Designing of Raw Material Scheduling Supply Multi On Supplier Strategies with Price, Lead time, And Stochastic Demand Variations. Case Study: Electricity Manufacturer

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Abstract. Raw Materials are one of the important things in manufacture. The availability of these items is very important for the production process to take place. The researcher will research an electricity company. The electricity company produces electricity equipment. The four types of electricity equipment are cartridges, thermocouples, tubular and mica heaters. Some of them have stochastic demand. Each of them has three components of the same raw material and used to make the product. However, the company cannot fulfill the demand because raw materials are not available, so consumers are looking for items elsewhere. This delay occurred because of the delay in sending raw materials, so the company has to wait until the ordered items arrive. This problem is being more complicated by the differences in parameters for each supplier such as price differences and lead time of arrival. Therefore, the company must determine the optimum scheduling and safety time by minimizing inventory costs as a result of Mixed Integer Linear Programming (MILP) being used in resolving these problems.

1. Introduction

Inventory is a list of items stored in stock. Inventory can be in the form of raw material goods or work in process, to finish good. Almost all goods in manufacturing began to be made from raw material. So, raw material becomes the main subject in making products. Inventory will impact on customer satisfaction, and calculating the optimum safety stock will result in high customer satisfaction and can minimize total inventory cost [1]. Besides that, inventory controls are also used to ensure that inventory requirements and usage can be carried out optimally [2]. Inventory control ensures the operational needs to be fulfilled on time and can use the inventory optimally [2]. The role of a supply chain is to deliver the right products, in the correct quantity, to the right customer, at the right place, at the right time, in the right condition, at the right price [3]. Meanwhile, random product placement has an impact on order picking processes that require time to search and move products because they are blocked by other products [4], and it will make the time wait to process the order. Certainly, it is very important in determining the stock of raw material supplies to be used in the production process of a product. Without stock, most production processes cannot be carried out. Procurement of the right stock is one very important key in a company. By determining the right stock of goods, it will be well-maintained. This is related to the sustainability of production so that it continues to run smoothly. This research is intended to minimize inventory costs with the final results that affect the optimal scheduling of raw material arrivals.

The electricity company which will be observed is located in the Cimone area, precisely in the city of Tangerang. The manufacturer produces 4 pieces of finish goods, namely cartridge, thermocouple,
tubular and band heater. Based on the work order data (SPK) and the order that came, the band heater had the highest presentation in the customer's request. The manufacturer has several problems, one of them is related to determining raw material stocks. In ordering the raw material stock, it is divided based on orders, namely local and imported. Ordering local raw material goods is done once in every third week of the month. The stock of local materials ordered is expected to come in the first week of each month. For imported raw materials come within 3 months after ordering, but often times, the order arrival time is delayed so that in the production process there is a shortage of raw material to make a product, then the production. The process experiences delay, therefore reorder will be made.

| Raw Materials   | Demand | Fulfil | Gap |
|-----------------|--------|--------|-----|
| Tubular         | 31%    | 31%    | 32% |
| Thermodetector  | 26%    | 27%    | 23% |
| Cartridge       | 43%    | 43%    | 45% |

Table 1. Fulfilment of Production Demand

There are 4 types of goods with the number of requests heater. Based on the table 1, The band has the highest production demand and demand is normal, then in tubular, thermodetector and cartridge has a demand that is stochastic, so more attention and better scheduling of arrival of goods are needed. However, the company cannot determine the best stock of raw material. If there are too many or lack of stocks it will increase the inventory cost of the company. So, the researcher must find the optimum safety stock and safety time. The researcher figures out there are gaps between demand and fulfilment. In tubular, there is 32% gap, thermodector 23%, and the cartridge has 45% gap. However, the company cannot fulfil the demand for goods. Here are a number of things that cause imperfections in demand, including raw materials that are lacking for production, the late arrival of suppliers, and others that will be explained in table 2.

| Causes of the Problem   | Percentage |
|-------------------------|------------|
| Nonstandard Material    | 15%        |
| Order Arrival Scheduling| 34%        |
| Lack of Quantity Order  | 13%        |
| Engine                  | 8%         |
| Human                   | 19%        |
| Administration          | 11%        |

Table 2. Percentage of Causes Problem

Based on the table above, the percentage shows order arrival scheduling has a very influential role in not fulfilling requests. The scheduling factor for poor order arrival will hamper the production process because the stock of raw material that is less or even empty will influence the product. This problem is exacerbated by the goods ordered not coming in the first week causing some goods production cannot be done. This condition makes the company must wait for the ordered material stock in order to be able to carry out the production process and goods. This inaccuracy in procurement also caused several main items to become out of stock and caused a shortage of raw materials for production. Due to the late delivery of suppliers who experience delays several times, production cannot be made.

