Production planning using dynamic programming approach

by Nunung Nurhasanah

PRODUCTION PLANNING USING DYNAMIC PROGRAMMING APPROACH

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ABSTRACT

PT. XYZ is a company which operates in mining and oil area. The production volume was produced in a large quantity with a various item, but in this research was constrained in premium product pursuant to calculation with AHP approach with value 0.328. In fact, demand of the premium was fluctuated so that company made one of the most strategies to control demand with an inventory control ways.

Therefore, at this research to control demand use forecasting method to determine its production volume. One of the applying to dynamic programming approach will be able to determine the production volume and optimal inventory quantity in each month. This thing was affected by using dynamic programming approach which had a unique character comparing with the others production planning method. At this case specially, dynamic programming solved a production planning problem with dividing in a few step of stage which in that step contained a few probability which was being happened. The research result was showed with the dynamic programming approach will gived an optimal production and inventory quantity, and company able to minimize the total production quantity and holding cost to 17.88%.

Key words: production planning, dynamic programming, minimize

1. INTRODUCTION

Fuel oil is society primary needs. At the present time on company which is moving in mining and oil area experienced growth. Too many company was emerging so that, will be affect determine production volumes be produces. So, the company have to planning determined production volumes with properly planned. It likes as business for minimized cost in the operational production

2. THEORETICAL BACKGROUND

2.1. Analytical Hierarchy Process (AHP)

AHP is an approach to decision making that is designed to assist in the completion of the measurement and comparison of multiple criteria complex problems. (Saaty, 1993)

2.2. Forecasting

Forecasting is the forecast (estimate) about something that has not happened. Forecasting is always wrong, so that forecast production by whatever method will always contain an error. Therefore, in using several forecasting methods and techniques of production to obtain the smallest error that shows higher prediction accuracy. (Makridakis, 1993)

2.3. Dynamic Programming Approach

Dynamic Programming is problem-solving method that is used to optimize the process of decision making by describing a solution to a set of Steps or stages so That the solution of the problem can be viewed from a series of interrelated decisions. In solving problems with dynamic programming approach we can using two approaches from dynamic programming there are: (Taha, 1996)

a. Dynamic Programming Forward, the solution producer can be developed from stage N (left) to stage 1 (right). Decision variable is $x_1, x_2, \ldots, x_n$.

b. Dynamic Programming Backward, the solution producer can be developed from N-stage system has started from stage 1 (right) and proceeded to stage N (left).

3. RESEARCH METHOD

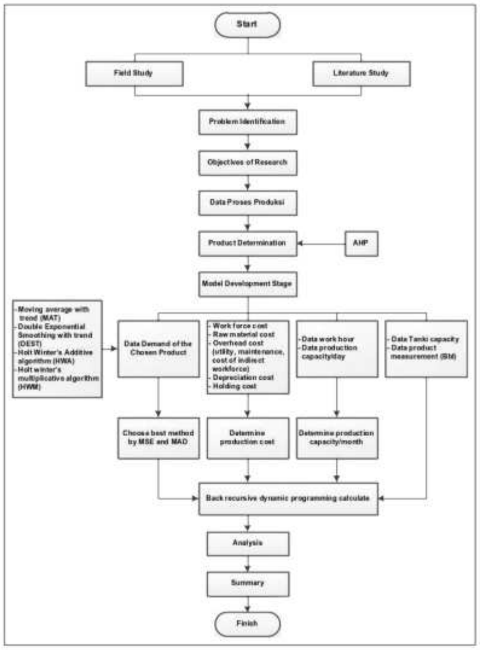

Figure 1. Thought Dynamic Model Framework Programme

With inventory closed was:

$I_t = I_{t-1} + X_t - D_t$ …………………………………….. (3.1)

Total Production of X_t can be shown as: Range of values is

$D_t - I \leq X_t \leq D_t$ ……………………………………… (3.2)

General equation recursively for this problem is in the form :

$F_t^*(I_t) = Min\{VCP_t(X_t) + VCH_t(I_t) + f_{t-1}^*(I_{t-1})\}$ .... (3.3)

$$D_t - I \leq X_t \leq D_t$$

Above recursive equation can be written by inserting equation (3.1), as follows :

$F_t^*(I_t) = Min\{VCP_t(X_t) + VCH_t(I_t) + f_{t-1}^*((i_t + X_t + D_t)\}$. (3.4)

$$D_t - I \leq X_t \leq D_t$$

With the restriction of production:

$$X_t \leq P_{max}$$
$$D_t - I \leq X_t \leq D_t$$

X_t is the amount of production in period t, resulting in the acquisition $F_t^*(I_t)$ and one value of X_t will produce optimal acquisition.

