Dynamic Deterministic Inventory Control in Continuous Manufacturing Company

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Abstrak— **Sistem pengendalian yang baik diperlukan untuk memudahkan pengendalian dan meminimalisir biaya, sehingga terdapat kecenderungan untuk mengasumsikan kondisi desterministik untuk kemudian dioptimasi. Walaupun demikian, dalam kenyataan, ketidakpastian dan fluktuasi terkadang ditemukan dalam beberapa kasus. Oleh karena itu, kondisi probabilistik tersebut dapat didekati dengan penjadwalan deterministik dinamis. Salah satu contoh adalah produksi Perusahaan X yang bersifat kontinyu, namun kebutuhan bahan utilitynya mengalami fluktuasi. Berdasarkan metode ini, biaya inventori dapat dikurangi dibandingkan dengan pengendalian statis yang selama ini dilakukan.**

Kata Kunci— **pengendalian inventori, model deterministik dinamis, manufaktur kontinyu, algoritma**

Abstract— ***Good inventory control system is needed in order to make the control simple, but also to reduce cost. Hence there is intention to assume deterministic condition, and then optimize it. However, uncertainty and fluctuation is found in many cases. Hence, the probabilistic condition can be approached by dynamic deterministic schedule. One of the examples is production of Company X which considered as continuous, with material demand of utility has fluctuation. The application of this method has reduced the inventory cost.***

Keywords— ***inventory control, dynamic deterministic model, continuous manufacturing, algorithm***

I. Introduction

Company has to pay the price for the probable inventory cost caused by the uncertainty and fluctuation of amount of goods stored. Generally, every company especially manufacture company emphasizes the stock of raw material in order to keep the company running. Being able to measure the inventory and optimize the inventory cost help the production process to run smoothly.

The methods applied in controlling the inventory are typically divided into three major group, probabilistic inventory, deterministic inventory, and uncertain inventory. Probabilistic inventory is divided into three group; a fixed time period model (*P*) which accommodates similar ordering period with different lot size, a fixed order quantity model (*Q*) which accommodates similar lot size with different ordering period, and single period inventory models.

However, in reality, the inventory is not necessarily controlled using the previous methods. Comprehending the real inventory control characteristic becomes crucial in determining the method that works best with the actual condition. Several factors play a great role in affecting actual inventory control characteristic. Some of the examples are the raw materials characteristic which is used in production (in order to control the stock of raw material), the pattern of goods' departure from the supplier, or the company purchasing policy. Yet, after the study of actual inventory control characteristics and available methods, some assumption made in order to accommodate things that are left behind.

However, in some cases and actual condition, the fluctuation of the quantity can be assumed very small. Understanding the characteristic of the stock in the warehouses is very important to determine the right control model to represent actual condition.

Dynamic deterministic model is appropriate with Company X's inventory control characteristic which has a known demand of raw material but different in number in every period. Company X's production profile is continuous since it uses utility raw material which produces clean water, demineralized water, even the electricity. It means that the problem can be perceived as dynamic deterministic.

There are three production shifts a day that continuously happen. This enables the company to have a more exact number of inventories stored in the warehouse since every shift doesn't require a quite distinctive amount of material. The controlling method that becomes the focus of this study is the Wagner-Within deterministic dynamic model.

The different raw material demand in every period is caused by different number of production (sterilized water, demineralised water, electricity, and so on). Another factor that determines the demand is weather. It requires more material to purify the water since it contains more precipitate in the storage. Furthermore, raw materials are required more during starting up production machine than running on the production.

According to those inventory control characteristic, deterministic dynamic inventory control method using Wagner-Within Algorithm is considered appropriate in Company X. This proposed method is going to be compared with the actual method in Company X which has the monthly purchase order this document is a template.

II. Literature Review

Inventory or stock is the goods stored which will be used or sold in the following period. According to [3], inventory is one of the factors that keep the production and sales running. Thus, it supposed to be appropriately maintained. A stock out event is as terrible as an overstock event since both conditions have their own obstacles and effects.

There are three motives which underlie the fact that it is necessary according to [2] which presented as follow:

Transaction motive secures the demand attainment. The amount of inventory used is operational inventory.

Precautionary motive constrains the uncertainty from both the supplier and purchaser. The amount of this inventory is safety stock or buffer stock.

Speculative motive enables the company to gain multiple profit in the future.

