Supplier	Total of coal	Ship capacity	Initial Capacity	September						
		Normal*	Bad*		24	25	26	27	28	29	30
A	Level Inventory			51,750	54,080	51,990	57,420	55,350	57,420	58,710	56,640
	1	755,550	7,500	Received	0	0	7500	0	0	7500	0
	Lead Time	5	6	Order	7500				7500		
B	Level Inventory			47,040	48,652	47,771	50,889	49,008	50,889	50,244	48,363
	2	552,151	5,000	Received			5,000	0	0	5,000	0
	Lead Time	16	24	Order			5,000		5,000		
	3	134,632	7,500	Received			0	0	0	0	0
	Lead Time	2	2	Order							

Table 2: The Comparison of Total Cost.

Cost Component	Before Simulation (USD)	After Simulation (USD)	Benefit (USD)
Procurement Cost	897,183,961	873,073,787.5	24,110,173.5
Transportation Cost	Not Available	363,454,502.5	Not Available
Total Cost	**897,183,961 + NA**	**1,236,528,290**	

Last year, Indonesian government launched instalment of power generation program with total capacity 35,000 Mega Watt (MW). This program will be completed in 2019. Majority of them are coal fired power plant. The most critical problem in coal power generation is the reliability of coal supply. It will need a huge demand of coal in 2019. Therefore local coal suppliers need to be mapped. Then scheduling each power generation will be arranged and optimized. The method in this research is being used to solve the problem.

5 CONCLUSIONS

The research proved that the model simulation could optimize total cost of coal demand in power plant. There are 24 of 25 existing power plant that should change their allocating and scheduling planning to increase cost effective. By optimizing supply chain management it could reduce total cost at least 24,110,173.53 USD per year. The method in this research is being used to ensure the reliability of coal supply to support government's program; Instalment of 35,000 MW power generation.

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