4. DATA PROCESSING

4.1. Product Priority Selection

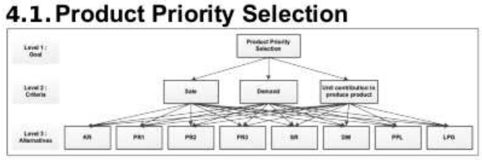

Figure 2. AHP Hierarchy Structure

Below here is the calculating AHP by Expert Choice 2000 software.

Table 1. AHP Result

PRODUCT	WEIGHT
PR3	0.328
LPG	0.220
PR2	0.130
PR1	0.118
SR	0.096
DM	0.043
PPL	0.040
KR	0.025

4.2. Forecasting Result

Base on table below that the results of forecasting the best method to choose is the Holt Winter Multiple Additive Algorithm (HWM), this is viewed from the smallest MAD.

Table 2. Forecasting Result

Method	MAD
Moving Average With Trend	262351.30
Double Exponential Smoothing With Trend	263528.80
Holt Winter Additive Algorithm	253439.50
Holt Winter Additive Multiplicative Algorithm	251735.80

4.3. Problem Solving Production Planning Using Dynamic Programming Approach

Below here is the notation for this model formulation:

T = Period: 1,2,3 ,..., n
N = Number of periods

I_{t-1} = Number of incoming inventory at the beginning of period 1
D_t = Total demand will be met in period t
X_t = Amount of product produced in period t
I_t = Inventory at end of period t
VCH_t = Cost savings per-unit variable in period t
$F_t^*(I_t)$ = Minimum total cost to supply early in the period in which there are still n the next period.
$f_{t-1}^*(I_{t-1})$ = Optimal decision cost in prior periods.
X_t^* = Level of production that produces $F_t^*(I_t)$
P_{max} = Maximum production capacity
I_{max} = Maximum Tank Capacity

a. Decomposition
Production planning problem period January-June 2010 in for stage, optimal solution are knowing to sub problems. Stage in the problem is January, February, March, April, May, and June.

b. State Variable

Table 3. State Variable

Periode	Forecasting 2010	Warehouse Capacity
January	2,315,810	1,392,000
February	2,395,662	1,392,000
March	2,475,513	1,392,000
April	2,555,365	1,392,000
May	2,635,217	1,392,000
June	2,715,068	1,392,000

PT. XYZ has 5 tanks save for finished goods premium product and each tank have capacity minimize:

$$\text{Minimum Capacity} = \frac{1{,}392{,}000}{5} = 278{,}400 \text{ barrel}$$

c. Variable Cost
(VCP) $. 27.92

d. Holding Cost
(VHC) $. 2.12

e. Decision Variable
Determine the allocation produce volumes every months base on increase total inventories as big as 278,400 Barrel.

$F_t^*(I_t) = \text{Min}\ \{VCP_t\ (X_t) + VCH_t\ (I_t) + f_{t-1}^*\ (I_{t-1})\}$

f. Calculation
Calculation of optimal production and optimal amount of inventory of production so as follows:

$F_0^*(I_0) = 0$
$I_0 = 0$

stage-one problem, the value of $F_0\ (I_0)$ is 0, because there is no burden of payment on the stage 0 that has been passed. Thus,

- For the month of June, F0 * (i) = 0
- For May

$F_1^*(I_1) = \text{Min}\ \{VCP_1\ (X_1) + VCH_1\ (I_1) + 0$
$F_2^*(I_2) = \text{Min}\ \{VCP_2(X_2) + VCH_2\ (I_2) + f_1^*\ (i_2+X_2-D_2)\}$

In general, recursive function for this case can be written as:

$F_t^*(I_t) = \text{Min}\ \{VCP_t\ (X_t) + VCH_t\ (I_t) + f_{t-1}^*\ (I_{t-1})\}$
$F_t^*(I_t) = \text{Min}\{VCP_t(X_t) + VCH_t(I_t) + f_{t-1}^*(i_t+X_t - D_t)\}$

Range nilai X_t is $D_t - I \le X_t \le D_t$
And so on until stage 6. The first stage will be represented by Table 4, and so on until Table 9.