If this problem continues to occur, the company will suffer losses. This condition increases high inventory cost and it will cause the loss of the company. These problems can be solved by Mixed integer linear programming (MILP).

2. Literature Review
In the section before, the researcher is using Mixed Integer Linear Programming (MILP) to solve this problem. In supplying goods, the company has several suppliers included in the multi-supplier strategy.
2.1. Mixed Integer Linear Programming (MILP)

Mixed Integer Linear Programming (MILP) is a linear integer programming model that can optimize a goal [6]. In the linear programming model, there are two functions, namely the objective function and constraint function. The objective function is a function that describes the goals/objectives in the problem model, while the boundary function is a form of presenting the available capacity limits to be allocated optimally and mathematically [2]. With the objective function that has been determined at the beginning, a decision variable is made which can be an integer, Boolean and fraction. The boundaries that have been made will determine the value of the decision variable. So, the optimal results from the objective function are found. There are 2 types of Integer Linear Programming based on decision variables, the first is Pure Integer Linear Programming (PILP) if all decision variables to be used are integers. Second, Mixed Integer Linear Programming (MILP), if the decision variable used is partly an integer and a fraction [6].

2.2. Multi-Supplier Strategy

Multi-supplier is a strategy to fulfill the material requirements applied by the company, where there are several suppliers stocking the same type of material. Effective costs incurred, eliminating the risk of monopoly prices from single suppliers, and choosing suppliers who can provide the best quality material to the company are the advantages of multi-supplier strategy [5].

2.3. Safety Time

Safety time is used in this research. Safety time is the minimum inventory that is converted into weekly time. This safety time is used to anticipate variations in demand during the lead time. In a multi-supplier strategy, the lead time variations of several suppliers will be considered. One method that can be used is the generalized lambda distribution method to get the mean and variance with the maximum approach. This method is used for the lead time of suppliers that are normally distributed and identical to the mean μ and variance σ² [7]. To know the maximum inventory level, it can be calculated by a continuous review [8].

3. Methods

Integer Mixing Linear programming is a general model that can be used in solving problems in optimally allocating sources of limited resources [9]. In the linear programming model, there are two functions, namely the objective function (objective function) and limiting function (constraint function). First of all, the minimum inventory and the maximum inventory level will be calculated by using Continuous review policy [10]. Inventory level will be monitored on an ongoing basis every day and will be reordered a number of Q if the amount of inventory that has been reached the reorder point (ROP). Second, the safety time that is used in this research will be calculated. Safety time is the minimum inventory that can be converted into weekly time [5]. This safety time is used to anticipate variations in demand during the lead time. After that safety time is calculated, we can have the optimal safety time and minimum inventory cost. Some of the costs used in minimizing inventory costs are Purchasing Cost (PC) which is the cost of purchasing by multiplying the quantity of raw material purchased with the price of each raw material. Opportunity Cost (OC) is the cost of storing inventory of items already purchased, Handling Cost (HC) is the cost of unloading goods from trucks until they enter the warehouse, and Ok cost of deficiencies are costs that occur when there are no goods when needed, which can result in lost sales or backorder [8][11][12][13]. To solve the problem, the expression below is used:

\[
\min TC = PC + OC + HC + Ok \\
PC = \sum_{i=1}^{l} \sum_{j=1}^{k} (q_{ij} \times p_{i})
\]

(1)  (2)  (3)
Where,

- \( q_{ij} \): Raw material supply quantity sent by suppliers;
- \( p_i \): Raw material prices;
- \( o_j \): Remaining stock at that time;
- \( I \): Set supplier of raw materials;
- \( b \): Tied up capital cost percentage;
- \( h \): Handling cost;
- \( m_j \): The total quantity of material handling;
- \( g \): Maximum quantity of material handling;
- \( c \): Handling cost charge;
- \( N_T \): Number of stock out product;
- \( C_u \): Cost of stock out product (IDR/unit).