A. Wagner-Within Algorithm

Applying the dynamic program principle, Wagner and Within developed the algorithm of the dynamic deterministic inventory problem solving in 1958. Tersine in [4] proposed the cycles as follow:

First Cycle

This cycle begins with calculating the total cost matrix (order cost and holding cost) for all the order possibilities during the planning period (made up of N planning period). Then, O_{en} is defined as the cost from period of e to period of n when the order is made at period of e up to n. The O_{en} is defined as follows:

$$O_{en} = A + h\sum_{t=e}^{n}\left(q_{en} - q_{et}\right) \text{ for } 1 \le e \le n \le N \qquad (1)$$

which:

A : order cost (rupiah per order)
h : holding cost (rupiah per unit per period)

$$q_{et} : \sum_{t=e}^{n} D_t$$

D_t : demand in period
e : early period limitation
n : maximum period limitation

Second Cycle

This phase begins with calculating f_n which defined as possible minimum cost from period of e to period of n with the assumption of zero as the degree of period of n inventory. Then, with $f_0 = 0$, it is followed with calculating f_1, f_2, f_3, ..., f_n in sequence. f_N is total cost of the optimum order which is calculated as follow:

$$f_n = \text{Min}\left[O_{en} + f_{e-1}\right]; \text{ for } e = 1,2,\ldots,n \text{ and } n = 1,2,\ldots,n \qquad (2)$$

In other word, all possible order combination in every period is compared. The best combination (f_n strategy) is utilized to fulfil the demand during period of e until the period of -n. f_N is the optimum number of order until the period of –n.

Third Cycle

This cycle begins with converting f_N to lot size which presented in Table 1.

III. Data Analysis

A. Data Collection

The data of one year raw material requirements is presented in Table 2.

Another data that are required to utilize Wagner-Within Algorithm:

1) Order Cost (A)

Order cost consists of the making of purchase order that was managed by two employees. It took five days to finish it. The calculation is presented as follow:

- 1 employee salary = Rp 2.500.000

TABLE 1

THE MATRIX OF F_N TO LOT SIZE CONVERTION

$f_N = O_{eN} + f_{e-1}$	The last order is executed in period of e to fulfil the demand from period of e to period of N.
$f_{e-1} = O_{ve-1} + f_{v-1}$	Two last orders must be executed during v period to fulfil the demand from period of v to period of e - 1.
⋮	⋮
$f_{u-1} = O_{u-1} + f_0$	The first order must be done during period 1 to fulfil the demand from period 1 to period of u-1.

TABLE 2

RAW MATERIAL REQUIREMENTS AND PRICE

***Raw Material* Z**	
Rp 77.280 / Kg	
Month	***Amount* (Kg)**
January	400
February	525
March	75
April	425
May	225
June	275
July	475
August	175
September	225
October	200
November	150
December	300
Total	3.450

- 2 employees salary = Rp 5.000.000
- PO making fee = (5 days/ 20 work days) x (Rp 5.000.000) = Rp 1.250.000
- Other expenses (Document, Internet, Phone calls, Electricity, etc) = Rp 250.000
- **Total order cost = Rp 1.500.000**

2) *Holding Cost (h)*

The holding cost was made by calculating the land price applied in the area of Company X since the land which was turned into warehouse was bought. The price was Rp1.500.000 per. The pallet used has 1,8 m^2 in width. It is able to carry 2 tons of raw materials. According to the expense per kg, the calculation was presented in Table 3.

Later on, the holding cost will be added by depreciation cost of raw materials stored in the warehouse. This number was attained by multiplying the monthly interest by the quantity of goods stored in the warehouse.

A. Wagner-Within Algorithm Calculation

The calculation of Wagner-Within Algorithm was executed after the collection of data and measurement of monthly raw material usage. The process is presented in Table 4.

a) First Cycle

$$O_{en} = A + h\sum_{t=e}^{n}(q_{en} - q_{et}) \text{ for } 1 \le e \le n \le N$$

A : Rp 1.500.000,- per order
h : Rp 1.350,- per period
L : 1 month

O_{11} = 1.500.000 + (400 – 400) x (1.350 + (77.280 x 0,005))
= **1.500.000**
O_{12} = 1.500.000 + [(925 – 925) + (925 – 400)] x (1.350 + (77.280 x 0,005))
= **2.411.610**
O_{13} = 1.500.000 + [(1.000 – 1.000) + (1.000 – 925) + (1.000 – 400)] x (1.350 + (77.280 x 0,005))
= **2.672.070**

and so on and so forth until $O_{1'12}$. Then the next iteration from $O_{2'2}$ to $O_{12'12}$ was perceived. The table on Appendix 1 is utilized to ease the calculation.