Stage 1 : June
$F_1^*(I_1) = \text{Min}\ \{VCP_1\ (X_1) + VCH_1\ (I_1) + f_0^*(i)$
$1{,}323{,}068 \le X_1 \le 2{,}715{,}068$

Stage 2 : May
$F_2^*(I_2)=\text{Min}\{VCP_2(X_2)+VCH_2(I_2) + f_1^*(i_2 + X_2 - D_2)\}$
$1{,}243{,}217 \le X_2 \le 2{,}635{,}217$

Stage 3 : April
$F_3^*(I_3) = \text{Min}\{VCP_3(X_3) + VCH_3(I_3) + f_2^*(i_3+X_3 - D_3)\}$
$1{,}163{,}365 \le X_3 \le 2{,}276{,}965$

Stage 4 : March
$F_4^*(I_4)=\text{Min}\{VCP_4(X_4)+VCH_4(I_4)+f_3^*(i_4+X_4-D_4)\}$
$1{,}083{,}513 \le X_4 \le 2{,}475{,}513$

Stage 5 : Febuary

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$F_5^*(I_5)$ =Min $\{VCP_5(X_5)+VCH_5(I_5) + f_4^*(i_5+X_5 - D_5)\}$
$1,003,662 \leq X_5 \leq 2,117,262$

Stage 6 : January
$F_6^*(I_6)$ = Min$VCP_6 (X_6)+VCH_6(I_6) + f_5^*(i_6 +X_6 - D_6)\}$
$923,810 \leq X_5 \leq 2,315,810$

5. ANALYSIS

Production Cost Comparison of Dynamic Program and Corporate Policies will be represented by Table 11 and 12.

Comparison with Inventories Total Production and Total Cost of Methods of Dynamic Program with Company Policy :

$$\text{Cost savings} = \frac{\text{Corporate cost - Cost by DP}}{\text{Corporate cost}} \times 100\%$$
$$= \frac{\$465.782.955 - \$382.521.731,32}{\$465.782.955} \times 100$$
$$= 17,88\%$$

Without a comparison of Total Production Inventory and Total Cost of Methods of Dynamic Program with Company Policy :

$$\text{Cost savings} = \frac{\text{Corporate cost - Cost by DP}}{\text{Corporate cost}} \times 100\%$$
$$= \frac{\$465.782.955 - \$421.385.369}{\$465.782.955} \times 100\%$$
$$= 9,53\%$$

6. CONCLUSION

1. Based on AHP, the selected product is a premium product with value 0328.
2. Production volume to be in production by applying the minimum inventory is 13,700,635 barrels of stock with a minimum of 1,392,000 barrels. Meanwhile, production volumes to be produced without the inventory was a minimum of 15,092,635 barrels.
3. The amount of production costs which must be issued by the company by using dynamic program by applying the minimum inventory is $ 382,521,732.00 while, the magnitude of production costs which must be issued by the company with a dynamic program without applying the minimum inventory is $ 421,386,369, the two results is less than the cost of production that must be removed when using the company's policy that is equal to $ 465,782,955.00.
4. Cost savings with dynamic programming method is 17.88% or a total of $ 83,261,223.68, And if company's implement the policy without the minimum inventory, cost savings in get is 9.53% or a total of $ 44,396,586.