Purchasing cost in equation (2) can be counted by multiple raw material price and quantity sent by each supplier. Opportunity cost in equation (3) is the cost of storing raw material in the inventory, Handling cost in equation (4) is the cost of decreasing raw material until it reaches the warehouse and if the raw material carried exceeds the amount of available capacity, a charge is charged for each excess of raw material quantity, and Shortage cost in equation (5) is the cost of lacking a number of raw materials so that goods cannot be produced.

There are limitations to the model in this study. 4 limitations of the model used in solving problems in the company. The limit consists of the total number of orders in one period, the lot size in each shipment, the quantity of raw material sent by the supplier and finally the warehouse capacity.

\[
OC = \sum_{i=1}^{I} (o_i \times \sum_{i=1}^{I} p_i / I) \times b
\]

\[
HC = h + \sum_{i=1}^{I} (\max (m_i - g, 0) \times c)
\]

\[
Ok = N_T \times C_u
\]

Equation (6) is the limit of each supplier related to the total number of orders in one period, the shipping lot size is shown in equation (7), in equation (8) and (9) shows that the value \( q_{ij} \) and \( x \) are non-negative and integer values. Equation (10) shows the company's boundary in warehouse capacity which is calculated using the amount of material handling, equation (11) shows the minimum inventory limit calculated using the remaining stock.

Safety time is used as a minimum inventory limit which will anticipate if there are uncertain variations in demand and lead time. With the uncertain lead time, the Generalized Lambda Distribution...
method is used to get the mean and variance with the maximum approach. Meanwhile, the parameters to be used are \( \lambda_1, \lambda_2, \lambda_3, \) dan \( \lambda_4 \) to obtain \( E(X_i) \) as the mean and \( \text{Var}(X_i) \) as a variance of supplier lead time \( n \) [5].

\[
E(X_i) = \mu + \sigma m_i
\]

\[
m_i = \frac{c_{n-1} + c_{n+1}}{2 \lambda_2 \sigma n + \lambda}
\]

\[
y = \mu D \times E(X_i) + z \sqrt{E(X_i) \times \sigma^2 + \mu D \times \text{Var}(X_i)}
\]

\[
\text{safety time} = \frac{y}{\mu D}
\]

Where,
- \( E(X_i) \): Mean lead time for \( n \) suppliers;
- \( \mu \): Mean of each lead time supplier;
- \( \sigma \): Standard lead time deviation of each supplier;
- \( m_i \): Order statistics parameter for \( E(X_i) \);
- \( v_i \): Order statistics parameter for \( \text{Var}(X_i) \).

The safety stock value in this study also applies as a minimum amount of inventory \( (y) \), and the calculation of safety time will be shown in equations (14) and (15).

4. Results
The demand data of finish good product in June 2017-May 2018 are tested by Kolmogorov Smirnoff test and the demand distribution for this case is stochastic demand. After the finish, good product demand had been tested and the researcher tested the demand distribution for raw material. The result for the demand distribution of raw material is normal. After that, the researcher calculated the minimum and maximum inventory level for each of product (Table 3).

| Raw Material Product   | Minimum Inventory | Maximum Inventory |
|------------------------|-------------------|-------------------|
| Heat Resistant Cable   | 2987.52           | 33330.27          |
| Serongsong 3mm         | 1585.91           | 2734.13           |
| Serongsong 6mm         | 1216.43           | 2589.58           |

Then the researcher calculated safety time existing so the calculation result is obtained (Table 4). The result of safety time existing for heat resistant cable is 1.29 week, serongsong 3mm is 1.20 week and Serongsong 6 mm is 1.06 week.

| Raw materials   | Safety Time, days | Safety Time, week |
|-----------------|-------------------|-------------------|
| Heat resistant cable | 9.00             | 1.29              |
| Serongsong 3mm  | 8.42              | 1.20              |
| Serongsong 6mm  | 7.36              | 1.05              |

To get the optimum safety time, steps in calculation stage must be calculated and the researcher must find the optimum order quantity, then the optimum safety time can be obtained (Table 5).
Table 5. Optimize Safety Time

| Raw Materials      | Safety Time, days | Safety Time, weeks |
|--------------------|-------------------|-------------------|
| Heat resistant cable | 38.87             | 5.55              |
| Serongsong 3mm     | 30.36             | 4.34              |
| Serongsong 6mm     | 28.97             | 4.14              |

Based on the safety time calculation, there are differences between the existing and optimize safety time. The optimize safety time have a longer time than before. Which means the stock that has been determined and calculated can reduce the amount of out of stock that occurs in the raw material. The next steps, calculate the total inventory cost, including purchasing cost, opportunity cost and handling the cost (Table 6).