TABLE 3

THE CALCULATION OF RAW MATERIAL *Z* HOLDING COST

Pallet Width (m^2)	**Pallet Capacity (Kg)**	**Warehouse Capacity per m^2 (Kg per m^2)**	**Holding Cost (Rupiah per m^2)**
1,80	2.000	1.111	**Rp 1.350**

b) Second Cycle

f_n is possible minimum cost from period of *e* to period of *n* calculated using the equation as follow:

$$f_n = \text{Min}\left[O_{en} + f_{e-1}\right];\ \text{for } e = 1, 2, \ldots, n \text{ and } n = 1, 2, \ldots, n \quad (3)$$

According to the above notation, f_n was calculated from the first period to the twelfth period. The calculation is accommodated by the use of a matrix. The matrix of second cycle calculation was presented in the following table with the computation attached in Appendix 2.

c) Third Cycle

The third cycle was converting the final result of the previous cycle into the following MRP table in Table 5.

IV. TOTAL COST CALCULATIONS

The calculation of inventory total cost was attained from the MRP for the raw material Z after the application of Wagner-Within Algorithm.

Number of one year order = 6 times

The number of raw material usage = Rp77.280 per kg

Order cost = Rp1.500.000 per order

Total cost of raw material (proposed) = (3.450 x 77.280) + (6 x 1.500.000) = Rp275.616.000

As the comparison, the actual cost of the monthly raw material order according to Company X policy is presented as follow:

Total cost of raw material (actual) = (3.450 x 77.280) + (6 x 1.500.00) = 284.616.000

Comparing to the actual total cost, the calculation of dynamic deterministic method can save Rp. 9.000.000,- or

TABLE 4

THE MATRIX OF F_N DISPERSANT RAW MATERIAL CALCULATION

e/n	1	2	3	4	5	6	7	8	9	10	11	12
1	1.500.000	2.411.610	2.672.070	4.885.980	6.448.740	8.836.290	13.785.030	15.912.120	19.037.640	22.163.160	24.767.760	30.497.880
2		3.000.000	3.130.230	4.606.170	5.778.240	7.688.280	11.812.230	13.635.450	16.370.280	19.148.520	21.492.660	26.701.860
3			3.911.610	4.649.580	5.430.960	6.863.490	10.162.650	11.682.000	14.026.140	16.457.100	18.540.780	23.229.060
4				4.172.070	4.562.760	5.517.780	7.992.150	9.207.630	11.161.080	13.244.760	15.067.980	19.235.340
5					5.672.070	6.149.580	7.799.160	8.710.770	10.273.530	12.009.930	13.572.690	17.219.130
6						6.062.760	6.887.550	7.495.290	8.667.360	10.056.480	11.358.780	14.484.300
7							7.017.780	7.321.650	8.103.030	9.144.870	10.186.710	12.791.310
8								8.387.550	8.778.240	9.472.800	10.254.180	12.337.860
9									8.821.650	9.168.930	9.689.850	11.252.610
10										9.603.030	9.863.490	10.905.330
11											10.644.870	11.165.790
12												11.189.850

TABLE 5

THE MRP OF RAW MATERIAL *Z* WAGNER-WITHIN ALGORITHM CALCULATION

Period	0	1	2	3	4	5	6	7	8	9	10	11	12
Demand (Kg)	0	400	525	75	425	225	275	475	175	225	200	150	300
Lot Order	0	1.000	0	0	925	0	0	475	600	0	0	150	300
Order	1000	0	0	925	0	0	475	600	0	0	150	300	

3,16%. This is only for one type of material. If all the types of raw material are calculated, the company will have a significant difference. The saving was attained from the fewer number of order compared to the today's actual number of order.

V. CONCLUSIONS

The dynamic deterministic method has been applied to the company. This method has saved Rp. 9.000.000 or 3,16% for one type of raw material. Even though the amount of saving has a quite small contribution, it proves that there is a space of improvement that can be done in order to attain more optimum total inventory cost.

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Roland YH Silitonga, menyelesaikan S1 di Teknik Mesin ITB dan S2 di Teknik dan Manajemen Industri ITB. Saat ini sedang menempuh program S3 di Teknik dan Manajemen Industri ITB, dan aktif sebagai staf pengajar ITHB.

Andreas Kurniawan, menyelesaikan S1 di Teknik Industri ITHB pada tahun 2014.