7. REFERENCE

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Table 4. First Stage on June 2010

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$\{VCP_1 (X_1) + VCH_1 (I_1) + F_0^* (I_1 + X_1 - D_1)$								
X1 / i	1,323,068	1,601,468	1,879,868	2,158,268	2,436,668	2,715,068	$X_1^*{}_{(Barel)}$	$F_1^*(i)$
0						75,804,698.56	2,715,068	75,804,699
278,400					68,621,978.56		2,436,668	68,621,979
556,800				61,439,258.56			2,158,268	61,439,259
835,200			54,256,538.56				1,879,868	54,256,539
1,113,600		47,073,818.56					1,601,468	47,073,819
1,392,000	39,891,098.56						1,323,068	39,891,099

Table 5. Second Stage on May 2010

$(VCP_2 (X_2) + VCH_2 (I_2) + F_1^* (I_2 + X_2 - D_2)$								
X_2 / i	1,243,217	1,521,617	1,800,017	2,078,417	2,356,817	2,635,217	$X_2^*{}_{(Barel)}$	$F_2^*(i)$
0						149,379,957.20	2,635,217	149,379,957
278,400					142,197,237.20	142,787,445.20	2,356,817	142,197,237
556,800				135,014,517.20	135,604,725.20	136,194,933.20	2,078,417.00	135,014,517
835,200			127,831,797.20	128,422,005.20	129,012,213.20	129,602,421.20	1,800,017.00	127,831,797
1,113,600		120,649,077.20	121,239,285.20	121,829,493.20	122,419,701.20	123,009,909.20	1,521,617.00	120,649,077
1,392,000	113,466,357.20	114,056,565.20	114,646,773.20	115,236,981.20	115,827,189.20	116,417,397.20	1,243,217.00	113,466,357

Table 6. Third Stage on April 2010

$\{VCP_3 (X_3) + VCH_3 (I_3) + F_2^* (I_3 + X_3 - D_3)$								
X_3 / i	1,163,365	1,441,765	1,720,165	1,998,565	2,276,965	2,555,365	$X_3^*{}_{(Barel)}$	$F_3^*(i)$
0						220,725,748.00	2,555,365	220,725,748
278,400					213,543,028.00	214,133,236.00	2,276,965	213,543,028
556,800				206,360,308.00	206,950,516.00	207,540,724.00	1,998,565.00	206,360,308
835,200			199,177,588.00	199,767,796.00	200,358,004.00	200,948,212.00	1,720,165.00	199,177,588
1,113,600		191,994,868.00	192,585,076.00	193,175,284.00	193,765,492.00	194,355,700.00	1,441,765.00	191,994,868
1,392,000	184,812,148.00	185,402,356.00	185,992,564.00	186,582,772.00	187,172,980.00	187,763,188.00	1,163,365.00	184,812,148

Table 7. Fourth Stage on March 2010

$\{VCP_4 (X_4) + VCH_4 (I_4) + F_3^* (I_4 + X_4 - D_4)$								
X_4 / i	1,083,513	1,361,913	1,640,313	1,918,713	2,197,113	2,475,513	$X_4^*{}_{(Barel)}$	$F_4^*(i)$
0						289,842,070.96	2,475,513	289,842,071
278,400					282,659,350.96	283,249,558.96	2,197,113	282,659,351
556,800				275,476,630.96	276,066,838.96	276,657,046.96	1,918,713	275,476,631
835,200			268,293,910.96	268,884,118.96	269,474,326.96	270,064,534.96	1,640,313	268,293,911
1,113,600		261,111,190.96	261,701,398.96	262,291,606.96	262,881,814.96	263,472,022.96	1,361,913	261,111,191
1,392,000	253,928,470.96	254,518,678.96	255,108,886.96	255,699,094.96	256,289,302.96	256,879,510.96	1,083,513	253,928,471

Table 8. Fifth Stage on February 2010

$(VCP_5 (X_5) + VCH_5 (I_5) + F_4^* (I_5 + X_5 - D_5)$								
X_5 / i	1,003,662	1,282,062	1,560,462	1,838,862	2,117,262	2,395,662	$X_5^*{}_{(Barel)}$	$F_5^*(i)$
0						356,728,954.00	2,395,662	356,728,954
278,400					349,546,234.00	350,136,442.00	2,117,262	349,546,234
556,800				342,363,514.00	342,953,722.00	343,543,930.00	1,838,862	342,363,514
835,200			335,180,794.00	335,771,002.00	336,361,210.00	336,951,418.00	1,560,462	335,180,794
1,113,600		327,998,074.00	328,588,282.00	329,178,490.00	329,768,698.00	330,358,906.00	1,282,062	327,998,074
1,392,000	320,815,354.00	321,405,562.00	321,995,770.00	322,585,978.00	323,176,186.00	323,766,394.00	1,003,662	320,815,354