Table 6. Total Cost After Optimize

| Raw material      | TC                  |
|-------------------|---------------------|
| Heat resistant cable | IDR 870,284,794    |
| Serongsong 3mm     | IDR 100,614,529    |
| Serongsong 6mm     | IDR 19,493,949     |

Lastly, the researcher will schedule the arrival of raw material supply using LINGO software. There are some raw materials stages that passed through the shipping process and management, which are: (1) Shipping, namely delivery process of raw materials from the supplier’s country of origin to destination country by sea. The shipping duration for each shipment depends on the supplier's country of origin. In this process, the status of raw materials depends on the agreement between the supplier and company, either it is still an inventory of the supplier or has become a company inventory. (2) Customs Clearance (CC), which is a process done at the destination country port. (3) Quality Inspection (QI), carried out by the QI Department of the company. (4) Raw materials will become ready stock inventory after turning off Quality Inspection, while raw materials which are not QI qualified will be separated and submitted to be replaced by the supplier [5].

| Supplier | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12  |
|----------|----|----|----|----|----|----|----|----|----|----|----|-----|
| S1       |    |    |    |    |    |    |    |    |    |    |    |     |
| SHIP     | 50000 | 0  | 0  | 50000 | 0  | 0  | 50000 | 0  | 0  | 50000 | 0  | 0  |
| QI       | 0  | 0  | 25000 | 0  | 25000 | 0  | 0  | 25000 | 0  | 0  | 0  | 0  |
| SR       | 0  | 0  | 25000 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 50000 |
| OUT      | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| S2       |    |    |    |    |    |    |    |    |    |    |    |     |
| SHIP     | 0  | 25000 | 0  | 0  | 25000 | 0  | 0  | 0  | 0  | 25000 | 0  | 0  |
| QI       | 0  | 0  | 25000 | 0  | 25000 | 0  | 0  | 0  | 0  | 0  | 0  | 0  |
| SR       | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 25000 |
| OUT      | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

Figure 1. Example of Raw Material Schedule Supply for Heat Resistant Cable

5. Conclusion and Recommendation

Based on the results of the calculations, it is found that:

1. Mixed integer linear programming models can help scheduled delivery of raw material supplies, taking into account uncertainty in demand, lead time of each supplier.
2. Safety Time Optimize for raw material heat resistant cable is 5.55 weeks, serongsong 3mm is 4.34 weeks, and 4.14 for serongsong 6mm. As well as the optimum safety time results that are converted from inventory values.

3. The mathematical model contained in this paper provides a smaller total inventory cost compared to the existing total cost. But the existing total cost cannot be displayed due to the company confidential.

For future research, it can be considered to make a schedule for the arrival of raw materials tailored to the production schedule so as to produce optimal scheduling between the arrival of raw materials and production scheduling.

References
[1] Prayoga Y, Ridwan AY, 2018 Santosa B Proceedings of the Internasional Conference on Industrial, EnteIDRrise and System Engineering (ICoIESE) 2 303-306.
[2] Mahtamtama E, Ridwan AY, Santosa B 2018 Proceedings of the 12th Internasional Conference on Telecommunication System, Services, and Applications (TSSA) 6618–6625.
[3] Razafuad R, Ridwan AY, Santosa B, 2018 Proceedings of the sixth International Conference on Information and Communication Technology (ICoICT) 0 310–318.
[4] Amalia Y, Ridwan A Y, Santosa B 2015 JRSI 4 48-53
[5] Masruroh NA, Prasetyorini AV 2015 JT 17 1
[6] Kamal A, Vinarti R A 2012 RSSI 1 1-6.
[7] Osman H, Demirli K 2012 International Journal of Production and Economic 135 299-307.
[8] Liliana, Damayanti DD , Kenaka S P 2018 JRSI 1-8.
[9] Arismawati P, Ridwan AY, Santosa B 2015 JRSI 2 4877.
[10] Muyassar N, Ridwan AY, Santosa B 2018 1st Asia Pasific Conference on Research in Industrial and System Engineering (APCORISE).
[11] Bahagia SN 2006 Sistem Inventori (Penerbit ITB: ID)
[12] Mely Permatasari P, Ridwan AY, Santosa B 2017 Proceedings of Material Science, Engineering, and Chemistry (MATEC web of Conference) 135 00056.
[13] Rahman AM, Iqbal M, Astuti MD 2016 JRSI.