Table 9. Sixth Stage on January 2010

$\{VCP_6 (X_6) + VCH_6 (I_6) + F_5^* (I_6 + X_6 - D_6)$								
X_6 / i	923,810	1,202,210	1,480,610	1,759,010	2,037,410	2,315,810	$X_6^*{}_{(Barel)}$	$F_6^*(i)$
0						421,386,369.20	2,315,810	421,386,369
278,400					414,203,649.20	414,793,857.20	2,037,410	414,203,649
556,800				407,020,929.20	407,611,137.20	408,201,345.20	1,759,010	407,020,929
835,200			399,838,209.20	400,428,417.20	401,018,625.20	401,608,833.20	1,480,610	399,838,209
1,113,600		392,655,489.20	393,245,697.20	393,835,905.20	394,426,113.20	395,016,321.20	1,202,210	392,655,489
1,392,000	385,472,769.20	386,062,977.20	386,653,185.20	387,243,393.20	387,833,601.20	388,423,809.20	923,810	385,472,769

Table 10. Recapitulation

Beginning Inventory (i)	June	May		April		March		February		January	
	X_1*	X_2*	F_2*	X_3*	F_3*	X_4*	F_4*	X_5	F_5*	X_6*	F_6*
0	2,715,068	2,635,217	149,379,957	2,555,365	220,725,748	2,475,513	289,842,071	2,395,662	356,728,954	2,315,810	421,386,369
278,400	2,436,668	2,356,817	142,197,237	2,276,965	213,543,028	2,197,113	282,659,351	2,117,262	349,546,234	2,037,410	414,203,649
556,800	2,158,268	2,078,417	135,014,517	1,998,565	206,360,308	1,918,713	275,476,631	1,838,862	342,363,514	1,759,010	407,020,929
835,200	1,879,868	1,800,017	127,831,797	1,720,165	199,177,588	1,640,313	268,293,911	1,560,462	335,180,794	1,480,610	399,838,209
1,113,600	1,601,468	1,521,617	120,649,077	1,441,765	191,994,868	1,361,913	261,111,191	1,282,062	327,998,074	1,202,210	392,655,489
1,392,000	1,323,068	1,243,217	113,466,357	1,163,365	184,812,148	1,083,513	253,928,471	1,003,662	320,815,354	923,810	385,472,769

Table 11. Comparison with Inventory

	DYNAMIC PROGRAMMING		PT. XYZ	
PERIOD	**PRODUCTION (Bbl)**	**PRODUTION COST ($)**	**PRODUCTION (Bbl)**	**PRODUTION COST ($)**
January	923,810	25,792,777	2,319,800	66,653,400
February	2,395,662	66,886,883	2,288,593	68,923,579
March	2,475,513	69,116,323	2,220,196	69,966,460
April	2,555,365	71,345,791	2,671,335	88,154,065
May	2,635,217	73,575,259	2,676,455	85,023,008
June	2,715,068	75,804,699	2,638,256	87,062,444
TOTAL	**13,700,635**	**382,521,731.32**	**14,814,635**	**465,782,955**

Table 12. Comparison without Inventory

	DYNAMIC PROGRAMMING		PT. XYZ	
PERIOD	**PRODUCTION (Bbl)**	**PRODUTION COST ($)**	**PRODUCTION (Bbl)**	**PRODUTION COST ($)**
January	2,315,810	64,657,415	2,319,800	66,653,400
February	2,395,662	66,886,883	2,288,593	68,923,579
March	2,475,513	69,116,323	2,220,196	69,966,460
April	2,555,365	71,345,791	2,671,335	88,154,065
May	2,635,217	73,575,259	2,676,455	85,023,008
June	2,715,068	75,804,699	2,638,256	87,062,444
TOTAL	**5,092,635**	**421,386,369.00**	**14,814,635**	**465,782,955**

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